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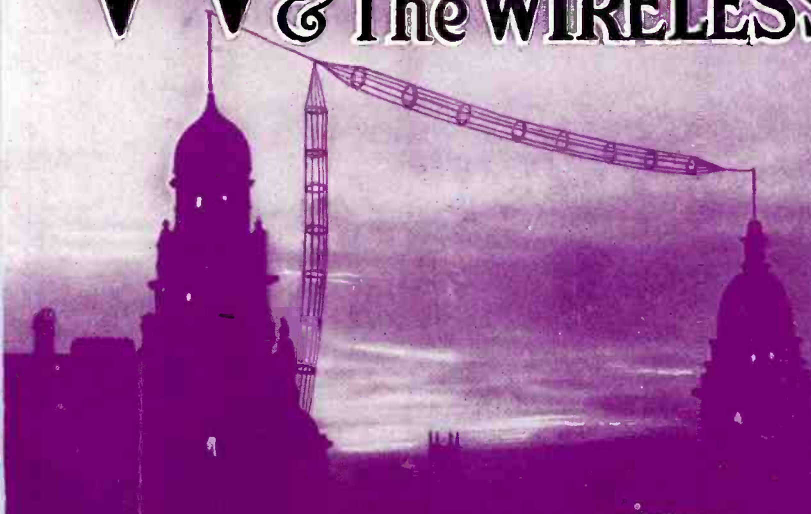

A Journal of Radio Research and Progress

Vol. IV
No. 42.

MAR.
1927.

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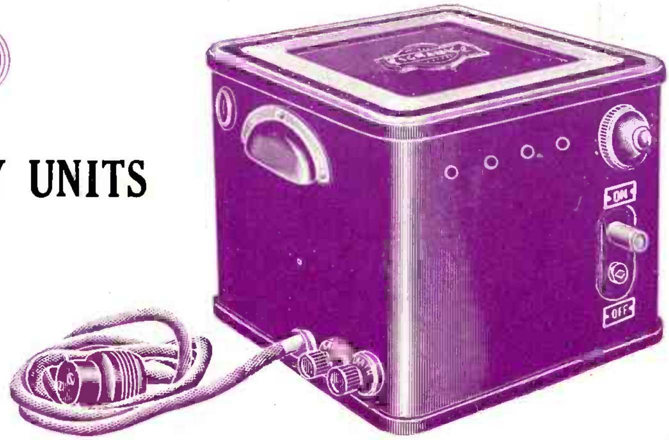

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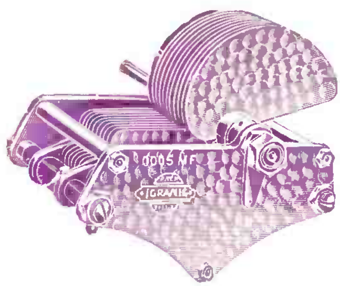

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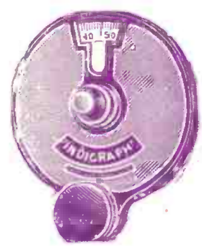

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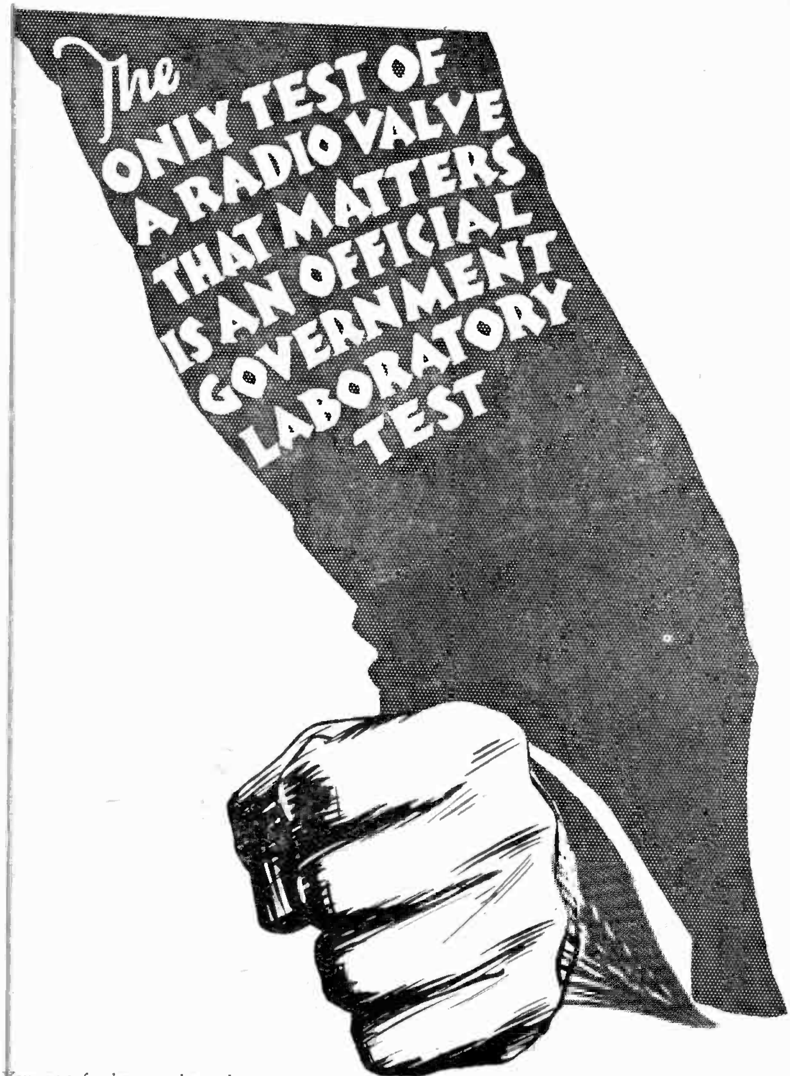

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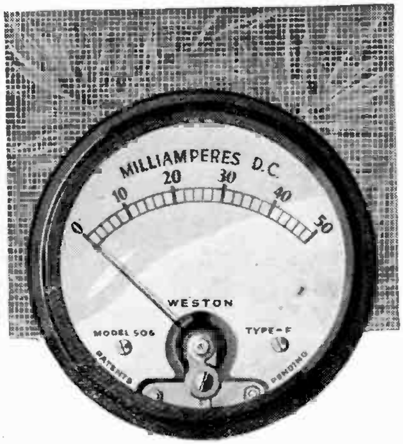

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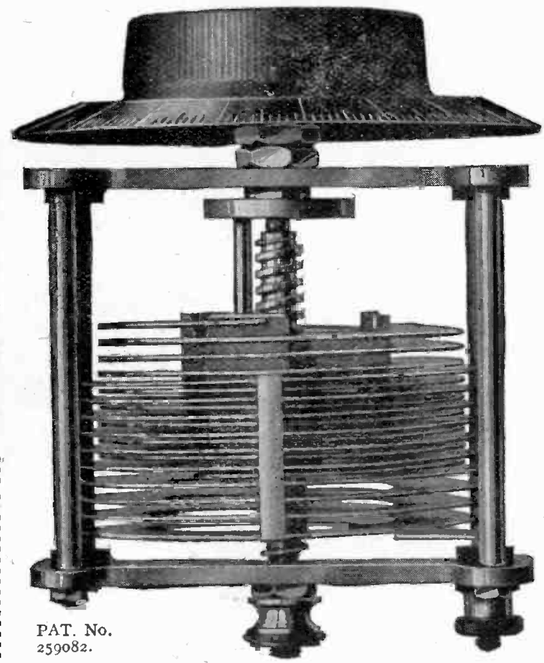

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EXPERIMENTAL WIRELESS
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A Journal of Radio Research and Progress

Technical Editor : Prof. G. W. O. HOWE, D.Sc., M.I.E.E. Editor : HUGH S. POCOCK. Assistant Editors : W. JAMES and F. H. HAYNES.

VOL. IV. NO. 42. MARCH, 1927. MONTHLY.

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The Editor is always prepared to consider suitable articles with a view to publication. MSS. should be addressed to the Editor, "Experimental Wireless and the Wireless Engineer," Dorset House, Tudor St., London, E.C.4. Especial care should be taken as to the legibility of MSS. including mathematical work.

Published Monthly, on the first of each month.
Editorial Offices : 139-40, FLEET STREET, LONDON, E.C.4. Telephone : City 4011 (3 lines).

Advertising and Publishing Offices : DORSET HOUSE, TUDOR STREET, LONDON, E.C.4.
Telegrams : "Experiwyr, Fleet, London." Telephone : City 2847 (13 lines).

COVENTRY : Hertford St. Telegrams : "Cyclist, Coventry." Telephone : 10 Coventry.

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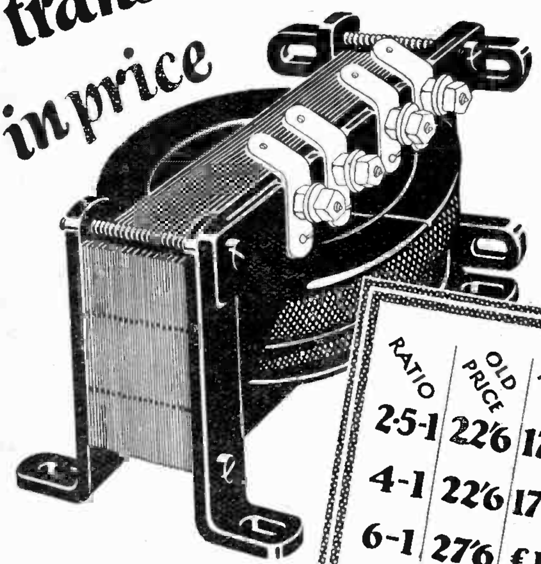

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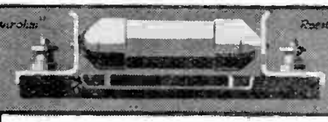

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EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. IV. MARCH, 1927. No. 42.

Editorial.

The Future of "Experimental Wireless."

"EXPERIMENTAL WIRELESS" has now been published for something over three years in all, it being just over two years since it was acquired by the present proprietors. During that time we have received many enthusiastic letters from our readers, and have ample evidence that the journal has been of very distinct value in developing and advancing the theory and practice of wireless research.

But the income from the sales of the paper, plus the small revenue we have been able to obtain from advertisers, has not been nearly sufficient to pay the expenses incurred in procuring, printing and issuing suitable editorial matter.

Our publishers have therefore been obliged to consider what steps, if any, can be taken to increase the revenue of the paper, or, alternatively, to reduce production costs to a level more nearly approximating to present, or possible, revenue.

It would, of course, be possible for us by modifying the technical nature of the contents to bring the journal within the requirements of a greatly increased body of readers, in fact it may be said that our readers could be increased in inverse ratio to the technical standard of the journal's contents.

It has been our aim, however, all the time, to cater for a comparatively small but advanced body of readers, and we had hoped that with the assistance of the advertisements of those members of the industry who cater for the requirements of the advanced worker, we should have been able to make the journal pay its way.

We regret to say, however, that we have not received the support that had been anticipated, and it would appear that there are only two courses open to us; either to increase the price of the journal to its public or, seeing that no journal can go on indefinitely as a losing proposition, to abandon its publication.

In the belief that the journal is serving a very useful purpose we have chosen the former alternative, and therefore, commencing with our April number, the price of EXPERIMENTAL WIRELESS will be 2s. 6d. per copy.

It may be that some of our readers will wish to consider carefully whether or not at the higher price their purchase of the journal shall continue. We hope it may, but the decision must rest with them. If the response is sufficient to enable us to carry on the journal without loss, we shall, of course, continue, but failing this, we shall have no option but to discontinue its publication, a course we should very greatly regret.

Should the conditions alter at a later date and it be found possible to make a reduction in the selling price, we shall certainly do so.

But in the meantine our readers must decide if EXPERIMENTAL WIRELESS is worth 2s. 6d. a copy to them, and we must abide by their decision.

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Further Measurements on Wireless Wave-Fronts.

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

1. Introductory.

In September, 1925, the authors described in this journal* a series of experiments which were based on the determination of the directions of electric and magnetic forces in wireless waves. The main object of these experiments was to ascertain to what extent downcoming waves, reflected or deflected from the upper atmosphere, were present at a receiver on the earth's surface during the occurrence of fading and directional night effects. A necessary part of the investigation was the determination of the conductivity of the ground in the neighbourhood of the receiver, and accordingly a large part of the experimental work consisted in making practical measurements of this quantity in various parts of the country. The results of such experiments showed the conductivity of the earth to be fairly high, and as a result of this it was concluded that it would not be possible to distinguish between downcoming waves and direct, horizontally travelling waves, when working on the long wavelengths for which the apparatus was originally designed. From such theoretical considerations, however, it was shown that the effect of the earth's high conductivity would be less detrimental to the success of the experiments if shorter wavelengths could be employed. The investigation was, therefore, continued with the apparatus modified for more accurate working on shorter wavelengths, while at the same time other methods of attacking the problem have been developed. These later experiments are described in the present article, and, as will be seen, they have proved much more fruitful in results contributing towards the solution of the original problem. Direct evidence has been obtained of the existence of downcoming waves at the earth's surface, and in some cases it has been possible to make fairly accurate measurements of the angle of incidence or elevation at which such waves arrive.

* *E.W. & W.E.*, 1925, Vol. II., p. 737.

2. Description of Apparatus.

In considering the extension of the experiments to shorter waves, it was decided to work on the broadcasting band of wavelengths between 250 and 500 metres, chiefly on account of the availability of transmissions at suitable times within this band. The present section then merely concerns the adaptation of the old apparatus for use on these shorter wavelengths.

The apparatus previously employed consisted of a rotating Hertzian rod receiver for measuring the direction of the electric force in the wave, and of a rotating tilting coil receiver for measuring the direction of the magnetic field.

The adaptation of the Hertzian rod apparatus for short wave working was effected without difficulty. It merely necessitated an improved arrangement of the leads from the rod to the receiving box, together with the substitution of a short-wave amplifier for the long-wave apparatus used hitherto. The apparatus remained substantially as shown in the photograph and diagram forming Figs. 5 and 6 on p. 740 of the previous article.

As regards the apparatus for measuring the direction of the magnetic field, however, it was considered necessary to construct an entirely new short-wave tilting coil. This was chiefly owing to the fact that in the previous paper the conclusion was drawn that the tilt of the magnetic field to the horizontal, which is the quantity to be measured, would not in any circumstances greatly exceed about three degrees on the broadcasting wavelengths. Thus, to make even a rough estimate of the angle of the downcoming wave by this means it would

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be necessary to obtain this angular tilt of the coil to an accuracy of about a quarter of a degree.

The principle of the apparatus remained the same but greater attention was given to the details of screening and the accurate levelling and aligning of the axes of rotation, and also to the construction of the graduated scales. For these purposes both the vertical and horizontal axes were made of brass

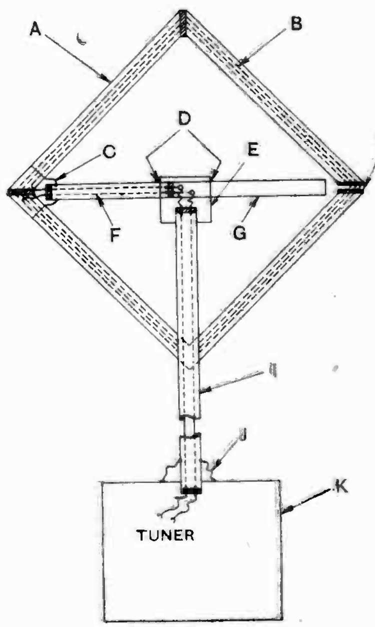

Fig. 1. *Diagram showing the screening arrangement employed on the new tilting coil receiver.*

A *Outer screen of 12 wires (two only shown).*
B *Receiving coil. inside screen.*
C *Screen wires bonded and connected to metal axis.*
D *Bearing.*
E *Screening box protecting flexible connector.*
F *Leading-in wires spaced apart and stretched tight.*
G *Horizontal tubular axis.*
H *Screen loops broken here.*
I *Vertical tubular axis.*
J *Vertical axis, bonded to screening box.*
K *Amplifier and tuning box (metal lined).*

tube of $1\frac{1}{2}$ in. and 1 in. diameter respectively. The leads were taken from the coil through the centre of their tubes down into the screened box which contained the receiving apparatus and into which the lower end of the vertical axis projected (see Fig. 1). In addition to this, the coil itself was surrounded by a screen of open wire loops arranged round the circumference of an imaginary cylinder. Thus, as will be seen from Fig. 1, actually every part of the apparatus was enclosed in a metallic screen protecting it both from direct pick up of signal E.M.F. and from antenna effect. As an extra precaution the hut in which the apparatus was erected was surrounded by a screen of open loops as a further protection against antenna effect (see photo, Fig. 2).

The vertical and horizontal axes of the coil were aligned by means of a plumb line and spirit level permanently attached to the coil, which was supported in a tripod stand with three levelling screws. By this means these axes could be set to an accuracy of 0.1°, while a second level attached to the coil at right angles to the first enabled the horizontal or tilt scale to be adjusted to about the same accuracy. The horizontal axis scale was made specially large so that the angle of tilt could be read to 0.1°.

The leads from the coil were connected to the primary of a tuned coupled circuit, and leads from the secondary were taken to the supersonic heterodyne amplifier employed with this receiver. The whole of this receiver with its associated batteries was enclosed within the screened box, and the telephone leads were brought out through a special screened cable. A sketch-diagram and photograph of the complete tilting frame coil apparatus is shown in Figs. 3A and 3B.

When the set was tested it was found to work very satisfactorily, variations of the tilt angle of 0.1° could be detected and the absolute accuracy of determination of the angle was probably about 0.2°. The apparatus had a conveniently large range of about 200 miles for making accurate measurements on the transmissions from broadcasting stations.

3. Method of making Measurements and Results Obtained.

(A) *Hertzian Rod Apparatus.*

The Hertzian rod apparatus is actuated by rotating the rod until a position is obtained when the signals pass through a minimum intensity or entirely vanish. The rod is then at right angles to the electric lines of force in the wave front. If, then, during this process the horizontal axis about which the rod is rotated is pointing in the direction

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of the transmitter, it is clearly the *sideways* tilt of this field which is being measured. If, on the other hand, the horizontal axis is set at right angles to the direction of the transmitter when being rotated, it is the *forwards* tilt which is obtained. These two tilts have been designated respectively as the angles A and B measured from the true vertical, which is the direction the electric in effect produced by the imperfect conductivity of the earth.*

Any variation of the angle A from zero is an indication of rotation of the plane of polarisation of the waves, while any variation of the angle B can only be due to the action of waves arriving at a definite angle of inclination to the earth's surface.

The results obtained from these measure-

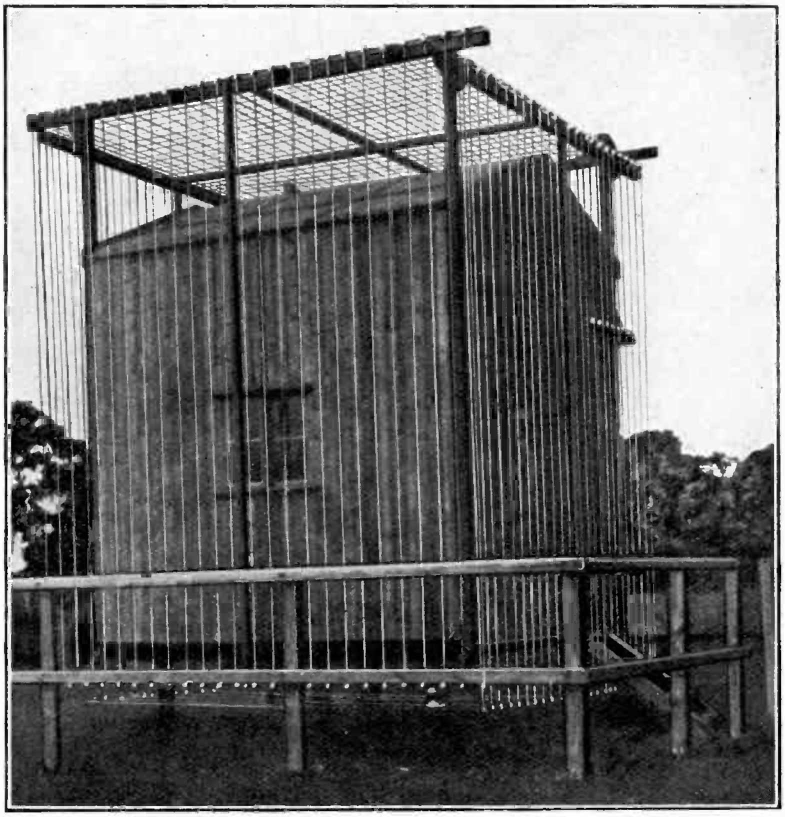

Fig. 2. *Photograph of hut containing the tilting coil apparatus, showing the arrangement of the surrounding wire screen for the reduction of antenna effect on the frame coil receiver.*

force would have in wireless waves travelling over a perfectly conducting earth. The experiments which were carried out with this apparatus consisted in measuring both A and B from instant to instant over a period of several hours, partly by day and partly by night. In the daytime A is invariably zero to within the limits of accuracy of the apparatus, while B has a small positive value, this forward tilt being

ments were plotted in the form of curves, and an example of these curves is shown in Fig. 4. It is at once apparent that though A and B remain steady during the day-time they are subject to marked variations in the neighbourhood of sunset and during the hours of darkness.

* See previous article, *E.W. & W.E.*, 1925, Vol. II., p. 737.

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We therefore have without any further analysis whatever very strong evidence (*a*) that the plane of polarisation of the waves is varying, and (*b*) of the existence of down-

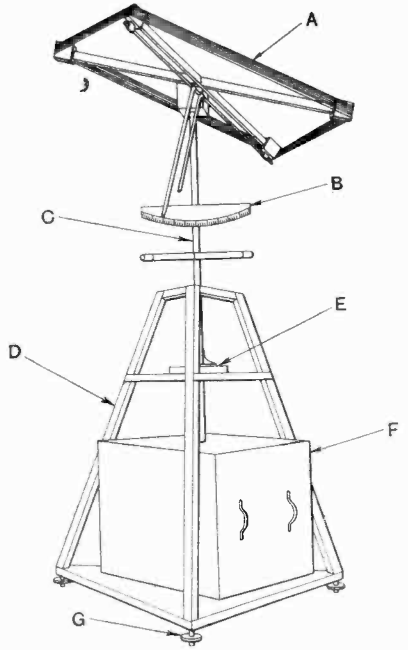

Fig. 3A. *Sketch diagram of the tilting coil receiver.*
A *Tilting frame coil.*
B *Scale for horizontal tilts or elevation.*
C *Vertical brass axis containing leads from coil to receiver.*
D *Tripod stand supporting frame coil.*
E *Scale for bearings or azimuth.*
F *Screened box containing receiving apparatus.*
G *Levelling screws for stand.*

coming waves. With this important conclusion concerning questions, which have so long remained unanswered, we will leave the Hertzian rod apparatus for the time being and turn to a consideration of the experiments carried out with the tilting coil.

(B) *Tilting Coil Apparatus.*

The direction of three of the components of the magnetic field of the waves could be observed by means of this apparatus: first, the direction of horizontal component designated by the angle "*C*" corresponding to the error in bearing of the transmitting station; secondly, that of the component in the vertical plane at right angles to the vertical plane of propagation designated by the angle "*D*"; and lastly the direction of the component in the plane of propagation designated by the angle "*F*." The angles "*D*" and "*F*" are measured from the horizontal, which is the normal direction of the magnetic field in wireless waves at the surface of a perfectly conducting earth. In all cases the measurements were made by determining the position of the coil when the received signal intensity passed through a minimum or zero. The angle "*C*" is measured by fixing the coil in a vertical plane and rotating it about its vertical axis. The angle "*D*" is measured by rotating the coil about its horizontal axis with that axis pointing directly away from the transmitter, while the angle "*F*" is measured by rotating the coil about its horizontal axis with that axis fixed in a direction at right angles to that of the transmitter.

Fig. 3B. *Photograph of the tilting frame coil receiver in operation.*

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Observations of these three angles were made during many periods of several hours' duration, usually at the same time that experiments with the Hertzian rod apparatus were being carried out. Some typical results are shown in Figs. 5 and 6 where they are recorded in the form of curves.

It will be seen that at night variations in all of three of the angles were observed, whereas it will be remembered that in the case of the longer waves only the angle *C* was found to alter.*

measured at all is almost conclusive proof of the arrival of a horizontally polarised downcoming wave. Thus the measurements of the direction of the magnetic field of the waves by means of the tilting coil receiver confirm the conclusions obtained from the experiments with the Hertzian rod apparatus. Further, it was found that whenever large variations of the apparent bearing were observed, the other angles *A*, *B*, *D*, *F* were also varying. This constitutes a very substantial proof that what has hitherto been

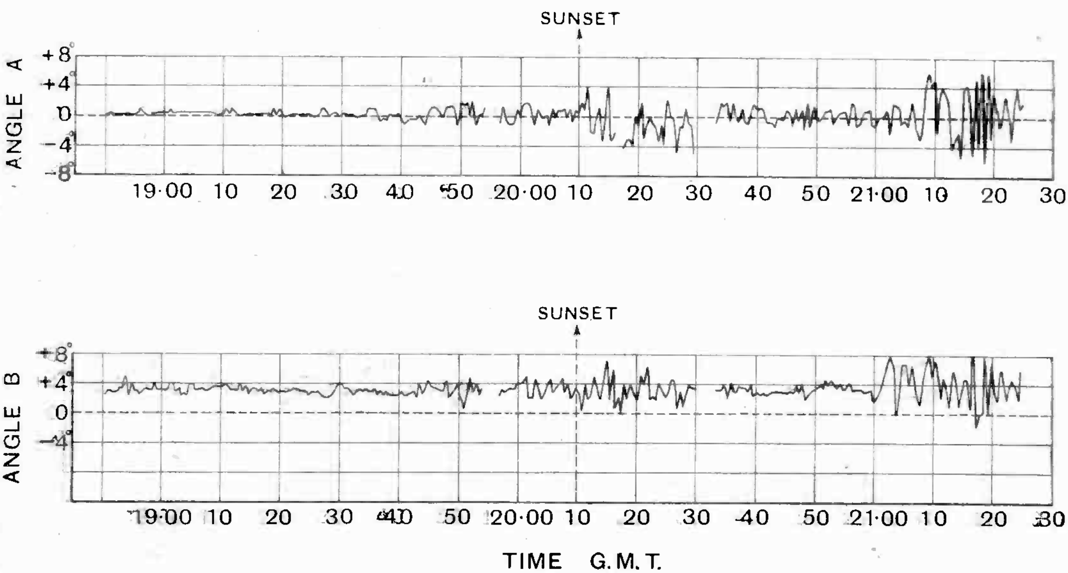

Fig. 4. *Observation of sideways and forwards tilt of electric field (angles* A *and* B*) made at Slough on transmissions from Bournemouth, 4th June, 1925. Wavelength = 386 metres.*

It is thus immediately evident from these results that variations in apparent bearings obtained on a frame-coil direction-finder are accompanied by variations in the angle of inclination of the magnetic field in the waves to the horizontal. The fact that the angle *D* can have a value other than zero indicates the arrival of waves with their plane of polarisation rotated from the normal position. As regards the angle *F*, a little consideration makes it clear that since under normal conditions no signal at all can be received with the coil in the position in which this angle is observed, the fact that it can be vaguely referred to as "night effect" in wireless direction-finding is due to the presence of downcoming horizontally polarised waves at the receiver. The original theory and experiments of T. L. Eckersley* in this direction are thus adequately confirmed, and the general results are in agreement with the recent work of Appleton and Barnett† on the cause of fading of wireless signals.

* See previous article.

* T. L. Eckersley, *Radio Review*, 1921, Vol. 2, pp. 60 to 65, and 231 to 248.

† E. V. Appleton and M. A. F. Barnett, *Nature*, 1925, Vol. 115, p. 333, and *Proc. Roy. Soc.*, 1925, Vol. 109, p. 621.

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4. Calculation of Angle of Incidence of Downcoming Waves.

We have now shown how properly constructed apparatus for measuring the inclination of the electric and magnetic forces in wireless waves may at once provide indisputable evidence of the existence of waves deflected from the upper atmosphere. It is now proposed to go further and demonstrate how the data so obtained may be made use of for the calculation of the actual angle of incidence and relative intensity of these downcoming waves.*

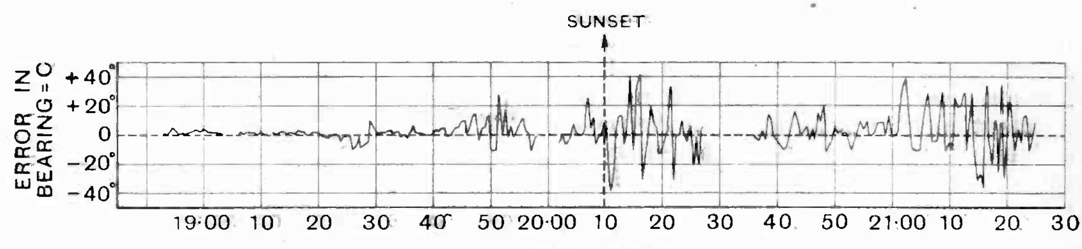

Fig. 5. *Observations of error in apparent bearing (angle* C*) of Bournemouth at Slough through a sunset period, 4th June, 1925. Wavelength = 386 metres.*

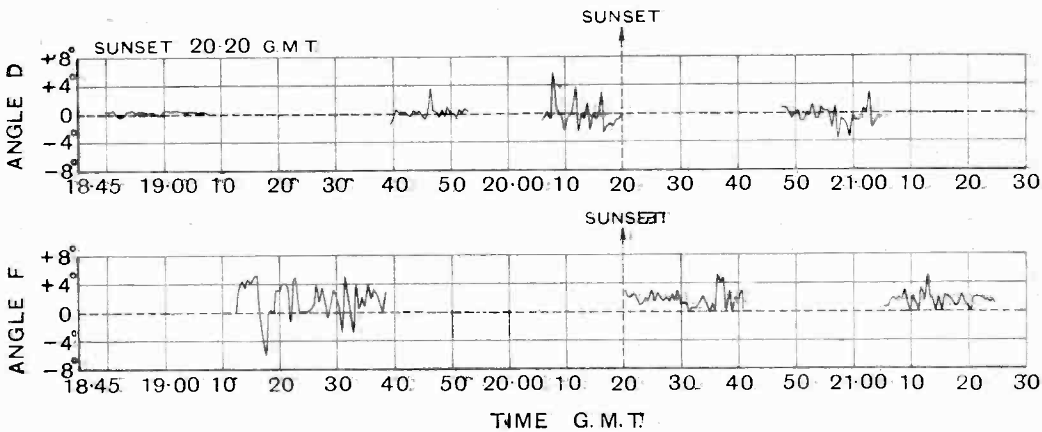

Fig. 6. *Observations of angles* D *and* F *on Bournemouth, 18th June, 1925. Wavelength = 386 metres.*

(A) *With Hertzian Rod Apparatus.*

Fig. 7 depicts a single wave of field strength E arriving at a receiver at O with an angle of incidence θ. The incident wave gives rise to a reflected wave with angle of reflection θ and intensity $\rho_v E$ where ρ_v is called the reflective power of the earth. The current induced in the Hertzian rod apparatus or in any aerial is clearly due to the resultant field of these two waves.

Let this resultant field be split up into a horizontal component X and a vertical component Z. Then if the resultant field is linear the angle of tilt B measured by the Hertzian rod apparatus is clearly given by

$$\tan B = \frac{X}{Z} \qquad \ldots \qquad \ldots \qquad (1)$$

Now it can be shown from the elementary theory of plane electromagnetic waves that

$$\frac{X}{Z} = \frac{1}{\sqrt{K'} \sin \theta} \qquad \ldots \qquad \ldots \qquad (2)$$

where K' is a constant depending chiefly on the conductivity of the ground and the

* A fuller discussion of the theoretical treatment used in this and the succeeding sections will be found in a paper recently published by the present authors.—*Proc. Roy. Soc.*, 1926, Vol. 110, p. 580.

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wavelength; so that we now have a formula for obtaining θ, viz.:—

$$\sin\theta = \frac{1}{\sqrt{K'}} \cot B \quad \ldots \quad (3)$$

We have not, however, yet arrived at the practical case as experienced during the investigation, for the above reasoning assumes the existence of a *single* arriving wave only at the receiver. Thus if we use the above formulæ we shall be determining the resultant angle of incidence of all the waves arriving, including that of the direct or surface travelling wave for which we know $\theta=90°$ (approx.).

In order to distinguish between the direct and downcoming waves at any instant we must know their relative magnitudes and also the phase relation between them.

For this purpose apparatus was constructed which enabled the relative signal strength as obtained on a vertical antenna to be measured. It consisted of a simple coupled circuit receiver connected to a three-stage untuned transformer-coupled H.F. amplifier and valve detector. A sensitive mirror galvanometer recorded the change in anode current of the detector valve, the normal anode current being balanced out through the galvanometer by means of a potentiometer. With this apparatus it was possible to detect changes in the anode current corresponding to a variation of 1 or 2 per cent. in the signal strength. During its operation the apparatus was calibrated from time to time by means of a specially constructed screened oscillator. Observations were made on this signal strength apparatus simultaneously with the observations on the tilting coil and Hertzian rod apparatus.

Since a vertical antenna was employed with this signal strength measuring instrument, the quantity measured by it is the total value of the vertical component of the electric field, a quantity which we have already designated as Z.

Let us divide the resultant vertical electric field Z up into two compounds, Z_0 due to the direct wave and Z_1 the contribution of the downcoming wave or waves.

The horizontal electric field X may be divided into two similar parts and if θ is taken to be the mean angle of incidence of the downcoming waves, its value will be given by the expression:—

$$\frac{X_1}{Z_1} = \frac{1}{\sqrt{K'}} \sin\theta \quad \ldots \quad (4)$$

But assuming that the direct wave alone is present in the daytime and does not change in intensity during night effect we have:—

$$\left.\begin{aligned} Z_1 &= Z - Z_0 \\ X_1 &= X - X_0 \end{aligned}\right\} \quad \ldots \quad \ldots \quad (5)$$

Also in the daytime

$$\frac{X_0}{Z_0} = \tan B_0 \quad \ldots \quad \ldots \quad (6)$$

where B_0 is the normal forward tilt of the electric force arising from the finite conductivity of the earth. Hence from equations (3), (4), (5) and (6) we get the expression for the angle of incidence of the downcoming wave as:—

$$\sin\theta = \frac{Z - Z_0}{\sqrt{K'}(Z \tan B - Z_0 \tan B_0)} \quad (7)$$

in which all the quantities are constant or measurable by means of the Hertzian rod or signal strength apparatus.

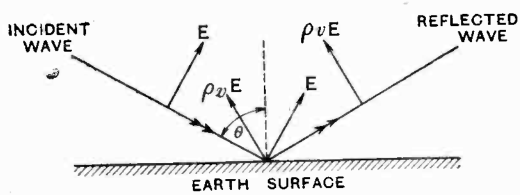

Fig. 7. *Showing the directions of the electric force in incident and reflected waves at the surface of the earth.*

A difficulty that was found to arise in practice was that during the occurrence of night effect the quantities Z and B varied so rapidly that in order to be able to plot a continuous curve of their instantaneous values it was found necessary to take readings at the rate of about one per five seconds. Although this was quite possible with the signal strength apparatus it was not so with the Hertzian rod apparatus owing to the unwieldy nature of its moving parts. Consequently it could not be guaranteed that the values of Z obtained corresponded to those of B at any given instant—a condition which must be fulfilled before equation (7) can be applied. It was therefore not possible to

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calculate the angle of incidence but by noting the maximum intensity of the downcoming wave over a short period on either side of instant at which B was measured, it was possible to obtain the *maximum* value of θ at that instant, a result which was naturally of considerable interest on many occasions.

(B) *With Tilting Coil Apparatus.*

Owing to the fact that there is no horizontally polarised direct wave the angle of incidence of the wave can be obtained directly from the measurements made on the tilting coil apparatus of the angle F by means of the relation

$$\sin \theta = \sqrt{K'} \tan F \quad \ldots \quad (8)$$

It is, however, necessary to make sure that at the instant at which F is measured the intensity of the downcoming wave is at least of the same order as that of the direct wave, for without this precaution instrumental errors are liable to arise of sufficient magnitude to vitiate the conclusions drawn from the calculation.

Particular examples of the value of the angle of incidence of the downcoming wave as obtained by this method are given in Table I. for observations made at Slough on the Bournemouth B.B.C. station.

TABLE I.

Calculation of θ from Angle F.

Observations on Bournemouth Broadcasting Station.

Date.	Time G.M.T.	F degrees.	θ degrees.	$\frac{E_1}{E_0}$
18.6.25	2107½	1.6	28	1.2
,,	2122½	2.0	34	0.6
,,	2124	1.2	19	0.5
25.6.25	2045	2.0	34	0.3
,,	2112½	1.0	16	>1.1
,,	2113	1.0	16	>1.1
,,	2113½	2.0	34	>1.2
,,	2114	2.0	34	>1.2

The two most interesting conclusions derived from this table are (1) that the angle of incidence can attain such a small value as 16° (*i.e.*, showing waves arriving at a very steep inclination) and (2) that θ can change rapidly within a few seconds, a fact which it scarcely seems possible to explain in any other way than by supposing that there are at times at least two downcoming waves at widely different angles of incidence and both varying rapidly in intensity and phase.

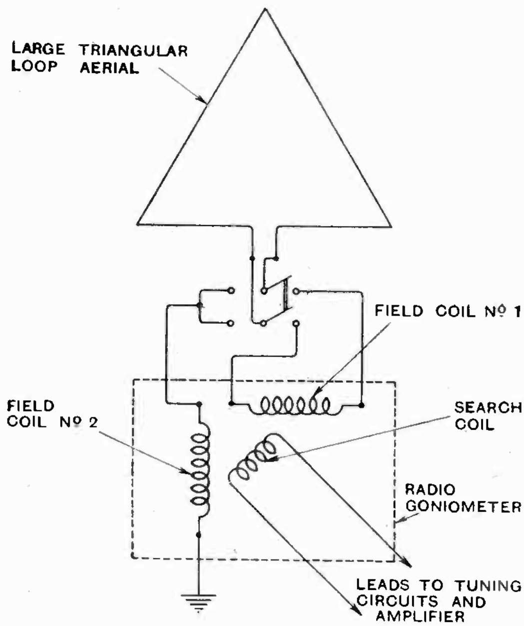

Fig. 8. *Circuit arrangement showing the loop-aerial method of comparing the intensity of the horizontal magnetic force and the vertical electric force in wireless waves.*

5. Improved Method of Obtaining Angle of Incidence of Vertically Polarised Waves.

The failure of the Hertzian rod apparatus for the actual measurement of θ owing to the rapidity of the night variations was fortunately not a great set back, as another and far more accurate method of obtaining the angle of incidence of the vertically polarised wave had been simultaneously developed.

A large receiving loop, formed of a triangle of height about 50 ft. and base about 60 ft., was erected in a vertical plane aligned accurately on the transmitting station under observation. This was connected to one or other of the field coils of a radiogoniometer at will by means of a change over switch, but arranged so that the loop was in series with the one field coil in one position of the switch and in the other position short circuited and connected to earth through the other field coils. The alternate circuits and the complete circuit diagram are shown in Fig. 8.

Considering now that the search coil of the goniometer is fixed in a given position the signal strength in position (1) is determined by the total magnetic field of all the vertically polarised waves that may be arriving. We will designate this magnetic field as β. In position (2) the signal strength is determined by the intensity of the total vertical electric field which we have already called Z.

To operate the apparatus the switch is rapidly alternated between the two positions while at the same time the search coil is rotated until a balance (*i.e.*, equal strength) is obtained. The construction of the goniometer is such that the tangent of the search coil angle is proportional to the current ratio in the two field coils and therefore to the ratio β/Z.

An elementary inspection of the phenomenon of the reflection of electromagnetic waves at a plane surface will bring to light the fact that

$$\beta/Z = \frac{1}{\sin\theta} \quad \ldots \quad \ldots \quad (9)$$

whatever may be the value of the conductivity of the surface.

By remembering that for a direct wave $\beta = Z$ (*i.e.*, electric field=magnetic field) we are able to get the absolute value of β/Z from the relative measurement which is all the above method affords.

Since we wish to distinguish between the downcoming wave and the direct wave we cannot use the simple formula (9) unless we are sure there is no direct wave present. In the experiments we are now describing this was not the case. Therefore, as with the Hertzian rod apparatus, it was necessary to obtain the relative intensity of the downcoming wave at the instant a determination of β/Z was made. This was done as before by simultaneously measuring Z.

The complete formula for obtaining θ has then to be modified in much the same way as was adopted above by introducing the component values of Z, Z_0 and Z_1. Thus from (9)

$$\sin\theta = \frac{Z_1}{\beta_1}$$

$$= \frac{Z - Z_0}{\beta \quad \beta_0}$$

so that

$$\sin\theta = \frac{Z - Z_0}{\frac{\beta}{Z} \times Z - Z_0} \quad \ldots \quad (10)$$

since $Z_0 = \beta_0$, where now all the quantities in (10) are directly measurable.

Since the apparatus could be operated sufficiently rapidly to follow continuously the changes in the value of β/Z, formula (10) could actually be applied to calculate instantaneous values of θ. This was done for many hundreds of instants at which observations had been made and thus the angle of incidence was obtained on a number of occasions. Table II. shows some typical results of measurements.

TABLE II.

CALCULATION OF ANGLE OF INCIDENCE AND RELATIVE INTENSITY OF DOWNCOMING WAVES RECEIVED FROM BOURNEMOUTH BROADCASTING STATION.

Date.	Time G.M.T.	Z.	β/Z.	θ degrees.	$\frac{E_1}{E_0}$
18.6.25	2030.00	17.0	1.6	21	0.7
,,	2032.50	15.2	1.3	27	0.4
,,	2034.40	16.5	1.4	25	0.6
,,	2102.10	16.5	1.6	21	0.7
,,	2104.05	20.0	1.9	19	1.2
,,	2104.25	19.6	2.1	17	1.4
25.6.25	2030.00	14.8	1.4	21	0.4
,,	2100.00	14.2	1.4	19	0.4
,,	2103.40	19.7	1.7	23	1.1

They are very interesting in showing that as with the horizontally polarised waves very small values of θ are possible and that these values may vary between fairly wide limits.

6. Calculation of Intensity of Downcoming Waves.

Having obtained the angle of incidence of the downcoming waves at a given instant, it is not a difficult matter to obtain the relative intensity of the downcoming waves.

In the case of the vertically polarised waves we calculate the intensity of the total horizontal magnetic component β from the measured values of Z and β/Z at a given instant and subtract from this the day-time value of the component, $B_0 (=Z_0)$. This gives β_1 the horizontal magnetic field, resulting from the combination of the incident and reflected waves. The amplitude of the incident wave is approximately half the value since there is nearly perfect

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reflection at the earth's surface, with the wavelengths under consideration.

The intensity of the horizontally polarised downcoming wave is obtained in much the same way. For this purpose, however, it is necessary to know the value of the horizontal component of the magnetic field of this wave, *i.e.*, that component which is responsible for the signals induced in a loop receiver aligned at right angles to the transmitting stations. This quantity (α) was measured indirectly by comparing the signal obtained by such a loop with those from a vertical aerial by exactly the same method employed in obtaining the quantity β/Z. It can be shown that if E_1 is the amplitude of the downcoming horizontally polarised wave

$$E_1 = \frac{\alpha}{2 \cos \theta} \text{ (approx.)} \quad \ldots \quad \ldots (11)$$

The values of the relative intensities of the downcoming waves as obtained in this way are given in the Tables I. and II. for each occasion that the angle of incidence was measured.

In the example given the intensity ranges from 0.3 to over 1.2 times that of the direct ray and this is typical of the values obtained throughout the experiments made on the transmissions from the Bournemouth Station.

7. General Conclusions.

It will be convenient to conclude this article by summarising the most important conclusions to be derived from these experiments. In the first place, no less than three independent methods have definitely shown the existence of downward reflected waves during the occurrence of the phenomena usually referred to as night effect in direction-finding or as fading in signal intensity measurements. Secondly, two of these lines of attack have clearly shown that the downcoming waves in nearly every case contain horizontally polarised components and thus make it highly probable that the waves are circularly or elliptically polarised. Thirdly, all three methods indicate that in the case of the experiments made on the transmissions from Bournemouth more than one downcoming wave is often present.

Further, the angle of incidence of the waves has been measured by two of the methods and its maximum value on definite occasion obtained by the third. The results in the particular case of the station first investigated (Bournemouth) show angles of incidence varying from 16° to 34°, while the angle of incidence may change from one limit to the other, or have any intermediate value in a very short space of time.

The most convenient way of explaining the plurality of angles of incidence is that multiple reflection from the upper layer is taking place. The largest angle observed during a given period will then correspond to a single reflection, and assuming the ordinary laws of reflection to hold, this makes the height of the upper ionised layer about 90 kilometres.

To account for the smaller angles of incidence observed, it may be supposed that the waves are reflected alternately at the upper ionised layer and the earth's surface. This is quite reasonable since with a value of the earth's conductivity as obtained in the author's previous measurements, the reflective power of the earth is of the order of 0.9 for small angles of incidence. For waves which had suffered two successive reflections from the upper layer at a height of 90 kilometres, as in the above case, the angle of incidence would be about 19°, which is in the neighbourhood of the lower limit recorded above.

In conclusion, the results here described are only to be regarded as of a preliminary nature. The investigation is being continued and it is hoped to publish a further report in the near future in which the outcome of its application to a number of other transmitting stations at other distances and on other wavelengths will be duly set forth.

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Telephone Transmitter Modulation Measured at the Receiving Station.

By Balth. van der Pol, D.Sc., and K. Posthumus, E.E.

(N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland).

In connection with a paper by Mr. L. B. Turner under the same title and published in *E.W. & W.E.*, January, 1927, it may be of interest to give a short account of a somewhat different method of modulation measurement which has been in use for some time in this laboratory. The method was used some time ago in an official test of the modulation of the Dutch Hilversum Station, the measurements being made in Eindhoven.

Our method, in which the modulation of a transmitter is measured at a receiving station, has the advantage of—

(*a*) requiring a very limited number of instruments, and

(*b*) of enabling one to know exactly what quantity is being measured.

Referring to Fig. 1, let L_1C_1 be a circuit tuned to the incoming frequency. This circuit is placed at the end of an H.F. amplifier delivering to the circuit a high frequency amplitude of about 10 volts or more. The greater this voltage the more accurate the results will be.

This H.F. alternating voltage is rectified by the diode D_1 (triode with grid connected to anode) with the aid of the capacity C_2 (500 $\mu\mu F$) and the resistance r (300,000 ohms). The values of C_2 and r are chosen in such a way (as is usual with grid rectification) that C_2 can be regarded as a short circuit for the high frequency current and as an open circuit for the low frequency current.

The potential across C_2 has therefore the form of Fig. 2, where n is the modulation frequency.

Further, with the aid of the diode D_2, the microammeter μA, and the battery B, together with the potential divider P, the crest value A and the minimum value B of Fig. 2 can be measured. In order to measure the voltage A (Fig. 2) it is only necessary to put the switch S on the A position, and to vary P till the current through the microammeter just vanishes. The reading of the direct current voltmeter $V_{D.C.}$ then gives one the voltage A of Fig. 2. When thereupon the switch S is moved to the position B and

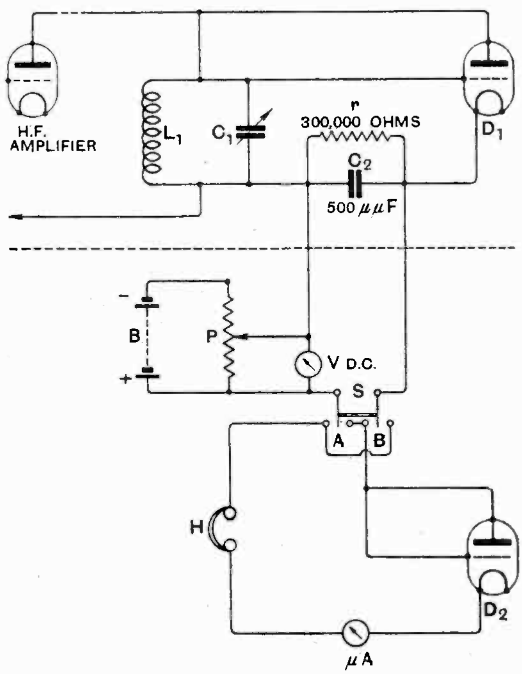

Fig. 1. *Circuit arrangement.*

the measurement is done in exactly the same way, the reading of $V_{D.C.}$ will give the voltage B of Fig. 2. When the microphone of the transmitter is quiescent, the two readings of the voltmeter $V_{D.C.}$ ought to be the same for both positions A and B of the switch S.

In carrying out the experiment one can listen in the telephones H. It will be noticed that these telephones are not abso lutely silent at the moment when, by the

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aid of the potential divider P, the micro-ammeter is brought to zero. The reason is obviously that the diode passes some audio-frequency current through its capacity. However, as soon as, by a small change of the setting of P, the microammeter begins to show a current, a peculiar cracking noise will be heard in the telephones, resulting from the peaks of the modulation being passed by the diode D_2. This moment, when the microammeter begins to pass the slightest current, can plainly be recognised by the peculiar sound in the telephones, so that in practice the microammeter μA can be dispensed with altogether.

The maximum and minimum value A and B being thus read from the voltmeter $V_{D.C.}$ the modulation ratio M can be determined from the formula

$$M = \frac{A - B}{A + B}$$

Incidentally, our method enables one to verify whether or not the carrier wave of a transmitter is changed in *mean* amplitude by the modulation. For when, as it ought to be, there is no change in the mean amplitude, the readings A and B during modulation will be such that they are related to the readings A_0 and B_0 when unmodulated by the equation

$$A_0 = B_0 = \tfrac{1}{2}(A + B).$$

When a high degree of accuracy is required one can determine the values of A and B within about 2 per cent. when the following precautions are taken :—

1. The modulation of the transmitter must be constant during *one* set of measurements (preferably the modulation must be a continuous constant note).

2. The H.F. amplitude across the L_1C_1 circuit must be of the order of 20 volts.

3. Small contact potential differences of the diodes D_1 and D_2 must be compensated by the insertion of a small P.D. (of the order of 1 volt or less, depending on the diodes used) in series with the anodes of these valves.

In conclusion, and in order to give some idea of the working of this circuit, we insert a set of measurements taken on the Hilversum Station during some special tests :—

1. Unmodulated
   ($I_{ant} = 14.5$ amps). $A = 17.75$V
   $B = 17.75\text{V},\ M = 0\%,\ \frac{A+B}{2} = 17.75$

2. Tuning note
   ($I_{ant} = 14.7$ amps). $A = 25.75$V
   $B = 10.75\text{V},\ M = 41\%,\ \frac{A+B}{2} = 18.25$

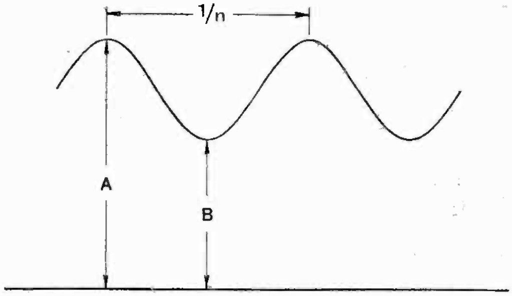

Fig. 2.

3. Organ
   ($I_{ant} = 14.5$ amps). $A = 22.4$V
   $B = 12.9\text{V},\ M = 27\%,\ \frac{A+B}{2} = 17.65.$

4. Tuning note (strong modulation)
   ($I_{ant} = 15.6$ amps). $A = 34.75$V
   $B = 9.25\text{V},\ M = 58\%,\ \frac{A+B}{2} = 22.$

5. Speech
   $A = 20.75 - 23.75,\ B = 16.65 - 14.25$
   $M = 11\% - 25\%,\ \frac{A+B}{2} = 18\ 7 - 19.$

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Spanish High-Power Station.

THE station at Prado del Rey about five miles west of Madrid and about 2,200 ft. above sea level has been erected by the Telefunken Company. The building was commenced in 1922. The aerial is supported on four masts 700 ft. high, square lattice structures of weldless drawn steel tubes, erected on the Ljungberg system. The aerial is of aluminium strand varying from 14.5 to 23 mm. diameter; the capacity is 18,000 $\mu\mu$F, the natural wavelength 5,300 metres, and the effective height 165 metres. Power can be drawn from a hydro-electric system or can be generated at the station by a 400 h.p. Diesel engine coupled to a 3-phase generator. The high frequency current is generated by an alternator coupled to a 3-phase induction motor; the generated frequency is 7,500, but this can be multiplied by 3, 4 or 5 by means of suitable transformers with saturated iron cores. There are thus three working wavelengths, viz., 13,870, 10,560 and 8,340 metres, of which the longest is regarded as the main. The installation is designed to deliver 150 kilowatts. Fig. 1 shows the aerial tuning coil of 30 mm. copper tube with its three tappings corresponding to the three wavelengths.

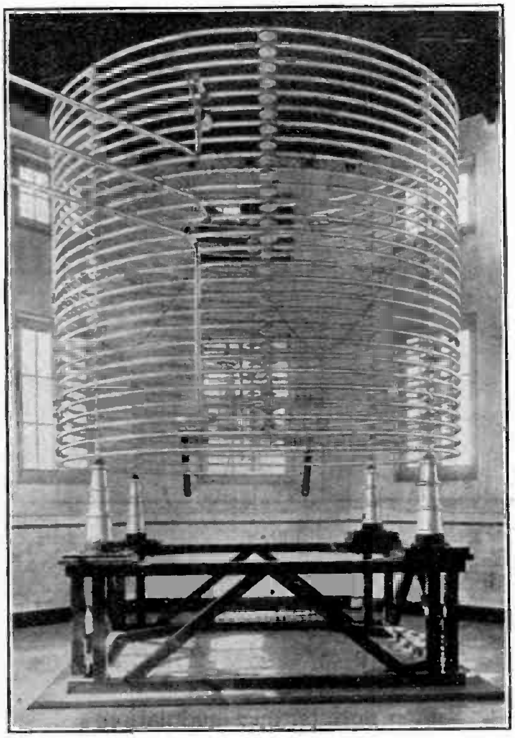

Fig. 1. *Copper tube aerial tuning coil.*

The receiving station is at Morata, 16 miles S.E. of Madrid and about 20 miles from Prado del Rey.

Fig. 2 shows the picturesque receiving building. The large tower contains the large revolving frame of 16 square metres area, the smaller tower one of 3 square metres area. The upper parts of these towers are particularly free from iron, whereas the ground floor room containing the instruments has a four-fold sheet iron lining.

Fig. 2. *The unique building of the receiving station.*

Both transmission and reception are carried out at an office in Madrid from which overhead wires run to Prado del Rey and Morata.

G.W.O.H.

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The Horizontal Hertzian Aerial for Transmission.

By Marcus G. Scroggie, B.Sc.

THE attention which is being directed to the use of short radio waves for long-distance communication has been responsible for considerable investigation into the matter of the most effective radiating system. For all waves longer than about 100 metres some form of inverted L or T aerial is almost always used, in conjunction with a buried earth connection, an earth screen or counterpoise, or a combination of these; the dimensions being roughly proportional to the wavelength to be radiated.

This type of aerial in normal circumstances radiates waves in which the electric field is vertically polarised, and the effect of the "flat top" has until comparatively recently been generally regarded as useful only in so far as it increases the effective height by increasing the capacity and so permitting more current in the vertical part of the aerial. The radiation from a horizontal wire has no effect on a distant receiver using a purely vertical aerial, provided its polarisation is not altered between the stations. Recent work, more particularly on short waves, has given rise to a reconsideration of the most effective form of aerial.

In an aerial system the arrangement of conductors must be chosen so that the inductance and capacity are correct for the wavelength to be radiated, but that condition fulfilled, the effectiveness of the aerial is mainly controlled by the resistance, which in its broad sense is of two principal kinds—the radiation resistance and the rest. The former should be as great as possible compared with the latter. Radiation resistance only begins to count when the physical dimensions of the circuit are of the same order as the wavelength, so it is desirable to have it opened out as much as possible. This condition is obviously best fulfilled by two straight rods or wires pointing away from one another, and this also happens to be the simplest arrangement, and was used by the first man ever to make a practical study of these radiations—Heinrich Hertz. It is true he complicated this simple system slightly by adding metal plates at the end of the rods to increase the capacity, but the general scheme of things was the same. (Fig. 1.)

The source of oscillations is introduced in the centre, and the plates are charged alternately in each direction. As a simple rod aerial, apart from loading, oscillates at a wavelength only double its own length, it would hardly be practicable in the case of, say, a 15,000 metre commercial station, to have a vertical rod $4\frac{1}{2}$ miles long with the transmitting station half-way up, though doubtless this would be a most admirable scheme from the point of view of efficiency. But for short waves, where the length of the aerial is reasonable, it is quite feasible to make use of it. Thus for 45 metres, which is of the order of wavelength most favoured for long-distance low-power work, the aerial is about 70 ft. long, which is quite suitable in ordinary situations.

Fig. 1.

The aerial can be placed at any angle, but it is most convenient to have it horizontal. It has been stated already that horizontally polarised waves, *if they are unaffected en route*, cannot be received on a vertical aerial. But in this world of imperfections they do not proceed in this unmolested manner, but on arrival are found to be quite badly distorted, and instead of being all in their original plane they will have a component at right angles. In general these components will not be equal (circularly polarised) but will be more in one direction than others (elliptically polarised). In the case of short waves, which are more liable to this form of alteration, the major axis of the ellipse may be at right angles to the original plane of polarisation. Smith-Rose and Barfield* have carried out a careful series of experiments, mainly with fairly long waves, which only exhibit this effect to a comparatively limited extent. Other investigators who have made measurements on this subject are referred to in their article.

In the case of short waves, the unexpectedly long ranges obtained with them are generally explained by supposing them to be reflected from the conducting Heaviside layer some 70 or 80 kilometres above the earth's surface, and thus avoiding the very large absorption on the ground-level which would otherwise render them inappreciable at a few miles distance. Their polarisation on arrival may therefore be greatly different from the original. In passing, it may be noted as an analogy that light waves reflected from clouds overhead are slightly polarised.

Some interesting measurements on short waves made by Pickard are described in *Q.S.T.*† The ratio of horizontal to vertical strength of originally vertical waves was measured for varying wavelengths, distances and times of the day. It was found that horizontal effects were greater at night, with the shorter waves and at great distances. With waves of the order of 80 metres the ratio of horizontal to vertical was greater than 1 at distances over about 25 miles, and amounted to 2.4 in cases. On the 40 metre band, horizontal reception formed as much as five-sixths of the whole.

Conversely, if one starts with horizontal waves, one would expect to receive them quite well on a vertical aerial in the above circumstances.

This matter has been gone into by the General Electric Company of America, who have found it advantageous to work with horizontally polarised short waves. In this case it will be clear from the preceding considerations that a receiver near the transmitter will receive very little, best reception being obtained at great distances. This is of course a most desirable feature, particularly for duplex work.

* "Some Measurements on Wireless Wave-Fronts." R. L. Smith-Rose and R. H. Barfield. *E.W. & W.E.*, Vol. II., pp. 737-749.

† "Horizontal Reception." R. S. Kruse. *Q.S.T.*, February, 1926, pp. 9-17.

Experiments in short wave transmission, using the simple Hertz aerial, have been carried out in America at the KDKA station, but these have, as far as the writer is aware, been confined to vertical aerials. So far as is known, no information is available as to reception in this country of this station on a horizontal aerial receiver. It must be pointed out that even if the lead-in is screened, an inverted L aerial does not give horizontal reception. It is necessary for the receiver to be inserted at the midpoint, and in addition to be carefully screened.

Granted that a horizontal Hertz, supported as far away as possible from everything else, is a desirable form of aerial for short waves, providing as it does the maximum ratio of radiation resistance to loss resistance, a difficulty is at once apparent. In order to excite the aerial it is necessary to introduce some oscillating source at its midpoint. Although it is not entirely out of the question, it is not in general convenient to have the transmitter high up in the air at the centre of the aerial. It is quite usual to have some form of current-indicating instrument located at that point, either an ammeter read through a telescope (daylight), or a lamp (night), but a centrally situated transmitter is only practicable for extremely short waves, as in beam experiments, etc.

It might seem that any form of line for conveying the radio-frequency energy to the aerial would upset its characteristics, but fortunately it is possible to convey energy to the centre of the aerial from the transmitter quite a distance away, and yet to produce sensibly the same results as if the transmitter were centrally located. This is sometimes done by means of a wire connected from a tapping on the transmitting inductance, or a coil coupled thereto, to a point on the aerial a little to one side from the centre. This method is now fairly well known, but the method employing the principle of standing waves on parallel wires is less familiar, and possesses some features of interest.

As far back as 1890 E. Lecher described his arrangement of two parallel wires which could be used for the direct measurement of the wavelength of electrical oscillations. The whole matter is very fully gone into in Scientific Paper No. 491 of the *Bureau of Standards*, and those who wish detailed

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information are recommended to consult this. Briefly, it may be explained that if oscillatory voltages are induced into one end of a pair of parallel wires, standing waves are set up on them ; that is to say, for any given wavelength there are certain fixed points on the wires where there is a high potential between them, and these points occur at half a wavelength apart.

These may be detected by some potential indicator, such as a neon tube which will glow at these points. For actual measurements the *Bureau of Standards* shows that it is better to short-circuit the lines with a low-resistance thermal ammeter and to measure the distance between consecutive points

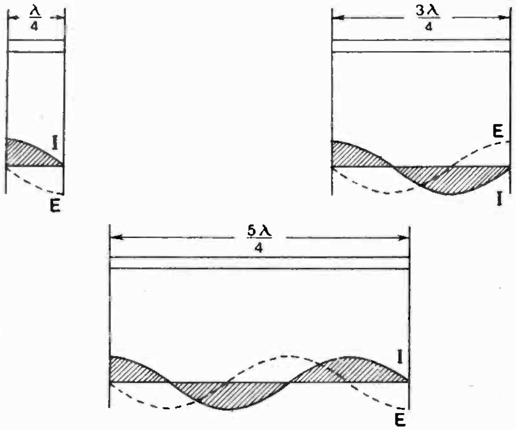

Fig. 2.

where maximum readings are obtained, which is half the wavelength impressed on the line.

The distribution of current and potential is different according as the line is open or closed. This can best be shown by diagrams. The principles are that the current and potential are 90° out of phase (when one is zero the other is maximum), that with an open line potential is a maximum at the free end, and with a closed line current is a maximum at this end. Further, in order that energy should be transferred into the line the current should be a maximum at the commencement.

Supposing the line to be open at the end, the distribution of current and voltage is shown in Fig. 2 for various lengths. In each of these cases the current is a minimum at the input, and the standing waves will not be detected. If the line lengths are as in Fig. 3 this state of things will be reversed. If the length of line is fixed and the wavelength varied each of these conditions can be noted in turn by connecting a neon tube

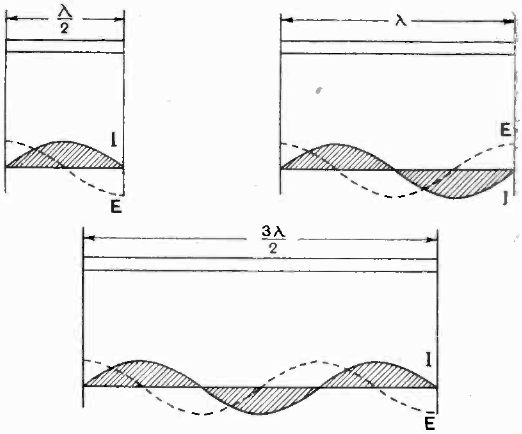

Fig. 3.

across the free end of the wires ; this will show the maximum of potential (E) by the brightness of its glow. The same glow will of course be obtained at all points where there is a maximum.

With a line closed at its free end by a short-circuiting bar or low-resistance ammeter, the distributions are reversed (Figs. 4 and 5).

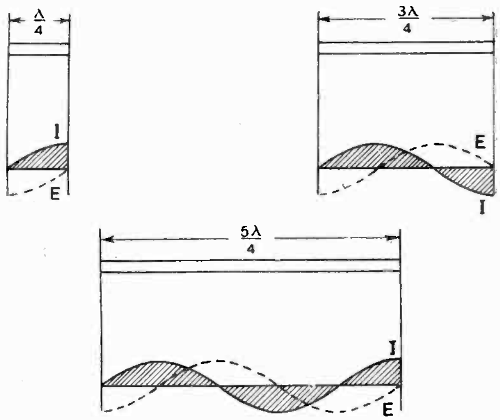

Fig. 4.

The conditions in Fig. 5 are those that concern us most. For the state of affairs at the end is (provided that resistance and other losses are negligible) the same as at

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the commencement. Therefore if a Hertz aerial is connected at the end the effect is the same as if it were connected directly on to the source, and the double line plays no part except that of a feeder. The effect

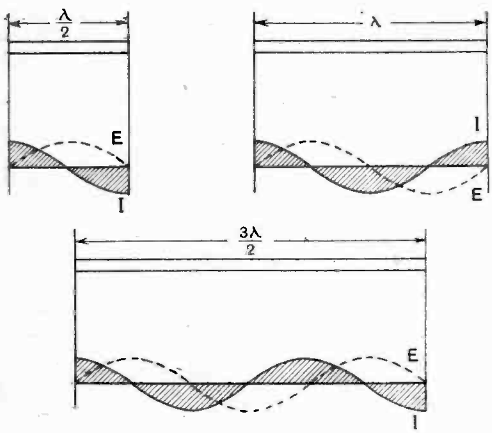

Fig. 5.

of resistance, either ohmic or due to radiation, etc., is to slow the velocity of transmission of the waves along the wires, so that the wavelength as measured along them is below the actual figure. This effect is not important in practical cases, but was detected in the experiments to be described. Also the distance apart of the wires is immaterial within wide limits, as by a happy circumstance the drop in inductance caused by bringing the wires closer is balanced by the corresponding rise in capacity.

Of course, it would be possible to upset the simple relations shown in the diagrams by inserting coils or condensers at any place, and in fact this is what happens at the input end where some form of inductance or capacity is necessary to couple to the source. Inductive coupling is most usual, and the electrical length of the line may conveniently be adjusted by a variable condenser, as this is a much more practical way of doing it than by cutting off or tacking on bits of wire. The reader will have gathered that it is necessary to work a Hertz aerial at a fixed wavelength depending on its length ; or at most, a submultiple of this fundamental wavelength is allowable. Accordingly, if 45 metres is the wave chosen, the total length of the horizontal part of the aerial must be 22.5 metres, or alternatively 45 metres, 67.5 metres, etc. The feeder can then be any reasonable length, and adjusted electrically to fit the wave used.

The arrangement is then as shown in Fig. 6. The feeder should be as nearly as possible at right angles to the aerial to avoid unbalanced effects, but this is not essential to quite good results. The ammeter A, does not necessarily indicate the greatest current anywhere, as it may not be located at the maximum position, but *other things being equal* the greater the current, the more radiation from the aerial, and the meter therefore serves a useful purpose in tuning. The condenser, coupling, etc., should be adjusted for maximum current indicated, thus putting the feeder in tune. The aerial has already been put in tune by making it the correct length for the working wavelength. So in operating the transmitter, it is first carefully adjusted to generate the correct wavelength : the feeder is then brought into tune as above. The transmitter wavelength should then be checked again.

In order to confirm the above procedure, which was arrived at theoretically, some experiments were carried out on a reduced scale with wires about 5 feet from the ground

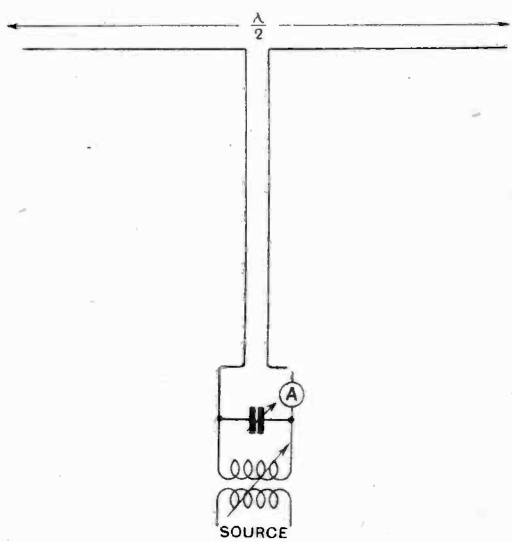

Fig. 6.

so as to allow ammeters to be inserted at various points. A simple Hartley circuit oscillator was used as source, and various coupling coils were used from 3 to 8 turns

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on a 3 in. tube. The first arrangement tried had the dimensions indicated in Fig. 7. The aerial being 9.5 metres long should work at 19 metres, and experiments were made to find out if on this assumption the correct conditions would be obtained, *i.e.*, the maximum current at the centre of the aerial. It was found that with the ammeter at the

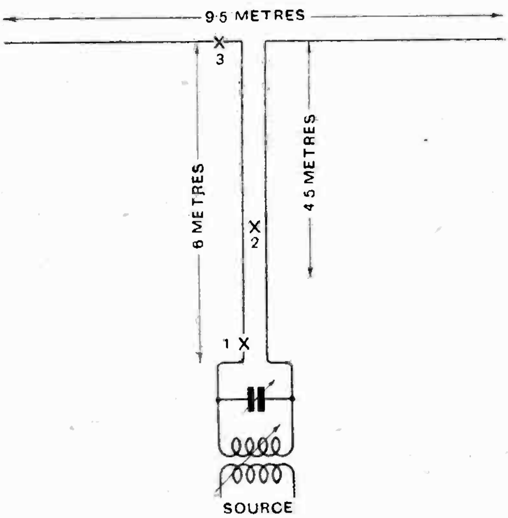

Fig. 7.

point (1) a maximum was obtained at 20 metres, and this current could be further increased by adjustment of the condenser. Further, it was found that this wavelength gave the maximum current whatever the initial value of the condenser. By placing the ammeter at point (3) it was found that the readings corresponded to those obtained at (1), though they were not equal. The drop in current due to working it at the wavelength corresponding to its physical length, *i.e.*, 19 metres, was trifling, as the resonance was not very sharp. A current several times larger than either of the preceding was noted by bridging the ammeter across at point (2).

The "aerial" was then removed, leaving the two parallel wires only. There was no resonance observed at (1) at 20 metres, but at 24 metres, or four times the length of the feeder. This corresponds to the case shown diagrammatically in the first example in Fig. 3.

The length of the "aerial" was altered to 7.5 metres and it then worked best on a little over 15 metres wave. Finally the feeder length was altered to 3.5 metres, and the working wavelength, *i.e.*, that which gave the maximum current at (1), was unaltered.

These experiments demonstrated clearly that one is justified in accepting the current reading at the input end as an indication of correct working, though its actual maximum value does not necessarily give the maximum aerial current.

A horizontal aerial 22.5 metres long and about 10 metres high has been erected, the feeder coming away to the side, as in Fig. 8. This is unavoidable, owing to the situation. The feeder wires are spaced 6 inches apart by thin ebonite strips. This system works on 45 metres and shows a great improvement over the inverted L aerial. It is also remarkably free from variations when swung about in the wind, even when no steps are taken to ensure constancy. Normally, however, the transmitter is run with quartz control. When used for reception, or transmission on other waves, the two feeders are joined at the lead-in and the aerial is used as T-type.

The recent low-power tests organised in November, 1926, by the R.S.G.B. have provided a good opportunity for obtaining practical data on the effectiveness of this aerial. The situation is such that results with other types of aerial have been extremely unsatisfactory, owing to high loss resistance and low radiation resistance. During the

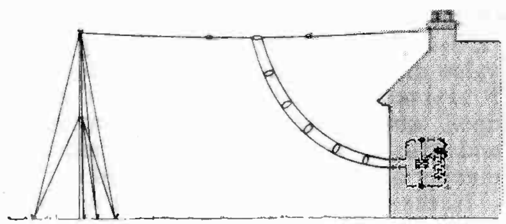

Fig. 8.

tests, using 4.8 watts input to the transmitter, two-way communication was established with America on more than one evening.

Mr. J. H. D. Ridley, operating British 5NN, after trying no less than five types of aerial with lack of success, also adopted the same form finally, and with the same power accomplished two-way working with 15 American stations during the week. It should be mentioned that both the aerials referred to lay north and south, and were thus favourably oriented for transatlantic working.

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The Tucker Microphone for Reception.

By Prof. H. E. Watson, D.Sc.

(Indian Institute of Science, Bangalore, India).

THE Tucker microphone consists essentially of a very fine, electrically heated platinum wire placed across the neck of a Helmholtz resonator. Upon the incidence of a note of the same pitch as its own fundamental, the resonator responds and a vibrating current of air is produced in the neck, which cools the platinum wire, changing its resistance and giving rise to an alternating current superimposed upon the direct heating current. By means of a transformer and amplifier this alternating current may be separated and magnified sufficiently to produce a note in telephones or a loud speaker. This beautiful instrument has been described in great detail by W. S. Tucker and E. T. Paris,* one of its many useful features being its extraordinary selectivity. An example is given in the paper referred to showing that in one case, a change in the frequency of the incident note of 6 per cent., or roughly a semitone, was found to reduce the intensity of the received note to one-fifth of the previous value.

In consequence of this property it is quite possible to select any particular note from a complex sound and, if necessary, measure its intensity. It was therefore suggested by G. G. Blake† that the instrument might be of value in the reception of wireless messages. It also occurred to the author that the effect upon atmospherics might be considerable and with a view to testing this possibility a number of experiments were carried out.

In the original paper of Tucker and Paris most of the experiments recorded are for frequencies not exceeding 250 and it is pointed out that at higher frequencies the instrument is less sensitive.‡ As 250 is not a suitable frequency for audible reception, it was decided to try to obtain results at about 1,000 periods. This was found quite possible when a wire 0.0001 in. in diameter was used in conjunction with the resonator. The size of wire used by Tucker and Paris was ordinarily 0.00024 in. Improved results might have been obtained with still finer wires, but these proved somewhat difficult to mount and no attempt was made to find the optimum thickness.

Of the several possible ways of conveying the sound to the resonator, the simple one of building the telephone into the resonator itself was adopted. As the primary object of the research was not the design of the most efficient resonator, and as the instruments first constructed were found to be suitable, no further investigations into this side of the subject were made although there is considerable scope for work in this direction.

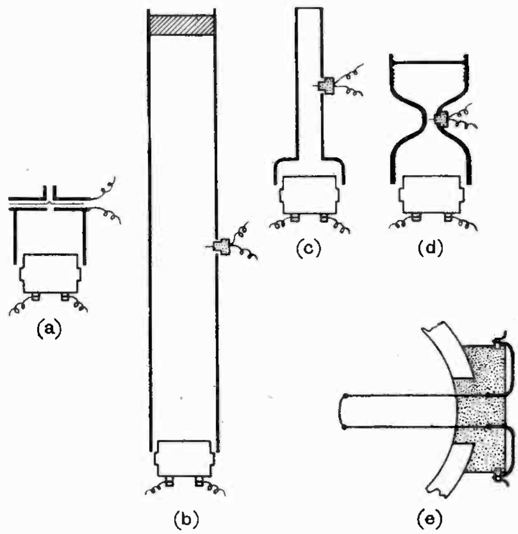

Fig. 1.

Fig. 1 shows four resonators which were constructed. (*a*) was of the Hughes pattern made of thick brass tube, 2 in. in diameter, with a bolted on cover insulated with mica and ebonite carrying a neck $\frac{5}{16}$ in. in diameter and $\frac{1}{2}$ in. long. A straight platinum wire instead of a grid was soldered to two discs of silver foil separated by mica. A Brown telephone receiver was cemented into the open end of the tube. The construction of this instrument was not simple, the

* *Phil. Trans.*, 1921, 221, A, 389.

† *Wireless World*, 1924, 14, 316.

‡ Since the present experiments, microphones have been exhibited suitable for higher frequencies.

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resistance of the platinum wire (about 400 ohms when hot) was rather high and the results obtained were not as good as with the resonators subsequently made. In these, the wire was soldered to two 40 S.W.G. Constantan wires mounted in an ebonite plug which could be inserted through a hole at the side of the resonator, the assembly being similar to that of a straight lamp filament. The arrangement is shown full size at (*e*) (Fig. 1). Constantan was used in order to secure rigidity while reducing the diameter as much as possible. The Wollaston wire was slightly curved before being soldered to the supports so that there should be no tension on the platinum when the silver coating was removed. Filaments of this type were comparatively easy to make if the soldering was done with an electrically heated wire. The filaments were $\frac{1}{8}$ in. long and worked quite well with a current of $15\mu A$ which was just insufficient to raise them to redness. The resistance with this current passing was about 120 ohms.

Resonators (*b*) and (*c*) were not of the Helmholtz type, but straight tubes closed at both ends. (*b*) was of glass 2 in. in diameter and 18 in. long, its fundamental frequency was 384 and the harmonic with three times this frequency was used as it was thought that shock excitation by atmospherics might tend to produce the fundamental which would not be so readily heard as the note of higher pitch. There was, however, no marked improvement. (*c*) was the simplest and perhaps the most satisfactory resonator tried. It was made from a thick brass tube $\frac{7}{8}$ in. in bore and 6 in. long enlarged at one end to receive the telephone. (*d*) was a double Helmholtz resonator of cast lead. The volume of the upper chamber could be adjusted by means of a brass plate which could be screwed up and down. Alternately a second telephone suitably adjusted as regards phase could be inserted at the top.

Most of the experiments were conducted with resonators (*c*) and (*d*) at a frequency close to 1,024. The general arrangement of the apparatus is shown in Fig. 2. *A* is a three valve receiver (1-v-1) with resistance capacity H.F. coupling, connected directly with an aerial 400 ft. long and 120 ft. high at the far end. This sufficed to bring in many of the high power stations at comfortable strength. *B* is a Mark C III. three valve audio-frequency amplifier which was screened to avoid local disturbances. The remaining connections are obvious from the diagram.

The apparatus was first tried in July, 1925, but as the monsoon had set in, the atmospherics, which are at their worst in April and May, had considerably subsided although still plentiful. It is, unfortunately, not possible to give quantitative figures for the effects observed, but the outstanding features were the apparent great reduction of the atmospheric-signal strength ratio and the reception of the usual crashes as a musical note. The effect upon aural reception was that although letters might be misread owing to mutilation

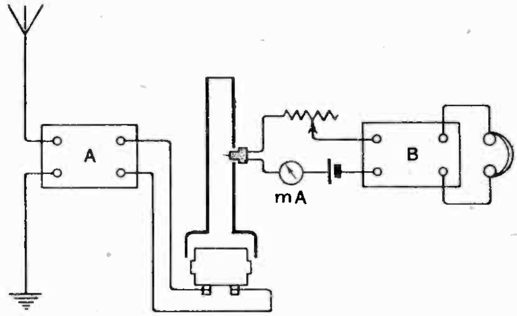

Fig. 2.

by atmospherics, the ear was not rendered insensitive by the crashes and reception was greatly facilitated. Further observations were made during a heavy local thunderstorm in October, 1925, when it was impossible to wear the headphones without great discomfort. On this occasion an ordinary type of telephone was used in resonator (*d*) and the atmospherics were barely detectable. This was partly accounted for by the lower sensitiveness of the combination, the final signal being distinctly weaker than the one obtained from the receiver alone, whereas in the previous experiments the two were of approximately the same intensity. The conclusion, however, is the same, viz., that very decided advantages are to be obtained by the use of the instrument.

An experiment was next conducted to gain some idea as to the performance of the instrument at the higher signalling speeds. A specially constructed rotating contact connected with a variable speed motor was made to send Vs on a local oscillator and these were received on the apparatus. Up to about 140 r.p.m., *i.e.*, 28 words a minute,

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the dots were clearly received, but above this speed they became somewhat blurred. The dashes remained audible at much higher rates. At 150 r.p.m. the duration of a dot is $\frac{1}{30}$ second, in which period the air in the resonator would execute about 33 complete vibrations. The exact number of vibrations necessary for the air to attain its maximum displacement will depend very much on the design of the resonator. If the damping is slight, the signal will build up rapidly in strength and a high speed will be attainable; on the other hand, if the damping is considerable, a single, very rapid impulse on the telephone diaphragm, such as might be produced by certain types of atmospheric, will have little effect when compared with that produced by the series of small impulses from the signal. In the experiment under consideration no attempt was made to separate the time constant of the resonator from that of the rest of the apparatus, so that the blurring may have been due to the latter and the performance of the resonator may have been better than has been indicated.

Finally, a few words may be said as to the selectivity of the microphone as experimentally determined. The apparatus was not suitable for quantitative measurements by the Wheatstone bridge method and so the experiments were merely qualitative. It may be mentioned, however, that they are the order which would be expected if the resonance curve at a frequency of 1,000 were similar to the one given by Tucker and Paris for 250 periods.

In one experiment, Madras (VWO) working on 4,000 metres was tuned in on the receiver already mentioned, which is perhaps as unselective as possible, autodyne reception being used. A local oscillator was arranged to transmit Vs on a near wavelength so that the signals received were much weaker than those from VWO. Tuning was carried out by means of a vernier condenser. When VWO was tuned in the Vs were almost inaudible; when the local oscillator was tuned in, the signals from VWO were audible but not loud enough to interfere with accurate reading. The change in the capacity of the condenser between the two settings was $6\mu\mu F$ on a total of 1,660 $\mu\mu F$, say 1 in 250 corresponding with a change in frequency of 1 in 500, *i.e.*, 150 cycles for the frequency of 75kC employed. The corresponding difference in the wavelengths of the two transmissions is only 8 metres. As it is the difference in frequency which determines the change in pitch of the beat note, it is this quantity, which we will assume to be about 150 cycles for signals not differing very widely in intensity, which determines the possibility of separating two signals whatever the operating frequency. Expressed in wavelengths, a separation could be effected of two stations working not less than 200 metres apart at 20,000 metres or 0.02 metre apart at 200 metres. By using a beat note of lower frequency, still sharper separation could be obtained, but, as already pointed out, other factors render this inadvisable.

Data regarding the performance of tuned audio-frequency transformers appear to be scanty. Reference, however, may be made to a recent paper on the subject by A. Pagès.* From the one resonance curve given, the selectivity of the transformers described appears to be considerably inferior to that of the hot wire microphone.

The effect of the microphone upon the confused noises usually heard when receiving upon the longer wavelengths with an unselective receiver, is striking. With perhaps a few exceptions, each station may be tuned in separately and clearly. For example, no trace of the strong signals from Saigon (HZA 15,750 metres) or Malabar (PKX 15,600 metres could be heard when listening to Lyon (YN 15,300 metres). The author has not had an opportunity of trying the apparatus in Europe, or it would no doubt be possible to give instances of the separation of signals differing still less in frequency. In very many cases, therefore, it is possible to dispense with elaborate high frequency filters which tend to weaken the signals and to use in their place a comparatively simple note magnifier. The chief drawback to the commercial use of the hot wire microphone is perhaps its fragility. Its average life has not been determined but should be considerable at the comparatively low temperature employed, moreover, filaments made as described can be replaced in a few minutes and may be handled with ordinary care. The experiments described are intended only to illustrate the possibilities of the instrument and a more extensive investigation should give greatly improved results.

* *L'Onde Electrique*, 1926, June, pp. 276-283.

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Further Notes on Simple Resonance Curves.

By Prof. E. Mallett, D.Sc., M.I.E.E.

IN the present article the resonance curves that are obtained under different conditions when two circuits are coupled together either magnetically or by a condenser are considered for the cases which give simple resonance curves. It is shown that the curves may be either of the ordinary type or the rather more complicated type obtained when the pole of the resonance circle, instead of lying on the circumference, lies outside the circle. Various applications of these "wiggle" resonance curves are described.

The subject is considered under the following headings :—

1. One circuit tuned, coupling by mutual inductance, either ω or C varied.
2. The same with condenser coupling.
3. Two circuits tuned, coupling by mutual inductance, the condensers varied.
4. The dynamometer effect.
5. Applications.

1. Coupling by Mutual Inductance.

Let us first consider the circuit of Fig. 1, in which an anode inductance of impedance $Z_1=R_1+j\omega L_1$ is coupled by a mutual inductance M with an oscillatory circuit of impedance $Z_2=R_2+j(\omega L_2-1/\omega C_2)$. If e_g is the voltage of angular frequency ω applied to the grid of the valve, μ the amplification factor and R_a the anode impedance or differential resistance (as suggested in an Editorial), we have for the anode current i_a and the current in the secondary i_2 the equations

$$\left.\begin{aligned}\mu e_g&=(R_a+Z_1)i_a+j\omega Mi_2\\ 0&=Z_2i_2+j\omega Mi_a\end{aligned}\right\} \quad .. \quad (1)$$

whence

$$i_a=\frac{\mu e_g}{R_a+Z_1+\dfrac{\omega^2M^2}{Z_2}} \quad .. \quad (2)$$

and

$$i_2=-\frac{j\omega M\mu e_g}{Z_2(R_a+Z_1)+\omega M^2} \quad (3\text{A})$$

$$=-\frac{j\omega M\mu e_g/(R_a+Z_1)}{Z_2+\dfrac{\omega^2M^2}{R_a+Z_1}} \quad (3)$$

Let us now suppose that either the condenser C_2 or the angular frequency ω is varied round about resonance. If C_2 is varied the whole of the quantities in equation 3 remain constant except Z_2, and if ω is varied this is in effect nearly true over the resonance range, since this is covered with only a very small change in ω. It is clear therefore that a simple resonance curve will result for i_2 plotted against C_2 or ω, but that both the decay factor and to a small extent the resonance frequency of the

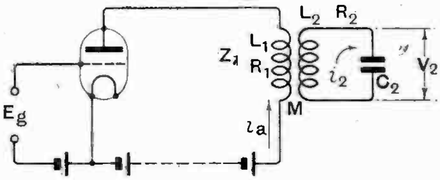

Fig. 1. *The voltage across the anode coil describes a "wiggle" resonance curve as the frequency or the secondary condenser is varied through resonance.*

oscillatory circuit Z_2 will be modified by the presence of the valve. This appears from the denominator of 3, which may be written

$$Z_2+\frac{\omega^2M^2}{(R_a+R_1)^2+\omega^2L_1^2}(R_a+R_1-j\omega L_1)$$

Generally speaking the square of the differential resistance R_a of the valve will be far greater than $\omega^2L_1^2$, and R_a will be far greater than R_1, so we may write for the denominator of 3

$$R_2+\frac{\omega^2M^2}{R_a}+j\left\{\omega\left(L_2-\frac{\omega^2M^2L_1}{R_a^2}\right)-\frac{1}{\omega C_2}\right\} \quad (4)$$

Thus the effective inductance of the oscillatory circuit is decreased a little and the resonant ω is

$$\omega_0=\frac{1}{\sqrt{\left(L_2-\dfrac{\omega^2M^2L_1}{R_a^2}\right)C_2}} \quad (5)$$

This alteration will generally be very small so that the effective decay factor is obtained from (4) as

$$\Delta^1=\frac{R_2+\dfrac{\omega^2M^2}{R_a}}{2L_2}=\frac{R_2}{2L_2}+\frac{\omega^2M^2}{2R_aL_2} \quad (6)$$

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We are interested in obtaining the largest possible voltage across C_2, which means the largest possible value of i_2, and it is clear from (3) that if M is made too great the current i_2 will actually be smaller than with a smaller value of M. The best value of M is obtained by differentiating 3A with regard to M and equating to zero. Thus

$$\frac{di_2}{dM} = -j\omega\mu e_g \left\{ \frac{1}{Z_2(R_a+Z_1)+\omega^2M^2} - \frac{2M^2\times\omega^2}{\{Z_2(R_a+Z_1)+\omega^2M^2\}^2} \right\}$$

Equating this to zero gives

$$Z_2(R_a+Z_1)+\omega^2M^2 = 2\omega^2M^2$$

which at the resonant frequency, when $Z_2 = R_2$, and neglecting Z_1 in comparison with R_a, gives $\omega^2M^2 = R_aR_2$,

or $$M = 1/\omega\sqrt{R_aR_2} \quad \ldots \quad (7)$$

as the value of the mutual inductance to give the largest possible value of current in the oscillatory circuit.

With this value of the mutual inductance the effective decay factor from (6) becomes

$$\Delta' = \frac{R_2}{2L_2} + \frac{R_2}{2L_2} = 2\Delta_2$$

The decay factor of the valve circuit is double that of the oscillatory circuit alone and this is the decay factor that would be obtained from a resonance curve of i_2 plotted against ω. This increase of decay factor is of great importance in measurements of high frequency resistance by drawing a resonance curve, or by adding resistances to the oscillatory circuit. It is only when M is very small so that ω^2M/R_a^2 is negligible compared with R_2 that the method can succeed, and this involves either a very powerful amplifier valve or very delicate measuring instruments. If the measurement is attempted by coupling direct to an oscillator the difficulty is accentuated, as now R_a must be replaced by the effective impedance of the circuit to which the oscillatory circuit is coupled, and this will generally be far smaller than the differential resistance of the valve.

Let us now consider the voltage across the anode coil Z_1 as the frequency is varied. The effective impedance of the coil is

$$Z_1 + \frac{\omega^2M^2}{Z_2},$$

and the current through it is i_a as given by 2. The voltage v_1 across it is therefore

$$v_1 = \frac{\mu e_g}{R_a + Z_1 + \frac{\omega^2M^2}{Z_2}} \times \left(Z_1 + \frac{\omega^2M^2}{Z_2} \right) \quad (8A)$$

Now usually we may neglect the effective impedance of the coil in comparison with R_a and write

$$v_1 = \frac{\mu e_g}{R_a}\left\{ Z_1 + \frac{\omega^2M^2}{Z_2} \right\} \quad \ldots \quad (8)$$

The vector diagram of this equation is easily constructed. $1/Z_2$ is, as has been seen before, a circle traversed in a clockwise direction as ω is increased, and since the ω changes over resonance are very small, ω^2M^2 is to all intents and purposes constant, so that multiplying the circle $1/Z_2$ by ω^2M^2 merely changes the scale. The addition of Z_1 is effected by choosing a new pole O_1 so that $O_1O = Z_1$. This is done in Fig. 2(a), where OPR is the circle ω^2M^2/Z_2 and $O_1O = Z_1$, so that O_1P is the vector sum of O_1O and OP, *i.e.*,

$$O_1P = Z_1 + \frac{\omega^2M^2}{Z_2}$$

for the particular value of ω considered. Multiplication by $\mu e_g/R_a$ merely alters the scale. If now we measure the values of the

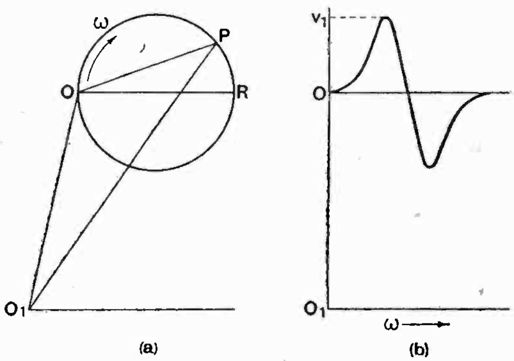

Fig. 2. *Showing how the wiggle curve is derived from a circle on a stick.*

voltage across the coil Z_1 and plot them against ω we shall obtain the curve of Fig. 2(b), which is drawn by measuring the values of O_1P for various positions of P and therefore for various values of ω. We have obtained another type of simple resonance curves. It is called simple still since only one tuned (or nearly tuned)

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circuit is involved. If two tuned circuits were involved we might call the resulting resonance curves compound, if three, triple, and so on. If a large number, as in a filter or chain conductor, the term chain resonance curves might be suitable.

This curve of Fig. 2(b) is very interesting, because it is derived from a circle whose damping is that of the secondary circuit alone, and is not influenced, except to a small degree, by the associated valve circuit. This is the case under the conditions contemplated in Fig. 2, where ω^2M^2/R_2 $(=OR)$ is of the same order as Z_1 $(=O_1O)$, and both are small compared with R_a.

If the curve of Fig. 2(b) is obtained experimentally it is possible by a simple construction to find the vector diagram of Fig. 2(a), and hence from the circle of Fig. 2(a) to find the $\omega/\tan\phi$ line as described in a recent article.* This line then will give the decay factor of the secondary circuit.†

2. Capacity Coupling.

The same type of "wiggle" resonance curve is obtained with direct coupling with

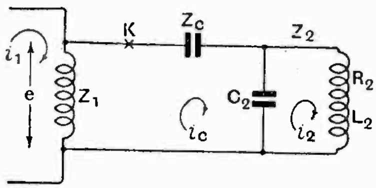

Fig. 3. *The case of coupling by condenser. Wiggle curves are obtained when the frequency, the coupling condenser or the tuning condenser are varied.*

a condenser, as indicated in Fig. 3. Then if i_1, i_c, and i_2 are the circuital currents, and e is the voltage maintained across Z_1, and

$$Z_c = -\frac{j}{\omega C_c}$$

is the coupling impedance, we have the following equations :—

$$\left.\begin{aligned} e &= Z_1(i_1 - i_c) & \text{(i)}\\ O &= Z_1(i_c - i_1) + Z_c i_c - \frac{j}{\omega C_2}(i_c - i_2) & \text{(ii)}\\ O &= Z_2 i_2 + \frac{j}{\omega C_2} i_c & \text{(iii)} \end{aligned}\right\} \quad (9)$$

* E. Mallett, *E.W. & W.E.*, Feb., 1927, p. 93.

† Details of how this measurement may be carried out are given in the *Journal of the Institution of Electrical Engineers*, Vol. 63, pp. 397-412.

Eliminating i_1 and i_2 from (ii) by means of (i) and (iii) we obtain

$$i_c = \frac{e}{Z_c - \frac{j}{\omega C_2} + \frac{j}{\omega^2 C_2{}^2 C_2}}$$

Now
$$-\frac{j}{\omega C_2} + \frac{1}{\omega^2 C_2{}^2 Z_2} = \frac{-j\omega C_2(Z_2) + 1}{\omega^2 C_2{}^2 Z_2}$$

$$= \frac{-j\omega C_2(R_2 +)\left(\omega L_2 - \frac{1}{\omega C_2}\right) + 1}{\omega^2 C_2{}^2 Z_2}$$

$$= \frac{\omega^2 L_2 C_2 - j\omega C_2 R_2}{\omega^2 C_2{}^2 Z_2}$$

$$= L_2/C_2 Z_2$$

neglecting R_2 in comparison with ωL_2.

Thus

$$i_c = \frac{e}{Z_c + \frac{L_2}{C_2 Z_2}} \quad \ldots \quad \ldots \quad (10)$$

and using this in 9 (i) and (iii) we obtain

$$i_1 = e\left\{\frac{1}{Z_1} + \frac{1}{Z_c + \frac{L_2}{C_2 Z_2}}\right\} \quad \ldots \quad (11)$$

$$i_2 = -\frac{je}{\omega C_2 Z_2 Z_c + \omega L_2} \quad \ldots \quad (12)$$

The current into the network is i_1 and the voltage across the coil Z_1 is e, so that the effective impedance is $Z' = e/i_1$, which from (ii) is

$$Z' = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_c + \frac{L_2}{C_2 Z_2}}} \quad \ldots \quad (13)$$

Considering the quantity

$$Z_c + \frac{L_2}{C_2 Z_2},$$

whose value will fluctuate considerably with frequency changes, we see that the resonance phenomenon will occur when Z is of the same order as L_2/C_2Z_2. In Fig. 4 the circle OPQ is the locus of L_2/C_2Z_2, with diameter $= L_2/C_2R_2$

and
$$O_1O = Z_c = -\frac{j}{\omega C_c},$$

so that

$$O_1P = O_1O \# OP = Z_c + \frac{L_2}{C_2 Z_2} \quad *$$

* The # sign is used for vector addition.

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and the smallest value of O_1P occurs when P is at A, so that O_1A produced passes through the centre of the circle. The value of O_1P is then a minimum O_1A.

Inverting from O_1 to obtain

$$\frac{1}{\left(Z_c+\frac{L_2}{C_2Z_2}\right)}$$

in 13, the circle $O_1P'D$ is obtained (Fig. 5(a), and the addition of $1/Z_1$ is carried out by choosing a new pole, O_2, such that $O_2O_1 = 1/Z_1$; then $O_2P' = 1/Z_1$, the circle being described clockwise from somewhere near O_1 as ω is increased, or as C_2 is increased.

It is clear that the curve of $1/Z'$ plotted against ω or C_2 is a wiggle curve drawn in the reverse direction from that of Fig. 2(b).

Resonance will occur, *i.e.*, P' will lie on D in Fig. 5 (a) or P on A in Fig. 4 very nearly when $|OO_1| = |OA|$, especially when C_c is large enough to make OO_1 small, which is the interesting case. That is, resonance occurs when

$$\left|-\frac{j}{\omega C_c}\right| = \left|\frac{L_2}{C_2Z_2}\right|$$

or
$$\frac{1}{\omega C_c} = \frac{L_2}{C_2\sqrt{R_2^2+\left(\omega L_2-\frac{1}{\omega C_2}\right)^2}}$$

Now when OO_1 is small OA is nearly vertical,

$$\left(\omega L-\frac{1}{\omega C}\right)^2$$

is large compared with R_2^2 and we have

$$\frac{1}{\omega C_c} = \frac{L_2}{C_2\left(-\omega L_2+\frac{1}{\omega C_2}\right)} \quad * \qquad (14A)$$

or
$$\omega_A = \frac{1}{\sqrt{L_2\left(1+\frac{C_c}{C_2}\right)C_2}} \qquad (14)$$

It is seen that the resonance frequency is lower than that of the secondary circuit alone. The effective inductance of the circuit has been increased to

$$L_2\left(1+\frac{C_c}{C_2}\right),$$

with the result that the frequency has been lowered. The effective decay factor is also lowered. The circle of Fig. 5 has been drawn as the inverse of the impedance,

$$\left(Z_c+\frac{L_2}{C_2Z_2}\right)$$

which is equal to

$$-\frac{j}{\omega C_c}+\frac{L_2\left\{R_2-j\left(\omega L_2-\frac{1}{\omega C_2}\right)\right\}}{C_2R_2^2+\left(\omega L_2-\frac{1}{\omega C_2}\right)^2}$$

$$\doteq \frac{L_2R_2}{C_2\left(\omega L_2-\frac{1}{\omega C_2}\right)^2} - j\frac{L_2}{C_2\left(\omega L_2-\frac{1}{\omega C_2}\right)} - \frac{j}{\omega C_c}$$

$$= \frac{L_2R_2}{C_2\left(\omega L_2-\frac{1}{\omega C_2}\right)^2} - j\frac{\omega L_2\left(1+\frac{C_c}{C_2}\right)-\frac{1}{\omega C_2}}{\omega C_c\left(\omega L_2-\frac{1}{\omega C_2}\right)}$$

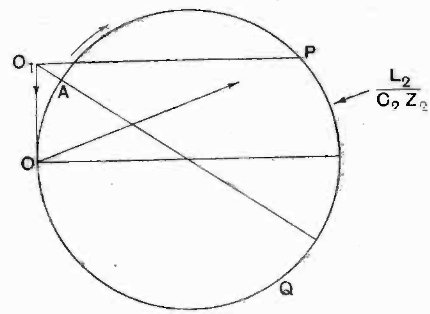

Fig. 4. *Circle diagram of condenser coupling.*

The effective decay factor of this impedance is therefore

$$\Delta' = \frac{\dfrac{L_2R_2}{C_2\left(\omega L_2-\frac{1}{\omega C_2}\right)^2}}{-2\,\dfrac{\omega L_2\left(1+\frac{C_c}{C_2}\right)}{\omega C_c\left(\omega L_2-\frac{1}{\omega C_2}\right)}}$$

$$= \frac{R_2}{2L_2\left(1+\frac{C_c}{C_2}\right)} \quad \ldots \quad \ldots \quad (15)$$

since by 14A

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

at resonance, and this holds nearly in the neighbourhood of resonance.

These conclusions have been confirmed experimentally. An oscillator-amplifier was

* The —*ve* sign is taken in extracting the root to make the right-hand side positive.

used to pass current through Z_1 and the voltage v across Z_1, was measured by a valve voltmeter. Then the circuit to the condenser was broken at K, Fig. 3, and the voltage v_1 across Z_1 measured again. On the assumption that the amplifier valve differential

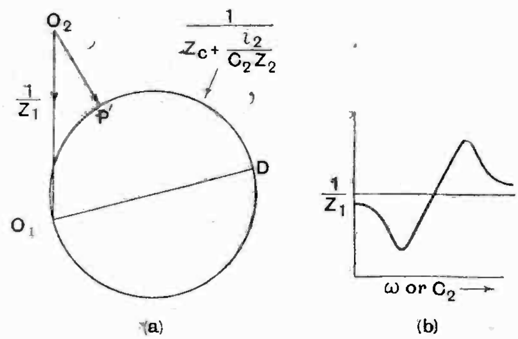

Fig. 5. *Showing how the wiggle curve is obtained with condenser coupling.*

resistance was so large that the current i_1 remained the same for the two readings, we have

$$i_1 = v\left(\frac{1}{Z_1} + \frac{1}{Z_c + \frac{L_2}{C_2Z_2}}\right)$$

and $\quad i_1 = v_1 \cdot 1/Z_1$

whence $$\frac{v_1}{v} = 1 + \frac{Z_1}{Z_c + \frac{L_2}{C_2Z_2}} \quad \ldots \quad (16)$$

which gives the vector diagram of Fig. 5 (a), multiplied by $|Z_1|$ and turned through nearly 90°.

Thus if ω is varied and v_1/v plotted against ω, or against the oscillator vernier condenser which is used to vary the frequency, the construction referred to before can be used to obtain the circle diagram and hence the value of Δ'.

This is done in Fig. 6. The values of the inductances and condensers were

$L_1 = 700\mu H$, $L_2 = 4{,}040\mu H$, $C_2 = 855\mu\mu F$, $C_c = 146\mu\mu F$.

The secondary coil used in this experiment was one whose resistance at about $\omega = .5 \times 10^6$ had been measured carefully on several occasions and found to be very nearly 9 ohms. In the present experiment the condenser C_2 was adjusted until resonance occurred at the same frequency. To do this it was found necessary to make C_2 $855\mu\mu F$, which with $10\mu\mu F$ self capacity of L_2 gives for the secondary capacity $865\mu\mu F$. Then from 14 the resonant frequency should be

$$\omega_A = \frac{1}{\sqrt{L_2C_2\left(1 + \frac{C_c}{C_2}\right)}}$$

$$= \frac{1}{\sqrt{4{,}040 \times 10^{-6} \times 865 \times 10^{-12} \times (1 + 146/865)}}$$

$$= .495 \times 10^6$$

which is quite close to that actually found.

From Fig. 6 the slope of the $c/\tan\alpha$ line is found to be 23.0. Since for the oscillators used $\delta\omega = 42.6\ C$, we have for the decay factor $\Delta' = 23.0 \times 42.6 = 980$.

From 15 this is

$$R_2/2L_2\left(1 + \frac{C_c}{C_2}\right)$$

hence

$$R_2 = 2\Delta' L_2\left(1 + \frac{C_c}{C_2}\right)$$

$$= 2 \times 980 \times 4{,}040 \times 10^{-6} \times 1.169$$

$$= 9.24 \text{ ohms}$$

in fairly close agreement with the 9 ohms previously found.

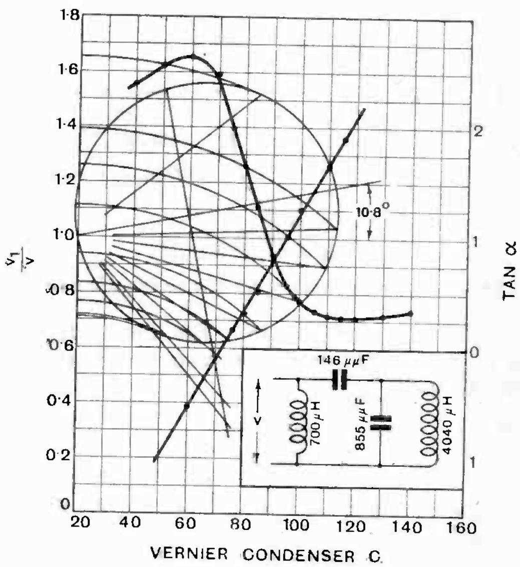

Fig. 6. *An experimentally obtained curve, showing the straight line and circle construction for the decay factor.*

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The value of the secondary current is determined from equation 12

$$i_2 = -\frac{je}{\omega C_2 Z_2 Z_c + \omega L_2} \quad .. \quad (12)$$

This gives in the case of capacity coupling a vector diagram as in Fig. 7. The straight line Z_2 (pole O) is turned through a right angle clockwise by multiplication by

$$\omega C_2 Z_c = -j\frac{C_2}{C_c}$$

and its pole is shifted to O_1 on adding ωL_2. Inverting the circle O_1D is obtained to represent $1/(\omega C_2 Z_2 Z_c + \omega L_2)$ and finally i_2/e, the secondary current per volt across the network is found by turning this circle clockwise through a right angle. The arrows show the direction in which the locus is traversed as ω increases starting from a very small value.

Maximum secondary current occurs when $\omega L_2 + \omega C_2 Z_c X_2 = 0$

giving $$\omega^2 = \frac{1}{L_2 C_2\left(1 + \frac{C_c}{C_2}\right)}$$

as before.

The resonance curve is obtained from the circle O_1D' and is evidently an ordinary

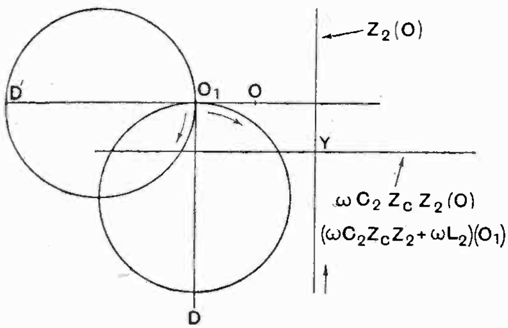

Fig. 7. *The secondary current vector diagram.*

simple resonance curve. The decay factor is easily shown, as in the case of the wiggle curve, to be

$$\frac{R_2}{2L_2\left(1 + \frac{C_c}{C_2}\right)}$$

If ω is kept constant and C_2 or C_c is varied the vector loci and resonance curves obtained are similar to those obtained when ω is varied. This is clear on reference to Fig. 4. If C_2 is varied P moves along the arc OAP just as it did when ω was varied, while if C_c is varied, O_1 moves along the line OO_1 and the ray is drawn from A to O_1. The actual vector changes are similar therefore in this case also.

3. Two Tuned Circuits.

If we have two tuned coupled circuits, and the condensers of the circuits are varied, simple resonance curves result which may be of either the ordinary or the wiggle type.

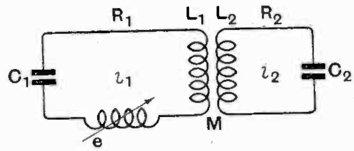

Fig. 8. *Two coupled circuits in which either of the condensers can be varied.*

Consider the circuit of Fig. 8 in which an E.M.F. e is introduced into the first. For the E.M.F. equations in the two circuits we have

$$e = Z_1 i_1 + j\omega M i_2$$
$$0 = Z_2 i_2 + j\omega M i_1$$

whence

$$i_1 = \frac{e}{Z_1 + \frac{\omega^2 M^2}{Z_2}} = \frac{e}{Z'} \quad .. \quad (17)$$

$$i_2 = \frac{e}{j\omega M - \frac{Z_1 Z_2}{j\omega M}} = \frac{e}{Z''} \quad .. \quad (18)$$

where Z' and Z'' are effective impedances for the primary and secondary currents respectively, defined by

$$\left.\begin{aligned} Z' &= Z_1 + \frac{\omega^2 M^2}{Z_2} \\ Z'' &= \frac{j}{\omega M}(Z_1 Z_2 + \omega^2 M^2) \end{aligned}\right\} \quad (19)$$

(i) Primary condenser varied.

In the expression for Z' varying C_1 will alter Z_1 without affecting the second term. The locus of Z' is found in Fig. 9. The vertical straight line CC' with pole O is the locus of Z_1, and the constant vector $\omega^2 M^2/Z_2$ is added by making $O_1O = \omega^2 M^2/Z_2$. Then the straight line with pole O_1 represents Z' and inverts to a circle to give the locus of i_1. The i_1/C_1 curve therefore appears as an ordinary simple resonance curve.

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If Z_2 at the frequency in question has a positive angle (the frequency above the resonance of Z_2) ω^2M^2/Z_2 has a negative angle, $O'O$ is drawn below the horizontal, the resonant frequency of Z' is lower than that of Z_1, and a larger condenser is necessary to tune. This is the case in Fig. 9, where the condenser value has increased as is indicated by c for resonance moving to c'. If Z_2 has a negative angle the resonant frequency of Z' is higher than that of Z_1 and a smaller condenser value is required. If Z_2 is tuned the resonant frequencies of Z_1 and Z' (as well as Z_2) are the same.

$$O_1c' = O_1O \cos \widehat{OO_1C'} + OC$$
$$= \left|\frac{\omega^2M^2}{Z_2}\right| \cdot \left|\frac{R_2}{Z_2}\right| + R_1$$
$$= \frac{\omega^2M^2}{R_2^2+\left(\omega L_2-\frac{1}{\omega C_2}\right)^2} \cdot R_2 + R_1 = R',$$

the effective resistance of the primary circuit.

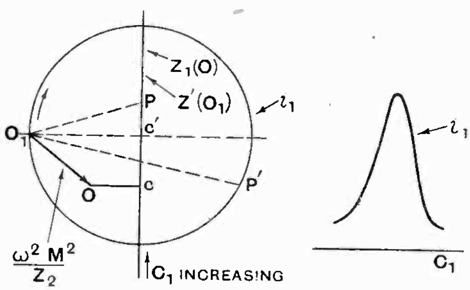

Fig. 9. *Diagram for variations of the primary current with variations of the primary condenser.*

$$\tan \alpha = \frac{CP-CC'}{O_1C'} = \frac{\left(\omega L_1 - \frac{1}{\omega C_1}\right) - \left(\omega L_2 - \frac{1}{\omega C_2}\right)}{R'}$$

and writing $\omega_1^2 = 1/L_1C_1$ so that $C_1 = 1/\omega_1^2L_1$,

$$\frac{d \tan \alpha}{d\omega_1} = -2\frac{\omega_1 L_1}{\omega R}$$

If the frequency is nearly that of the primary circuit resonant frequency, so that $\omega \doteq \omega_1$ then

$$\frac{d\omega_1}{d \tan \alpha} = \frac{R'}{2L_1}$$

and the circle and straight line construction carried out on a curve of i_1 plotted against ω_1 will give the effective resistance R'.

If i_1 is plotted against c_1 we obtain

$$\frac{d \tan \alpha}{dC_1} = \frac{1}{\omega C_1^2 R'} \doteq \frac{1}{C_1 R'}\sqrt{\frac{L_1}{C_1}}$$

and

$$\frac{dC_1}{d \tan \alpha} = R'C_1\sqrt{\frac{C_1}{L_1}}$$

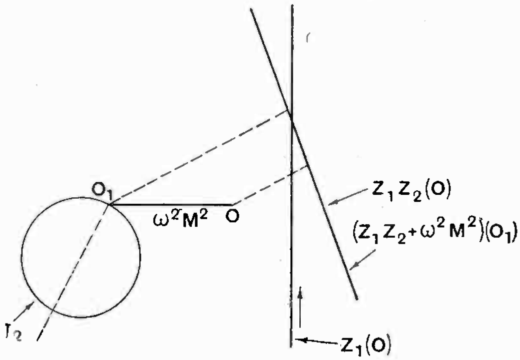

Fig. 10. *Diagram for variations of the secondary current with variations of the secondary condenser.*

which enables R' to be obtained from the slope of the line at resonance.

The secondary current will also give a simple resonance curve. For

$$Z'' = j\frac{\omega^2M^2 + Z_1Z_2}{\omega M} \quad \text{(from 19)}$$

Multiplying the vertical line Z_1 by the constant Z_2 and adding ω^2M^2 shifts the pole from O to O_1. Multiplying again by $j/\omega M$ turns the line through 90° counter-clockwise and this inverted gives a circle. See Fig. 10.

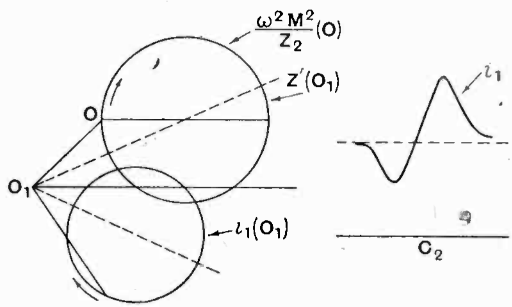

Fig. 11. *Diagram for the variations of the primary current with variations of the secondary condenser.*

(ii) *Secondary Condenser Varied.*—When the secondary capacity C_2 is varied exactly the same conditions apply for Z'' and i_2 as when the primary condenser is varied, since the expression for Z'' is symmetrical with regard to Z_1 and Z_2.

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But the i_1 curve has a different form.

$$Z' = \frac{\omega^2 M^2}{Z_2} + Z_1$$

Z_2 is now the varying vector, and the locus of $\omega^2 M^2/Z_2$ is a circle with pole O on the circumference. Adding Z_1 shifts the pole to

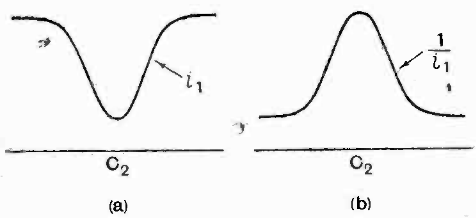

Fig. 12. *The special case of a tuned primary.*

O_1 fixed by making $O_1O = Z_1$. The locus of Z' is therefore a circle with the pole outside, and inversion to find i_1 gives another circle with pole outside. The curve of i_1 plotted against C_2 or ω_2 has the form therefore shown in Fig. 11.

In the special case when Z_1 is tuned so that O_1O is horizontal, the current curve is as shown in Fig. 12 (a), while the curve of $1/i_1$ is as shown in Fig. 12 (b).

In any case a curve of $1/i_1$, plotted against ω_2 is proportional to Z_2, the circle of which depends only on Z_2. The circle and straight line construction carried out on such a curve will therefore give the decay factor and hence the resistance of the secondary circuit alone. The scheme would be very similar to the "ammeter method" previously described.*

4. Dynamometer Effect.

A curve similar to these wiggle resonance curves is obtained by Mandelstam and Papalexi† by causing the currents from a primary and a secondary circuit to act on the fixed and the moving coil respectively of a dynamometer, as indicated in Fig. 13 (a), and plotting the deflection of the moving coil against the value of the condenser in the secondary circuit. The resulting curve is as shown at Fig. 13 (b). The primary is tuned to the source of supply, and the deflection is zero when the secondary is also tuned.

* *J.I.E.E.* Vol. 63, pp. 397-412.
† See *Jahr.* 4, 605, 1911, or *Ann. der Physik*, 33, 490.

The curve between the maximum deflections in the two directions is steeper the smaller the decay factors of the circuits. This effect was used for the precise measurement of frequency and for the measurement of the sum of the decay factors of the two circuits. The actual deflection for any setting of C_2 is proportional to $I_1 I_2 \cos \phi$, where I_1 and I_2 are the root mean square values of the currents and ϕ the phase angle between them. The mathematics is more complicated therefore than that in the cases we have considered. The curve, though similar to the wiggle curve, is not derived from a straight line and circle.

5. Applications.

(i) The application of the wiggle curve with mutual inductance coupling (Section 1) to the accurate determination of high frequency resistance and wavelength has

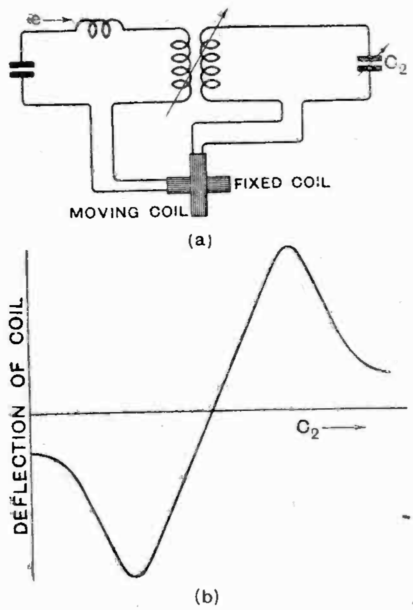

Fig. 13. *The dynamometer effect of Mandelstam and Papalexi.*

already been described in detail, as mentioned before. Further experience has proved frequency determinations made in this way to be of value, but unless an accurate resistance measurement is required the labour of the graphical construction does rather rule this method out.

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The capacity coupling wiggle curve however can readily be used for the rapid examination of coils for both resistance and inductance, although the accuracy obtained will not be of such a high order. A circuit is set up as in Fig. 3, supplied by a valve oscillator-amplifier arrangement and with a valve voltmeter for measuring the voltages across Z_1. The oscillator is set to the desired frequency, the coil to be examined placed across C_2 (L_2 in the figure) and the calibrated condensers C_c and C_2 adjusted until a reasonable wiggle is obtained on the valve voltmeter as C_2 is varied. Then, knowing the frequency, the value of L_2 is found at once from equation 14, the value of C_2 used being that at the middle of the wiggle, when the same voltmeter deflection is obtained with the key K open or closed. Then readings of the valve voltmeter are made at the maximum voltmeter reading and the minimum v' and v'' respectively with the key closed and v_1' and v_1'' with the key open. The difference of the ratios, *i.e.*,

$$\frac{v_1'}{v'} - \frac{v_1''}{v''} = D$$

is the diameter of the circle of Fig. 6. This from 16 is very nearly

$$\frac{\omega^3 L_1 L_2 C_c^2}{C_2 R_2}$$

so that R_2 is obtained from the expression

$$R_2 = \frac{\omega^3 L_1 L_2 C_c^2}{C_2 D}$$

Applying this to the curve of Fig. 6, where $D = .94$, we have

$$R_2 = \frac{.5^3 \times 10^{18} \times 700 \times 10^{-6} \times 4{,}040 \times 10^{-6} \times 146^2 \times 10^{-24}}{865 \times .94}$$

$= 9.3$ ohms

in close agreement with the value obtained by the straight line and circle construction.

This method can obviously be employed with any shape of coil, such as a toroid where the coupling by mutual inductance is not a simple matter, and it is rapid and fairly accurate.

(ii) The determination of frequencies can be made so precisely that measurements of capacities or inductances can quite readily be accurately made. For instance, if, after adjusting C_2 so that the voltmeter reading is at the middle of the wiggle, an unknown condenser is placed in parallel with C_2 and the value of C_2 altered until the voltmeter again indicates the middle of the wiggle, the difference between the two values of C_2 is the value of the unknown condenser.

BOOK REVIEW.

Les Ondes Electrique Courtes. By René Mesny. Pp. 163, with 68 Figs. Les Presses Universitaires de France. 30 fr.

Professor Mesny is well known to all those who read current French wireless literature as one of the foremost workers and writers in the field of radio in France. He has been one of the most active pioneers in short-wave research, and this book from his pen may be confidently recommended to anyone desirous of obtaining an authoritative review of this latest branch of radio-telegraphy. It is not a popular book but a scientific review in which mathematical analysis is employed where necessary. The first of the three chapters deals with propagation and is subdivided into three sections entitled "Observed Facts," "Theories" and "Experiments and Criticisms." The second chapter on Emission and Reception is subdivided under the headings, "Generation of Short Waves," "Transmitting Aerials," and "Reception"; whilst the last chapter deals with laboratory experiments on short waves and measurements, and discusses the borderland between electrical and optical phenomena. A very useful feature of the book is a very complete bibliography giving references to 171 original publications.

ERRATA.

"Some New Coil Impedance Diagrams." page 89, col. 1, line 4. Left-hand member should be $1 + \omega^2 C L_0$. Line 12 should read $\omega L_0 = -\frac{1}{\omega C_0}$

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Past and Present: A Few Notes.

Presidential Address to the Radio Society of Great Britain, by Brig.-General Sir H. C. L. HOLDEN, K.C.B., F.R.S., M.I.E.E., delivered at the Institute of Electrical Engineers, on Wednesday, 26th January, 1927.

I AM afraid I cannot emulate my immediate predecessors in the Presidential Chair by discoursing on highly technical matters connected with Radio Communication, nor indeed on atoms and kindred subjects, although the greater part of my life has been spent in either designing, making or experimenting with weapons intended for reducing everything to atoms, which object they accomplished most successfully from this point of view in the Great War. Incidentally, however, the war did good in some directions, notably in the more rapid development of wireless apparatus and methods of communication than would have taken place in peace.

Labouring under the above disadvantages I have thought it might be of some interest to my hearers if I recall to their memory the early history of the Radio Society of Great Britain in the first place, and then make a few remarks on inventions and improvements which have been made mostly in the last fifteen years and have brought the science of communication by wireless to its present pitch of perfection. In conclusion I would like to say a few words regarding the present activities of the R.S.G.B. and what the Society aims at accomplishing in the near future.

The R.S.G.B., or its forerunner the London Wireless Club (later Society), has now been in existence for 13 years, the Club having been initiated in July, 1913, by Mr. Réné H. Klein, well known to wireless experimenters, with whom were associated Mr. McMichael and Mr. Fogarty. I refer to these gentlemen personally as I feel that all honour is due to them for their action and forethought at a time when the science was in its infancy, and experimenters were in need of the help and the combined strength that good organisation ensures.

I should like to remind you also that it was Mr. Hope-Jones, who became the first Chairman of the Society, who advocated its establishment on a less modest scale than was originally contemplated, when it was launched as the Wireless Society, a course that was followed and justified by its immediate success. All the men, professionally or otherwise prominent in wireless science, became in one way or another associated with the new venture and contributed to its growth and usefulness, and are still loyally supporting it—with the exception of a few pioneers who have passed away. I need not dwell any longer on the early history as full details are available in a most complete and interesting article which was published in the *Wireless World and Radio Review* of November 25th, 1922, and subsequently reprinted by the R.S.G.B. in pamphlet form.

I can only add that any member who has not read this will not regret taking an early opportunity of doing so. Incidentally the part taken by the R.S.G.B. in the initiation of broadcasting, as it is now generally known, is fully described.

I have often wondered what device, if any, will supersede the thermionic or triode valve as we know it to-day, seeing that it is undoubtedly the perfection of this appliance that has made extraordinary feats of telegraphy and telephony possible. I need hardly go into the early history of the two-electrode valve which rectified only, as this is so well known.

The triode valve came into practical use on a rapidly increasing scale during the Great War, and appears to have followed the De Forest "Audion," which, though it contained the same three elements, viz., filament cathode, grid, and plate anode, differed from the latter in its manner of operation, and also in its degree of exhaustion which was very much more complete.

The triode valve, under the name of the Pliotron (the meaning of which word is "amplifier"), was developed from a form of rectifying valve known as the Kenotron, in the research laboratories of the General

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Electric Company of America by the addition of a fine wire mesh or grid for the purpose of controlling the current passing from the filament or cathode to the anode, and situated in the direct path between them.

This valve, as far as I know, was first described in an article written by Dr. Langmuir in the *General Electric Review* early in 1915, which was reprinted in the *English Electrical Review* in May, 1915.

The article in question is remarkable to my mind in that it contains such a store of information regarding the properties and action of this valve, and is eloquent testimony to the thorough manner in which the research which accompanied its development must have been carried out.

The best conditions necessary for the operation of the valve as a detector or as an amplifier, or again as an oscillator, are discussed at length, as well as the questions of grid bias and space charge—matters which have assumed increasing importance since then.

Full details are given of the elements of construction of the valves themselves and of experiments made with them in connection with H.F. transformers for radio frequency currents, as well as with L.F. iron-cored transformers for audio frequency currents. Typical illustrations are given of a radio receiving valve as well as of a valve destined for radio telephony purposes, and capable of controlling one kilowatt or more in the aerial.

The writer goes on to describe the method used to obtain a high tension direct current at 5,000 volts or more from the A.C. mains, or from an alternator smoothed by a condenser, rectified by a kenotron, and used to operate a pliotron oscillator the output of which is controlled by a small pliotron connected to the telephone transmitter. By this means the energy in the telephone transmitter circuit need be no greater than that in ordinary use.

He adds that it has been possible to connect up the radio telephone outfit with the regular telephone lines so that two subscribers can converse over their ordinary land lines when these are connected with their relative radio stations.

Since that time it is only in details of design construction and material that the valve has been improved, such as the substitution of the "dull" emitter filament, taking very much less current than the original "bright" one, and giving the necessary emission at a very much lower temperature and having the corresponding advantage of a much increased life. The principles of design, however, remain exactly the same.

I may be pardoned, I hope, for reminding you of what was done so long ago as 1914-15. My excuse for doing so is that it is an outstanding instance of the value of research which has thoroughly justified the expenditure of time and money in the far-reaching and important results produced.

A valve, which is practically three valves in one, has been produced in Germany within the last year, and it contains also the whole of the components and connections which comprise an ordinary three valve receiving set, minus of course the batteries. This valve, which is undoubtedly a real novelty, is reported to be something more than a freak and to act within its perhaps comparatively limited range of application, quite satisfactorily. It is not obtainable as yet in this country from radio dealers, and from inquiries I have made, the only sure and expeditious means of getting one is to go and fetch it yourself or get someone else to bring it from Germany, where there is no difficulty in purchasing them.*

The thermionic valve has other uses than for radio apparatus, and a comparatively new one is its employment in connection with the melting of precious metals in closed furnaces, especially for the melting and refining of platinum which I need hardly remind you requires a high temperature to reduce it to the fluid state, viz., 1,780° Centigrade or its equivalent 3,236° Fahrenheit. This is not, however, to be regarded as the high limit of temperature which the high frequency furnace is capable of, as such is limited only by the infusibility of the material of which the furnace is constructed in practice.

The frequency employed is of the order of 300,000 cycles per second and the current is delivered to the water-cooled primary of a transformer surrounding the secondary

* Since I made this statement I have been told they can now be obtained through an agency in England.

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which may be the mass of metal to be melted and from which it is separated by the wall of the furnace proper. The novelty in this of course consists in the use of high frequency currents instead of the low commercial periodicity ones which have been used in the induction furnaces for melting steel, etc., for many years.

A more interesting use to us is to be seen in its application to valve manufacture, where it is used for raising the interior portions of valves to a high temperature in order to release occluded gases whilst they are being exhausted, it having been found that heating them by the action of high frequency currents, apart from other practical advantages, from the point of view of more complete evacuation, is more effective than by the application of some source of heat to the exterior, overheating the filament, etc., the older method.

It appears likely that the use of the high frequency current type of furnace may find further applications in the future, and it is not unlikely that unless steps are taken to prevent it such a furnace would affect radio receiving apparatus which happened to be installed in its neighbourhood.

For this reason, if for no other, the high frequency current furnace may be of interest to my audience.

One of the most important subjects at the present time that is attracting the attention of the whole of the wireless experimental world, of which the members of the T. and R. section are a far from negligible part, is the short-wave one.

I have so far been unable to find any definite pronouncement of an authoritative character as to what is meant by a short wave, *i.e.*, the limits of its length. Captain Miles, in his lecture on this subject before the Society, in November, 1925, defined them, for his purpose at any rate, as those below 100 metres, but as far as I can judge others might put this figure at 200 or 300, or even more.

Anyhow, surely it would be a convenience if a conventional maximum limit for the short wave range were laid down.

Whether this range is expressed in metres, radio wavelength, or in frequency per second is immaterial compared to the question of the maximum limit.

The amateur, or, as I should prefer to term him, the radio experimenter, had a slice of luck when he was told years ago that he must confine his activities to wavelengths below 200 metres. It was not long before he discovered that the gift which he had despised was just what he had wanted, though he was unaware of it.

Although the success of the short wave long distance transmission is an accomplished fact, there are many phenomena connected with it the explanations of which are as yet conjectural, or perhaps I should say the reasons for which are not yet satisfactorily accounted for.

The Kennelly-Heaviside ionised layer in the atmosphere has much responsibility thrust upon it. Its height is constantly varying and this it would appear affects the distance covered by the "skip," but not the angle of incidence with the layer or departure from it. For the signals to reach the same point as before when the height of the Heaviside layer has been much altered, from midday to midnight, for example, it appears to be necessary for the transmission wavelength to be modified. Are the assumptions generally made, and the explanations given to account for these phenomena, correct? Again, one might expect that some form of the "beam" system would give as good, if not better, results than any based upon the relationship of the aerial and wavelengths for a given angle of departure. I believe that the noted authority, Dr. Alexanderson, has been carrying out experiments in America with a beam system on some such lines, but I have not heard what results he has obtained.

One point, however, stands out very clearly in any controversy respecting the merits of the long wave *versus* the short wave system, and that is the enormous disproportion between the energy required to obtain a long range result even where the conditions are most favourable to the long wave, and that required for good communication on a short wave.

Clearly there is much more experimental and research work to be done to explain the idiosyncrasies of the short-wave system by itself, and perhaps combined with the beam, which appears to offer great possibilities.

There is sometimes a tendency to feel disheartened because one's experimental equipment is meagre compared to that of research

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laboratories, etc., but this feeling should be counteracted by the fact that some of the most epoch-making discoveries and inventions have been made by men with apparatus of the simplest character. Outstanding instances in the electrical world are Professor Graham Bell, the inventor of the telephone, and Professor Hughes, the inventor of the microphone.

There is another and kindred matter I should like to make a brief allusion to, as it is of special interest to a number of our members. It is the automatic and accurate control of wave frequency.

This is such an important problem that I make no apology for referring to it, and indeed with the rapidly increasing number of transmitting stations, Government, broadcasting, and private experimenters', it is obvious that its importance must tend to increase if interference is to be minimised.

It naturally also affects the receiver according to the degree of selectivity of the apparatus in use. Three methods of control are employed at the present time, having as their basis :—

(*a*) The well-known oscillatory circuit tuned to the frequency required.

(*b*) The tuning fork maintained electrically, the frequency being obtained from one of its higher harmonics.

(*c*) The quartz crystal slab used as an oscillator.

Of these the only one that can be said to fulfil the following conditions which are most desirable, more especially to the experimenter with short waves, is the quartz crystal. These conditions are :—

(*d*) Simplicity owing to its rate being controlled by its actual dimensions.

(*e*) Constant frequency, owing to its rate not being affected by electrical variations in the circuit, small variations of temperature, etc.

(*f*) That it is practicable to make it of such dimensions that its fundamental will correspond with a wavelength as short as 45 metres.

That a quartz crystal has a natural period of vibration governed by its dimensions has been known for many years, but it is only comparatively recently that this property has been harnessed to do work for radio transmission.

Several of the members of the R.S.G.B. are fully alive to the properties and advantages, and one of them, Mr. Hinderlich, recently read a paper before the Society explaining how the crystals could be made, and giving other invaluable information as to their mounting and use.

Quartz crystal control has for some time past been employed for controlling the frequency of various broadcasting stations abroad and appears to be on the increase. It has not yet come into use for broadcasting in this country.

I understand that other materials besides quartz are found to possess similar properties though in a less degree—it would seem, therefore, that there might be a field for useful research in this direction. Such work, though it may turn out fruitless in the direction contemplated, not infrequently leads to unsuspected discoveries being made in other directions, and this fact may prove a partial incentive in undertaking it.

It is curious to note in contrast with the great and rapid progress of improvement in the apparatus used in radio communications, including receivers for broadcasting, how little the telephone, invented by Professor Graham Bell, has been improved or even materially modified.

I will recall to your minds the fact that, in its early form as first exhibited in England by the late Sir William Preece at the meeting of the British Association at Plymouth in August, 1877, it had a bar magnet with a polar extension of soft iron at one end, carrying a bobbin wound with the usual insulated copper wire, mounted centrally as regards the diaphragm of thin iron sheet (ferrotype used for photographic purposes). The wooden case formed the handle and the general arrangement was similar to the ordinary telephone exchange receiver in universal use to-day. There have been innumerable modifications, mainly of form, made between that date and the present time, the bipolar form of magnet with its two coils having taken the place of the single one, but it is nevertheless the fact that probably the best and certainly the most sensitive phone receiver to-day has its magnetic movement connected to the centre of the diaphragm which produces the sound waves, and the latest forms of loud-speakers which are claimed to produce the most

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natural results are somewhat similarly constructed.

The fact that after all these years only comparatively trifling modifications of the original instrument have been made is silent testimony to the inventive genius of Prof. Graham Bell.

On the occasion of the meeting alluded to the lecturer used the following words: "It is quite evident, however, that Bell's telephone is limited in its range." This statement, though perfectly accurate at the time and under the conditions then existing, would be truer now if the word "unlimited" were substituted for "limited" in view of the Transatlantic telephone service so recently inaugurated, and which, without the telephone, could not even have been conceived.

At the present time a good deal of attention is being paid to the matter of rectifiers for rectifying low frequency currents from electric supply companies' mains, either for charging accumulators for filament heating or for the higher voltages required for plate current, and alternatively for supplying both these requirements direct. The demand for rectifiers has arisen, I think, owing to the increased use of power valves for loud-speakers, which are designed to control much greater amperage than was usual a short time ago, when dry batteries were able to do all that was then required of them. There is still a field open to inventors to produce a perfect rectification device within the reach of those whose purses are somewhat slender.

Rectification of an alternating supply can be made by (1) mechanical means such as a motor generator or vibrating rectifier; (2) electrolytic means—for instance, tantalum or aluminium rectifying cells; (3) thermionic rectifying valves of one sort or another.

All these methods have disadvantages of one sort or another: (1) is costly, especially if arranged to supply both filament and H.T. current; (2) necessitates the use of cells and undesirable acid or alkaline solutions, and so far as the aluminium rectifier is concerned a good deal of attention to maintain it in running order; (3) is free from the disadvantages of (2) but entails a large drop in voltage, and when an ordinary valve is used arrangements have to be provided to heat the filament. If a mercury rectifier is used this requires also an additional device for putting it in action.

Although it is not suggested that the above are ineffective for their purpose, it is evident that there is a need for some rectifier which is free from all such disadvantages. A new departure in low frequency rectifiers was described and exhibited at a meeting of the American Physical Society in September last which would appear to have much in its favour if it is lastingly effective in its action. It was stated that the instrument, the size of a watch, say about $1\frac{1}{2}$ in. in diameter, would rectify a current of 3 amps with a drop of only $1\frac{1}{2}$ volts across its terminals. This rectifier consists of two discs of metal, one of copper and the other of lead, clamped together under considerable pressure. The face of the copper disc is covered with a layer of oxide of copper, stated to be produced by prolonged heating in air. If this rectifier comes up to expectations in actual practice it will prove of considerable value.

Probably there are other combinations that would act equally well, and this might be a fruitful field for research by an experimenter, and one which with a comparatively small expenditure might bring him in a rich harvest. It is in any case obvious that a simple device of the sort described could find many useful applications apart from radio ones.

Speaking quite generally, the conditions under which rectifying of an alternating current, either partial or complete, other than by mechanical means, takes place is not too well understood, and any contribution to existing knowledge, either from the theoretical or practical standpoint, would be welcome.

For radio purposes, after rectification some smoothing device is always necessary, and in most cases transformers have to be used to supply the right voltage, and in addition to this to have a centre tap in order to deal with the whole wave.

Early in 1925, and mainly at the instigation of the Society, a move was made by manufacturers and others in the matter of standardisation of radio components, and the essential qualities of which they ought to be made, as it was felt that the time had arrived when not only the members of the

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R.S.G.B., but also the users and makers of wireless apparatus generally, would be greatly benefited if they had some reasonable assurance as regards the reliability of insulating material, used for panels for radio instruments, such as ebonite that they might wish to purchase, and also the inter-changeability of components such as plug-in coils, to quote another example, and the limits of accuracy of fixed condensers.

The British Engineering Standards Association was approached and, having been readily satisfied of the necessity for and the advantages which would accrue to manufacturers and users alike if such standardisation was effected, set up the necessary Committee to carry the scheme into effect.

The first specification was published in November, 1925, and is entitled "British Standard Specification for Ebonite for Panels for Radio Reception Purposes," and numbered No. 234/1925. The specification lays down tests for quality of material which have to be complied with, as well as the dimensions recommended for panels and strips.

As has been the case in other industries, the idea of standardisation was not at first received with any marked enthusiasm by the majority of the manufacturers who, though often in favour of standardisation in principle, for one reason or another seem to find a difficulty in its application to their own products.

I am glad to say that this feeling and attitude seems to be gradually passing away. In the case of the standard ebonite I see that some of the well-known manufacturers are now offering material marked with the BESA mark, thereby guaranteeing that it complies with the specification.

Another specification for "Fixed Condensers for Radio Reception Purposes," No. 271/1926, has been recently published. Further work is in hand dealing with plug-in coils, and a specification for these will no doubt be issued before long.

It may seem to the casual observer that standardisation is quite a simple matter, but this in reality is not so, as it is only possible in practice to standardise such characteristics of parts and such dimensions as will not fetter nor interfere with design. The standardisation of even such a simple device, one would think, as the pin and socket of a plug-in coil raises all sorts of unforeseen difficulties, although when accomplished everyone expresses astonishment that it was not done long ago.

I think I have said enough to show that the Council of the Society is fully alive to the furtherance of the interests of the members, and is not afraid of undertaking pioneer work on their behalf. I feel confident too that I shall not be a false prophet if I prophesy that the standardisation of radio parts will be much appreciated by all parties in the days to come.

I myself attach some importance to the matter of standardisation and hope that our members will assist the movement in any way that they can by demanding and using, when they are able to, such products as are guaranteed to comply with the BESA specifications.

Another of the Society's enterprises, started in the latter part of last year, is being carried on in co-operation with the Wireless League. I refer of course to the Joint Scheme of Registration of Wireless Traders and Repairers under which it is hoped that purchasers and users of wireless apparatus may be guided as to which firms they may deal with with confidence as to quality of goods supplied and also be guided as to capabilities for effecting repairs in a proper manner.

Applicants for registration under one or both of the above categories are required to give full information, treated confidentially, of course, to the Joint Committee of the above two bodies, of their premises, resources, technical qualifications, etc. These are all examined and verified by personal inspection, and when necessary supporting evidence is called for from disinterested parties.

On the information thus obtained the Joint Committee decides whether the certificate, which is in effect also one of competence and fair dealing, shall be issued to the applicant or not. When a certificate is issued a plaque of conspicuous design is sent to be exhibited outside the premises.

Considerable support has already been accorded by traders to this scheme, and I feel confident that as the scheme becomes better known it will be appreciated by, and benefit both, the retailer and his customers.

Quite recently, last month in fact, the British Broadcasting Corporation has invited

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the R.S.G.B., the Wireless League, and two other associations to form a Committee which will hold its meetings at their offices in Savoy Hill, and will consider such questions, technical and otherwise, as may be brought before it by the above representative bodies.

In the evidence given for the R.S.G.B. before the Broadcasting Committee in January, 1926, it was pointed out that a closer touch between the R.S.G.B. and the B.B.C. was considered would be an advantage to both bodies, and we therefore welcome the formation of this Committee, and the Council has nominated two members to sit on it.

It is not out of place to remind you that our relations with the Government Departments are, as they always have been, amicable. The R.S.G.B. is duly recognised by the Postmaster-General and his officials, who are always ready to give us a hearing and consider our representations on subjects which come within his province.

As regards the future, there is plenty of scope for the R.S.G.B. as such, and for its individual members to continue the useful work they have done in the past for the furtherance of the science we have all so much at heart.

This particularly applies to the members of the Transmitter and Relay Section who were pioneers in the accomplishment on the short wavelength of communication by wireless with the Antipodes. There are several men whom we especially honour for their achievements, but they, as well as others, appreciate fully how many problems still remain to be solved, and how much remains to be done, in spite of the very rapid progress that has been made in the last year or so in almost every direction.

The Purpose and Design of Broadcast Receivers.

Informal Discussion at I.E.E. Wireless Section.

THE February meeting of the Wireless Section I.E.E., held on 2nd February, was devoted to an informal discussion on "The Purpose and Design of Broadcast Receivers."

In opening the meeting, Mr. E. H. Shaughnessy (who presided in the absence of the Section Chairman, Prof. C. L. Fortescue), made reference to the award of the Hughes Medal of the Royal Society to Admiral of the Fleet Sir Henry Jackson, and conveyed the congratulations of the meeting on this honour.

The discussion was opened by **Mr. C. F. Phillips** who said that the subject might seem hackneyed but was nevertheless a matter of general interest. The purpose of the receiver should be to bring home the fare provided by the B.B.C., and reproduce it with good quality and intensity. The price should be reasonable and maintenance easy. The reception of one or two stations was easy, but distant stations were frequently attractive. Was it possible to manufacture commercially a long range broadcasting receiver of good quality, easy of control and of reasonable price?

He then discussed briefly the straight radio-frequency set *versus* frequency changing (*i.e.*, supersonic heterodyne). With neutralising and shielding two-thirds or three-quarters of the valve μ could be realised on straight sets. Radio frequency stages were usually limited to two or three giving overall amplification of 1,000 to 1,500. Supersonic seemed simpler. With the lower frequency of the intermediate stages it was possible to utilise nine-tenths of the valve μ per stage, and 8,000 to 9,000 could be obtained. High quality was possible if the second detector was not overloaded and this was usually more serious than loss of quality by cutting the sidebands.

Broadcast sets now needed a definite rating, which could best be done in terms of power. He suggested specification of the D.C. power supplied to the last valve, and quoted 4 watts as a maximum

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necessary. With a valve of μ 3 and 3,000 ohms impedance, 4 watts—*i.e.*, 20mA at 200 volts—with 30-35 volts grid-bias allowed a swing of 160 volts in the last valve. This would represent 0.6 volt-amp in the loud-speaker and this volume was sufficient for a large room. As a minimum he suggested 1.2 watts, *i.e.*, 10mA at 120 volts, with 16 volts grid-bias. The reproduction was not so good but was ample for a small room.

It was, therefore, desirable to design for an input of 4 watts to the last valve and work backwards. The preceding stage could then give about 45, with 10 from the detector to the penultimate valve.

Dealing with rectification, the grid method was most sensitive but opinion was divided as to distortion. Rectification was better at the lower modulating frequencies, which was probably an advantage as the amplification fell off at lower frequencies while the loud-speaker was also less efficient. Grid rectification did damp the H.F. coupling circuits. With anode bend rectification, sensitivity was inferior but selectivity was better. Frequency distortion was absent, although wave form distortion was present. This method also called for more skill and additional control. Special methods of rectification were also known including those of Capt. Round, and of the B.B.C., referred to by Mr. Denman in his description (*Wireless World* of 26th January, 1927) of the apparatus at the Science Museum, South Kensington.

Resistance-capacity coupling was becoming popular, but design was full of pitfalls. With a well-designed transformer and valve it was easy to build an audio-frequency amplifier. With resistance-capacity frequency distortion should be absent, but only if stages were well designed. A time-constant of $\frac{1}{40}$ second was feasible with a coupling condenser of $0.1\mu F$ and $\frac{1}{4}$ megohm grid-leak. The usual equation did not hold as the coupling condenser and grid-leak and valve capacity were in parallel with the anode circuit. The anode resistance was a matter of some design. The higher the resistance the lower the anode volts. With a valve of $\mu=20$, a resistance of 50,000 ohms was suitable. The recent ultra-high resistance was impracticable at the higher frequencies as the next valve shunted the anode reactance and caused a fall of amplification at the higher frequencies.

Finally as regards the valve it was important to have a low impedance. The loud-speaker was in the same position in regard to this valve as the L.F. transformer primary in the previous stage. Its impedance should be greater than that of the valve. In using a transformer or choke for output the problem in a commercial set was serious. With 20mA in the last stage, the iron would have to weigh 2-4 lbs.

The ideal receiver design should be capable of operating on comparatively strong signals. The power and position of transmitting stations should be arranged for alternative programmes. There should not be more than one radio-frequency valve before the detector, and it should be not so much for amplification as for selectivity.

Mr. E. C. Pocock, who continued the discussion, did not think 4 watts excessive but very reasonable. The B.B.C. should supply alternative programmes and it would probably be found that demand for two close stations would be the aim of the sane majority of the public in the near future. He discussed selectivity and comparative distortion with superheterodyne and three radio-frequency valves, and the difficulty of using a highly selective set. The supersonic was good in this respect. As regards power valves, four or five watts were quite reasonable, and valve cost was not great compared with first cost. The L.F. amplifier and transformer were not yet fully exploited. It was possible to get a transformer good enough for any loud-speaker available. As regards the loud-speaker there was need for attention to design on known points.

Mr. P. W. Willans expressed agreement with the advantages of the supersonic heterodyne. It could be made reasonably cheaply and compact. A change of range was difficult on a multistage straight set. The object of design should be to take the fullest advantage of the high μ of the valves. A mixed amplifier was a good thing as regards sensitivity. With high μ valves one H.F. stage, two at intermediate frequency and one L.F. stage for the loud-speaker should be sufficient. In connection with the comparison of resistance and transformer

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couplings the use of a transformer was of advantage in getting rid of the higher frequency; as for example, getting rid of the intermediate frequency at the second detector of a supersonic set.

Mr. H. Bevan Swift queried what happens when receivers are in the users' hands. Change of valves, voltages, etc., might give quite different behaviour from that intended by the maker. He also discussed transformer coupling and flux density, pointing out that in practice the density was actually very small.

Mr. P. K. Turner said that the flux density was greater than suggested since the iron was subjected to the D.C. magnetisation. With a good transformer of about 6,000 primary turns with 3mA D.C., the flux density would be 3,000 to 4,000 lines. He did not think high power sets were at present feasible for really good quality. With a set having two valves and three transformers, at 6,000 metres an amplification of 10,000 was obtainable but only 2,000 could be used on account of the cut-off of the sidebands. In order to use six or eight stages it might be necessary to employ couplings of band pass filters. Information was necessary as to phase throughout the amplifier. Much of the music was actually in the form of transients.

Mr. B. S. Cohen discussed rectifiers, stating that a straight-line rectifier had been devised, and a four-electrode valve circuit had been used in this respect with success. The transformer had been suggested as a frequency limiter. Why not make more use of filters?

Mr. Willans pointed out that the leakage inductance did act as a choke or filter.

Mr. Carpenter briefly commented on the comparison of anode bend and grid rectification.

Mr. McPherson referred to selectivity by directional aerials. Should not more attention be paid to this? With a near station it was also useful as a volume control. With reference to overloading at the second detector of a superheterodyne, overloading could take place at any detector and called for attention. The efficiency of bottom bend was greater with large inputs. For the output transformer stage he would suggest the use of the push-pull system.

Col. H. Lefroy discussed the impedance of the loud-speaker and its relation to the anode impedance.

Mr. Morris dealt with oscillation. It was necessary for designers to standardise with a view to eliminating this trouble. Another speaker pointed out that any amateur with simple components could produce oscillation. This was a matter with which the manufacturer could not deal.

Mr. Dew asked for information of the time constant of resistance-capacity circuits, and of the loud-speaker as a radiator.

Mr. R. P. G. Denman thought that a market for high quality sets would grow. For good quality 4 watts was not high—he actually used 30. The straight-line rectifier referred to was very good, but he had been unable to detect any change on switching from it to a bottom bend rectifier.

Mr. W. A. Erlebach discussed the design of power transformers. Radio transformers were not different except for the super position of the D.C. He agreed that the flux density was low and that bulk of iron would make only little difference in quality.

Mr. C. F. Phillips concluded and summed up the discussion, replying briefly to several of the points raised by the other speakers.

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Mathematics for Wireless Amateurs.

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

(*Continued from page* 86 *of February issue.*)

9. (A) Series.

THE word "series" has essentially the same meaning in mathematics as in ordinary speech, and when a series of misfortunes is described as "one confounded thing after another" the same idea of an ordered succession of separate things is involved. Any ordered succession of numbers

$$a_1, a_2, a_3, a_4, a_5, \ldots \ldots a_n$$

is called a series, but a quite random succession, such as

$$18, 1, 5\tfrac{1}{2}, 7\tfrac{3}{8}, 5003, \text{etc., etc.,}$$

is not of any practical interest. It is form without significance, and these numbers might have been arranged by a trained monkey or a gust of wind. But in the matter of series, as in everything else, any sign of law or design gives significance to the form and the mind becomes interested. For instance,

$$0/1, 2/3, 4/5, 6/7, \text{etc., etc.,}$$

shows evidence of thought, and nothing less than human could have arranged this series. It is designed according to a definite plan and can be related to the simplest series of all, that of the cardinal numbers, by means of a general formula which expresses this law and summarises the design. The law can be put in the form

$$a_n = \frac{2n-2}{2n-1}$$

a_n being the nth term. The first term is obtained by putting $n=1$, *i.e.*, $0/1$, the second by putting $n=2$, *i.e.*, $2/3$, and so on. An ordered series of this kind really grows out of the idea of a function, for the general or nth term is a function of n, *i.e.*,

$$a_n = f(n)$$

where the argument n takes in succession the values 1, 2, 3, etc. Moreover, the function need not contain n and numbers only. It may contain one or more letter symbols as well. For instance,

$$1, 2x, 3x^2, 4x^3, \ldots \ldots nx^{n-1}$$

is a series the terms of which are functions of x and of n. Thus an infinite variety of form is included in the general idea of a series, and the series form of representation plays a very large part in theoretical and applied mathematics.

(B) *The Sum of a Series.*

Next to the form or law of a series, the most important thing to know about it is its sum, *i.e.*, the sum of its terms. Think of a number, for instance, say, 21493. This is the sum of a series, a series of powers of ten, for it is only a short way of writing

$$2\times10^4+1\times10^3+4\times10^2+9\times10^1+3\times10^0$$

Again 3.1415 is a short way of writing

$$3^4\times10^0+1\times10^{-1}+4\times10^{-2}+1\times10^{-3}+5\times10^{-4}$$

a series which symbolises the fundamental process of approximation. This illustrates the basic character of the summation of a series which we must now consider.

First we will take the simple case in which there is a limited, *i.e.*, finite, number of terms. The sum of such a series is of course just what the phrase implies, *i.e.*, the number which results from the adding together of all the terms of the series, but in this connection the word sum is usually given a rather special sense, and finding the sum of the series means finding some general formula which provides a shorter way of arriving at the result than by the detailed addition of the separate terms. Take for instance a simple "arithmetical progression" as it is called, in which each term differs from the preceding one by a constant number, *e.g.*, 3, 7, 11, 15, etc., or, in general terms, a, $a+d$,

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$a+2d,\ a+3d, \ldots\ldots a+(n-1)d$. The sum of n terms is

$$S_n = a+(a+d)+(a+2d)+(a+3d) \ldots \ldots \{a+(n-2)d\}+\{a+(n-1)d\}.$$

In this case a short formula can be found for the sum by means of a trick. Turning round the right-hand side,

$$S_n = \{a+(n-1)d\}+\{a+(n-2)d\} + \ldots\ldots (a+d)+a$$

and adding these two equations term by term gives

$$2S_n = \{2a+(n-1)d\}+\{2a+(n-1)d\} + \{2a+(n-1)d\}, \text{ etc.}, \ldots\ldots n \text{ terms in all.}$$

$$= n\{2a+(n-1)d\}$$

so that

$$S_n = \frac{n}{2}\{2a+(n-1)d\} = n(a+l)$$

where $$l = a+(n-1)d$$

i.e., l is the last term.

Again, for another simple form, the so-called geometric series in which each term bears a constant ratio to the preceding term, *e.g.*, $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, etc., or in general terms, a, ar, ar^2, ar^3, etc., ... ar^{n-1}, the sum of n terms is

$$S_n = a+ar+ar^2+ar^3+ar^4, \text{ etc.}, \ldots ar^{n-1}.$$

Therefore

$$rS_n = ar+ar^2+ar^3+ar^4, \text{ etc.}, \ldots ar^{n-1}+ar^n,$$

and by subtraction,

$$S_n(r-1) = ar^n - a = a(r^n-1).$$

Therefore $$S_n = \frac{a(r^n-1)}{r-1}$$

For instance, the sum of 32 terms of the series $\frac{1}{4}$, $\frac{1}{2}$, 1, 2, etc., would be

$$S_{32} = \frac{\frac{1}{4}(2^{32}-1)}{(2-1)}$$

$$= 2^{30} - \frac{1}{4}$$

This commemorates the tragic fate of the desperate fugitive who offered a blacksmith a farthing for the first, a halfpenny for the second, a penny for the third, and so on, for the 32 nails of the four shoes of his horse. The bill came to just under four and a-half million pounds.

In addition to the above two simple standard series, the arithmetic* and the geometric, there are various other types which can be summed by means of general formulæ, but these are not of much practical importance, so we will proceed at once to the much more general propositions relating to the sum of an infinite number of terms of a series.

*Pronounced with the accent on "met."

(c) *The Sum to Infinity. Convergency and Divergency.*

First, what is meant by an infinite series? Given a general term

$$a_n = f(n)$$

say,

$$a_n = \frac{1}{2^{n-1}}$$

for instance, then if there is no upper limit specified for n the number of terms can exceed any finite number, however large, *i.e.*, can be infinite. What, then, is the sum to infinity? It cannot mean the result of adding the terms together, for that is an unending process. It is conceivable, however, that S_n may have a finite limit when n is increased indefinitely, *i.e.*, it may be possible to find a quantity S such that by making n sufficiently large, S_n can be made to approximate to S within any standard, however small. The quantity S is then called the sum to infinity of the series. Actually it is the limit of S_n when n tends to infinity, *i.e.*,

$$S = \underset{n\to\infty}{lt.}\ S_n$$

This limit S will never be reached by the sum of any finite number of terms, but it can be approached to any desired standard of accuracy by taking a sufficiently large number of terms. Take, for example, the series quoted above for which

$$a_n = \frac{1}{2^{n-1}}$$

This is a geometric series of which the first term, a, is 1, and the common ratio r, $\frac{1}{2}$. From the formula given above

$$S_n = \frac{1 \times (1 - \frac{1}{2}^n)}{(1-\frac{1}{2})} = 2(1 - \tfrac{1}{2}^n)$$

Now by making n sufficiently large, $(1-\frac{1}{2}^n)$ can be made to differ from 1 by as little as we please, *i.e.*, it can be made to approximate to 1 within any standard, so that

$$S = \underset{n\to\infty}{lt.}\ S_n = \underset{n\to\infty}{lt.}\ 2(1-\tfrac{1}{2}^n) = 2$$

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In general, for the geometric series

$$S_n = \frac{a(1 - r^n)}{1 - r}$$

and provided r is less than 1 numerically the limit of $1 - r^n$ when r tends to infinity is 1, and

$$S = \underset{n\to\infty}{lt.} S_n = \underset{n\to\infty}{lt.} \frac{a(1 - r^n)}{1 - r}$$
$$= \frac{a}{1 - r}$$

It should already be clear that not all series will have a finite sum to infinity. In the above case, for instance, if r is equal to or greater than 1

$$S_n = \frac{a(1 - r^n)}{1 - r} = \frac{a(r^n - 1)}{r - 1}$$

will increase without limit as n tends to infinity. In fact, series can be divided into two classes—those which have and those which have not a finite limit for the sum to infinity. Series of the first kind are called convergent, and play a very large part in applied mathematics. The others are called divergent, and are not of much use to anyone. (Note: A series will be called divergent unless S_n tends to a finite limit as n tends to infinity, in accordance with the definition of limit; but it does not follow that S_n will increase without limit for all divergent series. For instance, the series $a, -a, a, -a$, etc., which is a geometric series having a as the first term and -1 as the common ratio, gives $S_n = 0$ or $-a$ according as n is even or odd, however large n may be. This kind of divergent series is called "oscillating.")

It is clear that the important thing to know about an infinite series is whether or no it is convergent. If it is, then although it may not be possible to find any simple expression for the limit of the sum to infinity, as close an approximation to it as may be desired can be found by actually calculating and adding together a sufficiently large number of terms, whereas if the series is divergent, this would be a vain pursuit of something which does not exist. Where a series is a function of n and of some other independent variable x, for instance,

$$1, x, x^2, x^3, x^4, \text{etc., etc.} \ldots x^{n-1}$$

the sum to infinity may be finite for a certain interval of values of x and infinite or oscillating for others. In fact, we have already shown that this series is convergent for all values of x between plus and minus 1 and divergent for all other values of x. In any case of this kind it will be necessary to know for what interval or intervals of values of the argument the series is convergent.

For these reasons a great deal of research has been directed to the discovering of tests for convergence, tests which can be applied to a series as a preliminary operation, to find out whether and under what conditions a sum to infinity actually exists. The research has so far failed to establish any single test of universal application which separates the sheep from the goats; but a considerable number of tests of very useful even though limited applicability have been developed. A few of the most useful of these will now be described, but for a full account of this rather difficult and voluminous subject some standard text-book, such as *Chrystal's Algebra*, should be consulted.

(D) *Tests for Convergency.*

The series will be represented by

$$a_1, a_2, a_3, a_4, \text{etc., etc.,} \ldots . a_n,$$

a_n being the nth term. Two perfectly general points should be noted first. The sum of any finite number of terms is finite. Therefore if a series can pass a test for convergence for all terms after a certain point, say the rth term, then it is convergent, even though the terms up to this point do not satisfy the convergency condition. Again, if a given series of positive terms is convergent, any series differing from it only in the sign of some of the terms will also necessarily be convergent.

A first minimum test of convergence is that

$$\underset{n\to\infty}{lt.}\ a_n = 0$$

for a series is not convergent unless S_n, S_{n+1}, S_{n+2}, etc., converge to a finite limit S, so that S_n, S_{n+1}, S_{n+2}, etc., differ from S, and therefore from each other by a quantity which can be diminished without limit by making n sufficiently large. Therefore

$$\underset{n\to\infty}{lt.}\ (S_{n+1} - S_n) = \underset{n\to\infty}{lt.}\ a_{n+1} = 0$$

(Note that $\underset{n\to\infty}{lt.}\ a_{n+1}$ is the same as $\underset{n\to\infty}{lt.}\ a_n$.)

A series of which this is not true cannot be convergent. Unfortunately, very unfortunately in fact, it does not follow that a series is convergent if $\underset{n\to\infty}{lt.}\ a_n = 0$.

For instance, the series

$$\frac{1}{1}, \frac{1}{2}, \frac{1}{3}, \frac{1}{4} \ldots \ldots \frac{1}{n}$$

fulfils the condition, but it can be shown that this series is divergent. The condition is therefore a minimum but not a sufficient one. It is nevertheless a useful point to remember, and will sometimes save further investigation.

A series is convergent if the ratio of each term to the preceding one is numerically less than unity; for

$$a_1 + a_2 + a_3 + a_4 + a_5 \ldots + a_n \ldots$$

etc., etc., *ad. inf.*, can be written in the form

$$a_1\left\{1 + \frac{a_2}{a_1} + \frac{a_3a_2}{a_2a_1} + \frac{a_4a_3a_2}{a_3a_2a_1} + \frac{a_5a_4a_3a_2}{a_4a_3a_2a_1} \ldots \text{ etc., etc., } ad.\ inf.\right\}$$

Now by hypothesis

$$\frac{a_2}{a_1} < r$$

$$\frac{a_3}{a_2} < r$$

etc., etc., where $r < 1$. Therefore the sum of the series is less than

$$a_1(1+r+r^2+r^3+r^4 \ldots \text{etc., etc., } ad.\ inf.)$$

But

$$1+r+r^2+r^3+r^4 \ldots \text{etc., etc., } ad.\ inf. = 1/(1-r)$$

since r is less than 1. The sum of the series is therefore less than $a/(1-r)$ and is therefore convergent.

Notice that this proof will break down unless

$$\frac{a_{n+1}}{a_n} < 1 \text{ numerically}$$

however large n may be. The series will therefore not be convergent unless

$$\underset{n\to\infty}{lt.}\ \frac{a_{n+1}}{a_n} < 1 \text{ numerically.}$$

Conversely, if the above condition is fulfilled the series is convergent; for let

$$\underset{n\to\infty}{lt.}\ \frac{a_{n+1}}{a_n} < r \text{ where } r < 1$$

Then, by definition, if m is made large enough

$$\frac{a_{m+1}}{a_m} \sim r < \epsilon$$

however small ϵ may be, and if ϵ is made small enough

$$r + \epsilon < 1$$

since $$r < 1$$

If, therefore,

$$\underset{n\leftarrow\infty}{lt.}\ \frac{a_{m+1}}{a_n} < r$$

where $r<1$, we can find some fixed term, say the mth, from and after which a_{m+1}/a_m is less than 1. The series will therefore be convergent as already shown.

In addition to the above, there are two comparison theorems which are of use. Given two series

$$a_1, a_2, a_3, a_4, a_5 \ldots a_n \ldots \text{etc., etc., } ad.\ inf.$$

and

$$b_1, b_2, b_3, b_4, b_5, \ldots b_n \ldots \text{etc., etc., } ad.\ inf.$$

of positive terms, then if the a series is convergent and each term of the b series is less than the corresponding term of the a series, the b series will also be convergent. This is sufficiently obvious without any formal proof.

Another comparison, not so obvious, is this. If the ratio of corresponding terms is always finite the series will be either both convergent or both divergent. Suppose the a series to be convergent, its sum to infinity being S_a, and let k be the largest value of the ratio b_n/a_n of any two corresponding terms. Then the sum of the b series is less than kS_a, and the b series is therefore convergent. If, on the other hand, the a series is divergent, its sum to infinity being infinite and r is the smallest value of the ratio of two corresponding terms b_n/a_n, the sum of the b series is greater than r times the sum of the a series and, the b series is therefore divergent.

A useful test series to which the above theorems can be applied is

$$\frac{1}{1}, \frac{1}{2^k}, \frac{1}{3^k}, \frac{1}{4^k}, \frac{1}{5^k} \ldots \ldots \text{ etc., etc., } ad.\ inf.$$

which can be shown to be convergent if k is numerically greater than 1, and divergent if k is equal to or numerically less than 1.

All the above tests of convergence have been stated in relation to series of positive terms, but in view of the general statement

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made above about series of which the terms vary in sign, there should be no difficulty in applying them to such series. It should be pointed out, however, there are series which are divergent if all the terms are positive but convergent if they are alternatively positive and negative. In fact it can easily be shown that a series having alternately positive and negative terms is convergent if each term is less than the preceding, and if the terms decrease without limit in absolute magnitude.

(E) *Some Important Series.*

One of the most useful series in the whole of mathematics is

$$1,\ mx,\ \frac{m(m-1)}{1.2}x^2,\ \frac{m(m-1)(m-2)}{1.2.3}x^2, \text{ etc., etc.}$$

This, for a reason which will appear later, is called the Binomial Series. The general or nth term is

$$a_n = \frac{m(m-1)(m-2)(m-3)\ldots(m-n+2)}{1.2.3.4\ \ldots\ (n-1)}x^{n-1}$$

and the $(n+1)$th term is therefore

$$a_{n+1} = \frac{m(m-1)(m-2)(m-3)\ \ldots\ (m-n+1)}{1.2.3.4\ \ldots\ n}x^n$$

This, by the way, introduces a new notation. The denominator in a_{n+1} is the product of all the whole numbers from 1 to n. This is a group which very frequently occurs in mathematics, especially in series. It is written for shortness $\underline{|n}$, and is called "factorial n." There is an alternative and more recent notation in which it is written $n!$ This has the advantage that it is all on one line. It is still called "factorial n" in this form, though one of the brighter sort of mathematicians always refers to it as "n By Jove!" The name has not been adopted in teaching circles because it is liable to disturb a class.

Returning to our series the first thing to notice is that if m is any positive whole number the series terminates at the $(m+1)$th term, because the $(m+2)$th term contains the factor

$$m-(m+2)+2=0$$

and all subsequent terms will contain this factor also.

If m is negative or fractional, however, the series is infinite, *i.e.*, does not terminate. Under what conditions will it be convergent? In the absence of any obvious answer the first thing to investigate is the ratio of a_{n+1} to a_n. This is

$$\frac{(m-n+1)}{n}x = -x\left(1-\frac{m+1}{n}\right)$$

This ratio can be made to approximate to $-x$ within any desired standard by sufficiently increasing n, however large m may be. Thus, if x is less than 1 numerically there will in every case be a term in the series from and after which the ratio of a_{n+1} to a_n is less than 1. The series is therefore convergent provided x is less than 1 numerically.

Another important series is

$$1,\ \frac{x}{1!},\ \frac{x^2}{2!},\ \frac{x^3}{3!},\ \frac{x^4}{4!},\ \frac{x^5}{5!}\ \ldots\ \frac{x^{n+1}}{(n-1)!}\ldots \text{etc., etc., } \textit{ad. inf.}$$

This is called the Exponential Series. In this case

$$\frac{a_{n+1}}{a_n} = \frac{x^n}{n!}\times\frac{(n-1)!}{x^{n-1}} = \frac{x}{n}$$

Now, however large x may be, there will always be some term in the series from and after which x/n is less than 1 numerically. This series is therefore convergent for *all* values of x.

The series

$$x,\ -\frac{x^2}{2},\ \frac{x^3}{3},\ -\frac{x^4}{4},\ \frac{x^5}{5}\ \ldots\ (-1)^{n+1}\frac{x^n}{n}\ \ldots \text{ etc., etc., } \textit{ad. inf.}$$

is called the Logarithmic Series. Here

$$\frac{a_{n+1}}{a_n} = -\frac{nx}{n+1} = -x\left(\frac{n}{n+1}\right)$$

and this will always be less than 1 numerically provided x is less than 1 numerically. This series is therefore convergent for all values of x between plus and minus 1.

There is, of course, a host of other series which play a large part in applied mathematics, but these will be considered individually as they occur.

Examples.—Series.

1. Show that the series of which the nth term is $an+b$ is arithmetic. What is its first term, and the sum of the second fifty terms?

2. The first term of an arithmetic series is n^2-n+1, and the common difference is 2. Show

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that the sum of n terms is n^3, and thence show that

$$1^3 = 1$$
$$2^3 = 3+5$$
$$3^3 = 7+9+11$$
$$4^3 = 13+15+17+19$$
etc., etc.

3. Prove that if the sum of n terms of a series is $a(r^n - 1)$, the series is geometric. Find the first term and the common ratio.

4. Prove that in an infinite geometric series (common ratio less than 1) the ratio of any term to the sum of all that follow it is constant.

5. Show that the series of which the general term is $1/(n^2 - x)$ is convergent except when x is the square of an integer.

6. Discuss the convergency of the series having as nth terms :—

(*a*) $1/(x+n-1)$

(*b*) $(1+n)/(1+n^2)$

(*c*) $\dfrac{3.5.7 \ldots\ldots (2n+1)}{4.7.10 \ldots\ldots (3n+1)} x^n$

Answers to Examples in February Issue.

1. $+\infty$; $-\infty$; b/d ; $\bar{b}/\bar{d}$.
2. Discontinuity when $x = 3$ and when $x = 4$: $-\infty$; $+\infty$; $+\infty$; $-\infty$; 1 ; 1.
3. b/c ; b/c.
4. 3/8 ; 3/8 ; 3/8 ; 3/8 ; $+\infty$; $-\infty$.
5. 0.
6. The limit when $x \to a$ is $1/\sqrt{2a}$.

A Modified Beat Method of Comparing Two High-Frequency Oscillations.

WHEN it is desired to make an accurate comparison between the oscillation frequencies of two high frequency oscillators the method adopted is usually somewhat as follows: The oscillator under calibration is set so that the frequency of the generated oscillations differs somewhat from the standard, so as to produce an audible heterodyne note in the telephones. A musical note for comparison is produced by a tuning fork or by two independent high frequency oscillators, and the oscillator under calibration is adjusted by means of the beats between the two musical notes. When the beats vanish the difference between the two high frequencies is equal to the frequency of the musical note. A second reading is then obtained in the same way, and the mean of the two readings corresponds to the frequency of the standard.

The writer has recently devised a modification of this method which has the advantage that the correct calibration is obtained directly.

In this method a third oscillator is employed and the tuning fork or its equivalent is dispensed with. The third oscillator is used as an autodyne and is connected to the telephones or low frequency amplifier as the case may be.

The autodyne is arranged in reference to the other apparatus so that it picks up the signals both from the standard oscillator and also the oscillator under calibration, and it is adjusted so as to heterodyne these signals at some convenient frequency. Of the two notes which are audible in the telephones one will represent the difference between the frequency of the third oscillator and the frequency of the standard, and the other the difference between the third oscillator and the instrument under calibration. The two audible notes will beat together in the manner with which we are already familiar, and the beat frequency will represent the difference between the standard oscillator and the instrument under calibration.

The instrument under calibration is adjusted until the beats vanish and the two instruments are then in absolute synchronism.

In applying the method in practice it is necessary to guard against the possibility that beats may be obtained when the frequency of the autodyne is adjusted midway between the frequencies of the other two oscillators. This apparent ambiguity can be disposed of, however, by slightly altering the adjustment of the autodyne. If the correct adjustment has been obtained the beat will persist at a constant frequency while the musical note is varied, whereas if the adjustment is incorrect the beats will vanish altogether.

K.E.E.

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Abstracts and References.

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PROPAGATION OF WAVES.

EINE URSACHE DER ÄNDERUNG DES POLARISATIONSZUSTANDES KURZER WELLEN (A cause of the alteration of the state of polarisation of short waves). — N. von Korshenewsky. (*Zeitschr. f. Hochfrequenz*, 28, December, 1926, pp. 184 185.)

In short wave reception it has been observed that the incoming waves differ from those transmitted with regard to their state of polarisation. If linearly polarised waves are sent out, they arrive at the receiver, in general, elliptically polarised in a plane perpendicular to the direction of propagation, or in a special case, linearly polarised but with a different direction of oscillation from that transmitted. There thus arises on the way from transmitter to receiver an oscillation component perpendicular to the direction of oscillation and to the direction of propagation of the wave sent out. This phenomenon has been attributed by some physicists to the earth's magnetic field influencing the plane of polarisation in a way corresponding to the Faraday effect in optics. This explanation of the rotation solely through the magnetic effect is opposed, however, by various theoretical considerations. It has also been contradicted by the results of experiment; for example, the effect to be expected on altering the direction transmitter-receiver with regard to the earth's magnetic field was not found. (Pickard, *Proc. Inst. Radio Eng.*, 14, 205-212, 1926.)

In this article, a cause for the influencing of the direction of polarisation of short waves during their propagation through the atmosphere is found in the azimuthal deviations the rays undergo on their way from transmitter to receiver.

The introduction of an oscillation component perpendicular to the direction of oscillation of polarised waves and perpendicular to the direction of propagation cannot be explained by means of reflection and refraction in the layers of the atmosphere so long as this reflection and refraction is considered to occur only in the vertical plane passing through transmitter and receiver, *i.e.*, so long as the path of the electromagnetic ray is thought of as a plane curve lying in this vertical plane. Rotation of the plane of polarisation can then only be effected by refraction and reflection when the plane of polarisation either coincides with the plane of incidence (understood as in optics) or is perpendicular to it. If, however, the direction of oscillation is inclined to the plane of incidence at some angle between 0° and 90°, then with diverse refraction and reflection of the parallel and perpendicular components a rotation will be possible. As a matter of fact, the electromagnetic ray cannot possibly describe a plane curve in the vertical plane between transmitter and receiver, for this could only be the case if the layers had the same refractive power and were absolutely concentric with the earth's surface and if all reflecting surfaces were orientated orthogonally to this vertical plane. This case, of course, does not occur in nature. On the contrary, the electromagnetic ray travelling between transmitter and receiver must undergo lateral deviations and curvatures brought about by a gradation of density in the ions or electrons in a direction perpendicular to the vertical plane passing through transmitter and receiver, and further by reflections taking place at surfaces having diverse angles of inclination with the vertical plane. Consequently the electromagnetic ray, undergoing deviation in an azimuthal as well as a vertical direction, describes a curve that does not lie in the vertical plane through transmitter and receiver, but in planes inclined to it. The trajectory of the ray represents a complicated space curve. However, with refractions and reflections taking place in planes inclined to the vertical, the direction of oscillation that may be vertical or horizontal at the transmitter is inclined relatively to the plane of incidence to the refracting or reflecting layers, so that resolution into two components in the plane of incidence and perpendicular thereto is possible. Since, however, the refracting and reflecting conditions with regard to these two components are in general different, the refracted or reflected ray that arrives at the receiver will be in a state of polarisation that has changed relatively to the incident wave on account of the difference in the refractions or reflections of the two components. Thus, for instance, if with a lateral refraction there is merely an alteration of the amplitude relation between the components oscillating in the plane of incidence and that at right angles to it, then the plane of polarisation of the refracted ray will be rotated through an angle, but if, on the other hand, as will generally be the case, there is also a phase displacement between these two components, then the refracted ray will be elliptically polarised.

AU SUJET DE LA NOUVELLE FORMULE DE PROPAGATION DE KIEBITZ (On Kiebitz's new propagation formula). — R. Mesny. (*L'Onde Electrique*, 5, December, 1926, pp. 650-656.)

Kiebitz has recently made out a new theory of wave propagation around the earth (*Ann. d. Phys.*, 80, 1926, 728, these abstracts *E.W. & W.E.*, January, 1927, p. 49), which leads to the formula :—

$$E^{\frac{\text{volt}}{m}} = 0.377\,\frac{h}{\lambda}\,\frac{I\,(\text{amp})}{d\,(km)}\,\frac{\gamma\,(\text{rad.})}{\sin\gamma}$$

Where E is the electric field at a point on the earth and γ the arc of the great circle joining this point to the transmitter. This formula gives numerical values pretty near those observed for the maximum fields at night, both for the long

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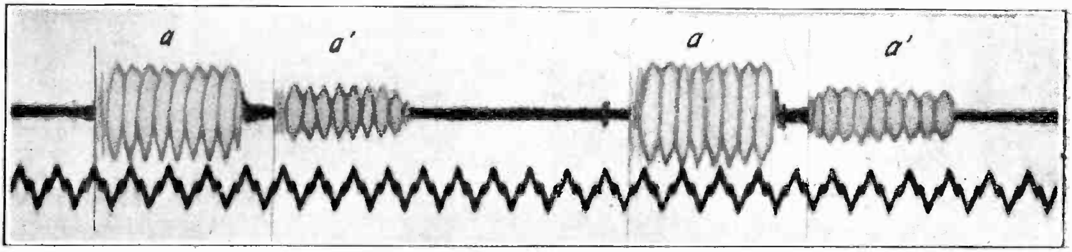
waves from Rocky Point heard at Berlin and for the very short waves from Nauen picked up at Buenos Aires. The author, however, sees in this agreement only a chance coincidence, the object of this article being to show that Kiebitz's theory is entirely fanciful.

The theory is obtained from Maxwell's equations by introducing the simplification that the electric and magnetic fields are practically equal at each instant at some distance from the transmitter, and Mesny here does the calculation again by a different method which shows that this simplification is incompatible with Maxwell's equations and the resulting theory cannot in any way correspond to reality.

NEUES ÜBER DIE AUSBREITUNG VON KURZEN WELLEN (New results on the propagation of short waves).—E. Quäck. (*Zeitschr. f. Hochfrequenz.*, 28, December, 1926, pp. 177, 178.)

During printed reception at Geltow of the American short wave station 2XT ($\lambda = 16.175$ m.), disturbing double signs were often found, the time of whose retardation permitting the conjecture that they are caused by waves that have traversed a longer path in the opposite direction round the earth. Such double signs have been recorded graphically, a specimen oscillogram being reproduced where *a* are the principal signs, and *a'* the double signs.



Further, with the 8kW short wave transmitter at Nauen and a wavelength of 15 metres, signs were successfully sent right round the earth and likewise recorded. For this the signs required on an average .138 second, giving a path of 41,200 km., assuming the normal velocity of light. This path would correspond to a great circle around the earth at a height of about 182 km.

WIRELESS COMMUNICATION AND TERRESTRIAL MAGNETISM.—C. Chree. (*Nature*, 119, 15th January, 1927, pp. 82, 83.)

Some remarks from the point of view of a magnetician on a conducting layer in the upper atmosphere, firstly with regard to the history of the conception, and then on the evidence for the existence of the layer and its varying conductivity that is derived from the observations of terrestrial magnetism.

We are reminded that estimates of the altitude of a stratum of high electrical conductivity were made long before the time of wireless communication. In 1790 Cavendish obtained on strictly scientific grounds an estimate of from 84 to 114 km. for the altitude of an auroral arc. Prof. Störmer's methods of high precision have supplied numerous results for the lower level of auroræ, which have long been well known, the levels showing variations with similar limits to those recently obtained by Appleton and Barnett. Dr. Chree further points out that the continual existence of high electrical conductivity in the upper atmosphere was first advanced as an hypothesis by Balfour Stewart, about 1882, and that if any name is to be associated with a conducting layer in the upper atmosphere, it should be neither Heaviside's nor Kennelly's, but Stewart's.

With regard to arguments for the existence of the conducting layer on the side of terrestrial magnetism, apart from auroræ, the strongest in the opinion of the writer is derived from the observed large universal increase of the diurnal variation of the magnetic elements as we pass from sunspot minimum to sunspot maximum. It is this argument that has led practically all, if not all magneticians, to accept the upper atmosphere as the seat of electrical currents to which the regular diurnal variation of the magnetic elements is due. The results further show that, whether in years of many or of few sunspots, the regular diurnal variation tends to be larger on disturbed than on quiet days. This seems to imply that in addition to local irregularities in the conductivity of the conducting layer, due presumably to the irregular distribution of the sources of ionisation, there is during magnetic disturbance a decided increase in the average conductivity. This phenomenon is comparatively trifling in Southern England, but increases in importance as we go North, which suggests that the natural place to study the relationships between wireless and magnetic phenomena is not the South of England but the North of Scotland, or still more northern regions, where magnetic disturbance is much larger and more persistent.

Referring to this letter in *Nature* of 29th January, p. 157, Dr. Eccles explains why he chose the name "Heaviside layer" for the upper portion of the atmosphere the aid of which is so often invoked to account for many of the facts of wireless telegraphy. In the spring of 1902 Heaviside raised the question as to whether Mr. Marconi's recent success in telegraphing from Cornwall to Newfoundland might not be due to the presence of a permanently conducting upper layer in the atmosphere. The suggestion was gradually approved during the years that followed, and about 1910 Dr. Eccles used the convenient name "Heaviside layer" in

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a paper, to indicate the portion of the atmosphere that functions so usefully for the purposes of wireless telegraphy. The existence of a conducting stratum in the atmosphere and its probable connection with the aurora must have been surmised by every observer of electric discharge in rarefied gases even before the date of Cavendish, also Balfour Stewart suggested that a conducting layer might have to do with certain variations of the magnetic elements, but there is as yet no proof that the auroral layer is the same as the Stewart layer, or that either of them is the same as the physically present layer called for convenience the Heaviside layer.

Dr. Eccles wishes to urge that full advantage be taken of the solar eclipse next June for learning more about the Heaviside layer.

THE HEAVISIDE LAYER.—E. V. Appleton. (*Wireless World*, 20, 5th January, 1927, pp. 2-4.)

Prof. Appleton explains in simple language how he and Mr. Barnett proved experimentally that the layer exists.

EINFLUSS DER SONNENFINSTERNIS VOM 14 JANUAR 1926 AUF DIE FORTPFLANZUNG DER DRAHTLOSEN WELLEN (Effect of the sun's eclipse of 14th January, 1926, on the propagation of wireless waves). *Zeitschr. f. Hochfrequenz.*, 28, December, 1926, pp. 189, 190.)

In the Dutch East Indies a whole series of tests were organised by the Postal Service for the moment when the eclipse shadow passed over these islands. The results of the observations, however, were in general negative, *i.e.*, no effect of the sun's eclipse on the propagation of wireless waves could be detected with any degree of certainty. This result might be expected at stations some distance from the shadow track, but the same absence of definite effect was observed at Tarakan and Palembang, right in the path of the shadow. A single exception occurred at Rantja-ekek, where the signals from Tananarive (15,600 m.) and Bengkalis (1,650 m.) were received much weaker than usual. On the other hand, the signals from Saigon came in more strongly than usual at this station, as also did those from Malabar at Sitoebondo.

RADIO SIGNAL STRENGTH AND TEMPERATURE.—L. Austin and I. Wymore. (*Proc. Inst. Radio Engineers*, 14, December, 1926, pp. 781-784.)

Continued daily observations at Washington on signals from Tuckerton and New Brunswick appear to prove that there is some kind of inverse relationship between signal strength and local temperature, though the effect is often masked by other influences. Curves are given showing the degree of temperature—signal relationship for the year 1924. In the curve of monthly averages, the connection between signal and temperature is said to be evident, the average signals of February being more than twice as strong as those of July, and considerably stronger than would be required by the inverse distance law. The day-by-day relationship is less satisfactory, varying from fairly clear in the winter months to obscure in midsummer.

ADDRESS OF THE PRESIDENT, SIR ERNEST RUTHERFORD, AT THE ANNIVERSARY MEETING, 30th November, 1926. (*Proc. Roy. Soc.*, 113, A, January, 1927, pp. 481-495.)

Reference is made to recent striking advances in radio communication and to the new avenues of research in the electrical state of our atmosphere that are being opened up by the study of the mode of propagation of wireless waves over the earth.

ÜBER DEN DURCH DIE HESS'SCHE HÖHENSTRAHLUNG BEDINGTEN IONISATIONS—UND LEITFÄHIGKEITSZUSTAND DER HÖHEREN LUFTSCHICHTEN (On the state of ionisation and conductivity of the upper layers of the atmosphere, brought about by the Hess vertical radiation). H. Benndorf. (*Physik. Zeitschr.*, 27, 1st November, 1926, pp. 686-692.)

According to our present knowledge, the following radiations call for consideration as ionisers of the upper layers of the atmosphere :—

1. The ultra-violet of sunlight.
2. Corpuscular rays from the sun.
3. The Hess vertical radiation.

The effects of sunlight and corpuscular radiation from the sun have been investigated respectively by Swann (*Terr. Mag.*, 21, 1, 1916) and Elias (*Zeitschrift. f. Hochfrequenz.*, 27, 66, 1926). This article considers the effect on the conductivity of the upper atmosphere of the penetrating vertical radiation.

The subject of this radiation is of particular importance as it is the only radiation of the three that would remain unaltered by day and night. The ultra-violet of sunlight, of course, does not come into question at all for night ionisation, while the action at night of corpuscular radiation from the sun is at the most doubtful. It is true Elias has put forward the suggestion that this radiation is deviated by the earth's magnetic field to the night side of the earth, producing there marked ionisation. The author, however, is of the opinion that, apart from the fact that we know very little for certain about this radiation and its magnetic deviability, it is most improbable that it occurs in the atmosphere distributed at all uniformly, which would have to be the case to account for the state of ionisation of the atmosphere, during the night as well, that is to be concluded from the propagation of electric waves.

Assuming a cosmic radiation with a mass absorption coefficient between the limits $2.2 . 10^{-3}$ and $4.5 . 10^{-3}$ cm.$^2/g$, the ionisation and conductivity of the atmosphere are here calculated for different heights. It is found that at a height of 100 km. the conductivity (for direct current) assumes a value about 10^{10} times that at the earth's surface, the air at this height conducting as well as dry ground. There is also a very marked rise in the conductivity between 70 and 80 km. Thus the Hess vertical radiation provides a source of ionisation by night as well as by day that entirely suffices, solving the problem of the night ionisation for which no explanation was hitherto forthcoming—or only a very unsatisfactory one.

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BEITRAG ZUM PROBLEM DER LEITFÄHIGKEIT DER ATMOSPHÄRE (Contribution to the problem of the conductivity of the atmosphere).—R. Stoppel. (*Physik. Zeitschr.*, 27, 1st December, 1926, pp. 755-761.)

Observations carried out both at Hamburg and in the North of Iceland showed the electrical conductivity of the air to have a daily period with a maximum between 4 and 6 in the morning local time, uninfluenced by the period of midnight sun, but much reduced at times of auroræ. The variations of conductivity are not dependent upon changes of sunlight, temperature, pressure or degree of saturation of the air, but are thought to be due to a cosmic factor at present unknown.

A DYNAMICAL THEORY OF THE ELECTROMAGNETIC FIELD. (*Nature*, 119, 22nd January, 1927, pp. 125-127.)

Clerk Maxwell's own abstract of his historic paper communicated to the Royal Society on 27th October, 1864, reprinted from the Proceedings of 8th December, 1864.

This paper constitutes the opening chapter in the history of radio communication. It shows that electric and magnetic effects cannot be produced instantaneously at a distance, but must be propagated through space with the velocity of light, also the wave-nature of these electrical disturbances and their mode of propagation. The famous equations contain the complete theory of electrical waves and their transmission through space.

ÜBER DIE EINDEUTIGKEIT DER LÖSUNG DER MAXWELLSCHEN GLEICHUNGEN (On the unambiguousness of the solution of Maxwell's equations.—A. Rubinowicz. (*Physik. Zeitschr.*, 27, 15th November, 1926, pp. 707-710.)

PROPERTIES OF CIRCUITS.

UNTERSUCHUNGEN ÜBER DIE SCHWINGSCHALTUNG VON NUMANS-ROOSENSTEIN (Experiments with the Numans-Roosenstein oscillatory circuit).—E. Mittelmann. (*Zeitschr. f. Hochfrequenz.*, 28, December, 1926, pp. 188-189.)

In the course of an investigation on double-grid valves, the author made a study of the Numans circuit in order to obtain information as to the oscillation relations under different working conditions. The characteristics of the space charge current for several tetrodes coming into the investigation were obtained with the circuit arrangement shown. Tetrodes with a thorium filament were found to behave somewhat irregularly. A stable state of oscillation was first obtained when a wolfram filament was employed, and the Telefunken valve RE26 was used for the investigation. A series of experiments with this valve are described here: the dependence of oscillation amplitude on heating current, the oscillations being found to suddenly cease when the heating current reaches a certain value, also the dependence of oscillation amplitude on the space charge tension applied, and on the wavelength (when here, too, the oscillations suddenly break down for a certain position of the condenser). The results are shown graphically.

THE OUTPUT CHARACTERISTICS OF AMPLIFIER TUBES.—J. Warner and A. Longhren. (*Proc. Inst. Radio Engineers*, 14, December, 1926, pp. 735-755.)

Discussion of the factors determining amplification, the use of plate characteristic curves for calculating output, the conditions for maximum output with low distortion, the calculation of the maximum undistorted output, and the relation of valve design to power output.

Some of the constants of the more commonly used radiotrons are tabulated; the first half of the table shows the constants of the valves themselves and the second half gives the maximum undistorted output (assuming not more than 5 per cent. second harmonic current in the load), the load resistance at which the maximum output is obtained, the input grid voltage required to produce this output, and the amplification of the valve with this same load resistance.

APERIODIC H.F. AMPLIFICATION.—H. Kröncke. (*Wireless World*, 20, 5th January, 1927, pp. 27-28.)

Further notes on the work of von Ardenne and Heinert.

SUPERSONIC TRANSFORMERS. — N. McLachlan. (*Wireless World*, 20, 5th January, 1927, pp. 21-24.)

Part V., dealing with the influence of input impedance of valves.

RESISTANCE-COUPLED RELAY CIRCUIT.—N. McLachlan. (*Wireless World*, 20, 19th January, 1927, pp. 67-70.)

Description of a form of valve circuit suitable for actuating a relatively slow operating relay for remote control work.

SIMPLE RESONANCE CURVES AND THEIR MODIFICATION BY VALVE CIRCUITS.—E. Mallett. *E.W. & W.E.*, 4, February, 1927, pp. 93-103.)

TRANSMISSION.

ZUR THEORIE DER SEITENBÄNDER (On the theory of side bands). — R. Hiecke. (*Zeitschr. f. Hochfrequenz.*, 28, December, 1926, pp. 185-187.)

If the carrier wave of a broadcast transmitter is modulated by superimposing a note frequency, there appear besides the carrier wave of frequency ω_1 also waves of frequency $\omega_1+\omega_2$ and $\omega_1-\omega_2$, as is seen from the equation for the modulated wave:—

$$I=(A+B \sin \omega_2 t) \sin \omega_1 t = A \sin \omega_1 t + B/2 \cos (\omega_1-\omega_2)t - B/2 \cos (\omega_1+\omega_2)t.$$

The side frequencies for the whole range of the note frequencies together make up the side bands of the carrier wave. Undistorted note reproduction is then only obtained in the receiver when the carrier wave is present with both side frequencies in their original amplitude relations; accordingly part of the latter must on no account be suppressed by too great selectivity. Frequently, however, one meets with the view that with the reception of

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both side bands the frequencies $\omega_1+\omega_2$ and $\omega_1-\omega_2$ together produce a beat note of frequency $(\omega_1+\omega_2)-(\omega_1-\omega_2)=2\omega_2$, *i.e.*, the octave of the modulating frequency, and for this reason one of the two side bands has to be suppressed in the transmitter. This article shows mathematically that this view is entirely incorrect.

DIE STRAHLUNG DER KOMPLIZIERTEN RECHTWINKELIGEN ANTENNEN MIT GLEICHBESCHAFFENEN VIBRATOREN (The radiation of complicated rectangular antennæ with similarly disposed vibrators).—M. Bontsch-Bruewitsch. (*Ann. der Physik*, 81, 1926, pp. 425-453.)

By a complicated antenna is meant here an aerial, consisting of a number of vibrators and a system of conductors, by which the energy is led. The author calls all antennæ "rectangular," the wires of which are arranged perpendicular to one another in three directions only. In this case, the axes of the radiating vibrators coincide with one of these directions. The radiation resistance R of an antenna of this kind can be defined as the ratio of the output P radiated to the square of the sum of the currents at the anti nodes of the vibrators. In the case of n similarly disposed vibrators loaded with equal current this resistance is :—

$$R = \frac{P}{(ni)^2}$$

The losses in general are distributed unequally between the different vibrators, but sometimes it is practically more advantageous to have to deal with a mean value of the radiation resistance of each vibrator, defined as follows :—

$$r = \frac{P}{ni^2} = nR$$

This paper calculates the output radiated for such an antenna system.

LOW-POWER CRYSTAL-CONTROLLED TRANSMITTERS. J. Clayton. (*Q.S.T.*, 11, January, 1927, pp. 14-18.)

ZUR KONSTRUKTION DER RADIOSPIEGEL (Construction of the radio reflector).—W. Tatarinoff. (*Zeitschr. f. Hochfrequenz.*, 28, October, 1926, pp. 117-120.)

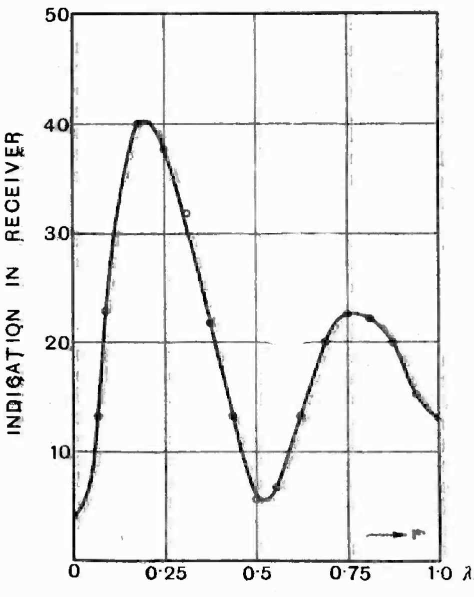
When constructing the reflector for directional radio transmission, it is important to know the phase displacement on the reflection of the wave from the resonating conductors. This phase displacement ψ depends in general on the tuning of the resonator, on its form and its position with respect to the antenna. The dependence of ψ upon r, the distance between antenna and resonator, was investigated experimentally by the author for the case when the two rectilinear conductors are a half-wave in length. The investigation, which is described, showed that ψ is a function of r, a graph of the relationship being given—showing that when $r=0$, $\psi=180°$, and that with increasing r, ψ approaches asymptotically to 90°. This curve enables the distance to be calculated at which the reflector must be placed for the reflected ray and that falling directly on the receiver to agree in phase. The solution of the equation :—

$$\psi(r) + 4\pi r = 2k\pi$$

that is required is most easily obtained graphically as the point of intersection of the two curves—

$$y = \psi(r) \text{ and } y = 2\pi(k - 2r).$$

The calculated values for different whole numbers k do not exactly correspond, however, to the current maxima in the receiver, since with the decrease of the distance r, the amplitude of the resonator is increased. The maxima in the receiver therefore correspond to somewhat smaller distances than those obtained from calculation. These displacements of the maxima should gradually diminish as r becomes larger, *i.e.*, as k increases. This was proved to be the case in the experimental tests, when the resonator was first placed close up to the antenna and then gradually removed to the distance $r=\lambda$. The changes of amplitude in the receiver as the distance increased are represented in the figure below :—



Some composite antennæ and reflectors are then examined—a grid reflector being found not nearly so good as a plane reflector of tinfoil or a tuned reflector with four conductors.

Lastly, from the fact that ψ is a function of r, some further conclusions are drawn with regard to the construction of parabolic mirrors.

RICHTCHARAKTERISTIKEN VON ANTENNENKOMBINATIONEN (Directional characteristics of antenna combinations).—A. Esau. (*Zeitschr. f. Hochfrequenz.*, 28, pp. 1-12 and 147-156.)

Second and concluding parts of an article begun in *Zeitschr. f. Hochfrequenz.*, 27, p. 142 (these abstracts *E.W. & W.E.*, September, 1926, p. 570). While the first part derived a general formula for the directional characteristic of the combination of two antennæ, discussing the special cases of two antennæ either both undirectional or both

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directional, the second part considers the combination of a directional and an undirectional antenna from both the theoretical and practical view-point, also the production of the cardiode characteristic by combining three undirectional antennæ and the double frame arrangement. The third and last part further discusses the combination of three undirectional antennæ (Braun's triangular arrangement), and the Marconi bent antenna, also the arrangement of two bent antennæ in series and in parallel, the characteristics of the combinations being shown to assume a somewhat different form when the distance between transmitter and receiver is taken to be finite.

RECEPTION.

NOTES ON THE DESIGN OF RESISTANCE-CAPACITY COUPLED AMPLIFIERS.—S. Harris. (*Proc. Inst. Radio Engineers*, 14, December, 1926, pp. 759-763.)

An analysis of the coupling in the resistance-capacity coupled amplifier is given, in which the variation of the voltage ratio with frequency is considered. A method is given for determining the values of the resistances and capacities for which the variation of voltage ratio over a given frequency range will be a definite and known amount.

LA SUPPRESSION DES PARASITES EN T.S.F. PAR LES FILTRES ACOUSTIQUES (Eliminating disturbances in wireless telegraphy by means of acoustic filters).—A. Nodon. (*L'Onde Electrique*, 5, December, 1926, pp. 657-663).

The application of the principles of electromagnetic filters employed in wireless telegraphy to eliminate atmospherics has enabled M. Canac (*Journ. de Physique*, 8, 6, June, 1926) to institute acoustic filters for getting rid of troublesome harmonics in the high, low and medium regions respectively of the audio range. The filters, coupled in pairs, free telephonic reception from alien sounds, after which it can be amplified as much as desired by means of valves.

THE DESIGN OF A HETERODYNE TYPE LOW FREQUENCY GENERATOR.—H. Kirke. (*E.W. & W.E.*, 4, February, 1927, pp. 67-76.)

STEREOPHONIC RECEPTION.—M. von Ardenne. (*Wireless World*, 20, 26th January, 1927, pp. 117-118.)

THE PERFORMANCE OF AMPLIFIERS.—P. K. Turner. (*E.W. & W.E.*, 4, February, 1927, pp. 77-80.)

HIGH QUALITY REPRODUCTION. — R. Denman. (*Wireless World*, 20, 26th January, 1927.)

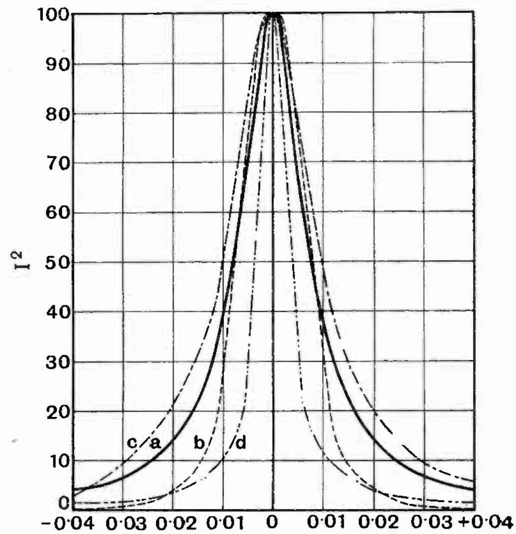
Description of a combination broadcast-gramophone equipment.

A SHORT-WAVE SUPER-REGENERATIVE RECEIVER.—E. Dallin. (*Q.S.T.*, 11, January, 1927, pp. 40-43.)

FIVE-METRE RECEIVERS.—R. Kruse. (*Q.S.T.*, 11, January, 1927, pp. 36-39.)

ÜBER INDUKTIVE KOPPLUNG IN EMPFANGSKREISEN (On inductive coupling in receiving circuits). —D. v. Seelen. (*Zeitschr. f. Hochfrequenz.*, 28, October, 1926, pp. 114-117.)

From the tension equations of two inductively coupled circuits, the relation is deduced between primary operating tension and secondary current. Assuming the different constants to be of about the same order of magnitude as they occur in radio-telegraphic receiving circuits, the values of the current received with different degrees of coupling are calculated. The current received at the coupling maxima is of the same value as with resonance and optimum coupling. The sharpness of tuning of the circuit combination with different degrees of coupling is found by comparison with the resonance curve of a single circuit. The results are shown in the figure below.



Resonance curves calculated for equal (optimum) current received with unaltered circuit adjustment.

For all curves I^2 is a maximum when $\omega = 5.10^6 \sim 375m$.

(*a*) ——— *resonance curve of the single circuit* $\delta_0 = 2.10^4\ sec^{-1}$.

(*b*) . . . . . . *resonance curve with* $k = 0.0056$, $\delta_0 = 2.10^4$, $\delta_1 = 1.10^4\ sec^{-1}$.

Path of I^2 in the coupling maximum with $k = 0.5$; δ_0, δ_1 as before :

(*c*) — . — . — . — *natural frequency of the circuit* $< \omega$.

(*d*) — . . — . . — . . *natural frequency of the circuit* $> \omega$.

With the help of the formula for the primary current as a function of the primary tension the physical significance of the relations suggested is pointed out.

DEVELOPMENTS IN TUNED INVERSE DUPLEX.—D. Grimes. (*Q.S.T.*, 11, January, 1927, pp. 9-13.)

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THE PERFORMANCE OF MODERN BROADCAST RECEIVERS.—P. K. Turner. (*Electrical Review*, 99, 31st December, 1926, pp. 1072-1073.)

An account of work at the Research Department of Burndept Wireless, Ltd.

VALVE DESIGN AND THERMIONICS.

DETERMINATION OF ELECTRONIC CHARGE FROM MEASUREMENTS OF SHOT-EFFECT IN APERIODIC CIRCUITS.—N. Williams and H. Vincent. (*Physical Review*, 28, December, 1926, pp. 1250-1264.)

An outstanding difficulty in the measurement of electronic charge from shot-effect in a tuned circuit has been regeneration into this circuit. Former methods of dealing with that feature have added tedious computations to Schottky's original calculation. The solution presented here yields the result in such a form that much of the labour is eliminated, the solution being of great mathematical simplicity and measurement of high-frequency resistance and resonance frequency becoming unnecessary.

AN EFFECT OF LIGHT ON THE ELECTRON EMISSION FROM HOT FILAMENTS.—W. Crew. (*Physical Review*, 28, December, 1926, pp. 1267-1274.)

The increase in the electron emission from hot, oxide-coated platinum filaments when illuminated by the full radiation from a water-cooled quartz mercury arc was measured, for different filament temperatures, as a function of potential between filament and anode. The photo-electron currents were large enough to be readily measurable with a galvanometer, measurements on one filament showing the photo-electron current increasing with potential to a maximum of about 14 volts. No photo-electric fatigue was observed. It was found that, for the most part, the photo-currents are due to radiations of wavelengths shorter than $\lambda 3{,}000$. Plain platinum and tungsten filaments were tried, but only oxide-coated filaments gave an appreciable emission due to the light. It is suggested that the action of the light is to free electrons from a thin film of metal of which the work function varies with temperature of the filament.

THE UX-213 RECTRON AND THE UX-874 VOLTAGE REGULATOR.—O. Pike. (*Q.S.T.*, 11, January, 1927, pp. 44-46.)

FILAMENTLESS VALVES FOR A.C. SUPPLY. (*Wireless World*, 20, 26th January, 1927, pp. 115-116.)

Discusses the introduction of an indirectly heated cathode to eliminate the filament battery.

MEASUREMENTS AND STANDARDS.

CONTRIBUTION À LA REALISATION D'UN ETALON DE FAIBLE CAPACITÉ (Contribution to the production of a standard of small capacity). —F. Bedeau. (*L'Onde Electrique*, 5, December, 1926, pp. 613-649.)

A study of the measurement of small capacity at high frequency. It is shown that extremely sensitive methods exist to-day for measuring very small variations of capacity and yet the values given for various physical constants differ considerably from one another. The fact is all capacities are at present evaluated in terms of standards of inductance and resistance, a procedure that becomes necessary when the capacity to be measured is large, since an air condenser standard of large capacity is difficult to realise. This, however, is no longer the case for a standard of low capacity, and in this paper the author describes his attempt to produce such an air condenser standard capable of employment in high frequency measurements, with which he believes very small variations of capacity are measurable with greater accuracy than that at present obtained. This number contains the introduction and first two chapters of the work. In the first chapter, the author gives his reasons for choosing a cylindrical condenser as standard of capacity and discusses the different sources of error, and in the second chapter he explains how the ratio of the radii is obtained and gives the results of his measurements.

SHIELDED OSCILLATOR FOR HERTZIAN WAVES.—J. Tykocinski-Tykociner. (*Physical Review*, 29, January, 1927, p. 217.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1926.

A thermionic tube is mounted at each end inside a brass cylinder in contact with the cold electrode. The grids of the tubes are connected by means of an insulated rod placed concentrically in the cylinder. The electromagnetic field of the oscillator is confined to the space inside the cylinder, where a standing wave is produced along its axis with a potential node in a plane dividing the length of the cylinder in two equal parts. The variation of frequency is produced by condensers mounted inside the cylinder. The cylinder is closed at each end by means of rotating shielding caps which serve as dials for the tuning mechanism. Measurements on antennæ or Lecher wires were made undisturbed by the stray field of the oscillator, by connecting them with two points of the rod, reached through holes made in the cylinder on both sides of the nodal plane. Standard 5 and 50-watt oscillating tubes were used. With an oscillator having a cylinder 100 cm. long and 7.3 cm. in diameter, a frequency of 60×10^6 to 65×10^6 was produced. A shorter cylinder 66 cm. long and 4.8 cm. in diameter gave a frequency of 85×10^6.

THE RESISTANCE OF COPPER WIRES AT VERY HIGH FREQUENCIES.—W. Roberds. (*Physical Review*, 29, January, 1927, pp. 165-173.)

At frequencies of the order of 10^7 cycles the distributed capacity of single loops of wire may cause sufficiently unequal current distribution in the loop to account for large apparent discrepancies between observed and calculated resistances. For a given frequency, more uniform current distribution is gained by decreasing the size of the loop and simultaneously increasing the capacity of the tuning condenser. Curves are plotted with ratio of observed to calculated resistance as ordinate and condenser setting as abscissa. For No. 20

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copper wire at 0.86×10^7 cycles the ratio increases to at least 1.05 as the current distribution along the wire is made more and more nearly uniform. For No. 16 oxide-coated copper wire the ratio reduces to at least 1.35. The discrepancy in both cases is accounted for by the same value of condenser resistance. Observed resistance of a given loop is shown to vary greatly as condenser resistance is changed.

Since curves run on bright copper wire coincide with curves run on exactly the same wire after it had gained a heavy coating of oxide, it can be definitely stated that the presence of oxide has no appreciable effect on the resistance.

RADIO-FREQUENCY MEASUREMENTS. (*E.W. & W.E.*, 4, February, 1927, pp. 108-110.)

A book of importance to radio experimenters entitled "The Theory and Practice of Radio Frequency Measurements: a Handbook for the Laboratory and a Text-book for Advanced Students," by E. B. Moullin, has recently been published. The book is reviewed here, chapter by chapter, by Mr. Dye; also in *Nature* of 29th January, p. 155, there is a brief article on the book by Prof. Appleton.

SIGNAL FADING MEASUREMENTS.—R. L. Smith-Rose. (*Wireless World*, 20, 12th January, 1927, pp. 32-37.)

The measurement of signal fading is briefly discussed and practical details are given for constructing and calibrating the necessary apparatus.

AERIAL TESTING.—J. Catterson-Smith. (*Journal of the Indian Institute of Science*, 9B, III., pp. 21-28.)

Description of an extension of a method of testing due to Dr. Eccles ("Handbook of Wireless Telegraphy and Telephony," 2nd edition, 1918, 121). Graphical representation of aerial tuning characteristics is used to show the linear relation between tuning inductance and the reciprocal of the tuning capacity.

The use of a high frequency bridge method of determining the tuning characteristics and aerial resistance is explained.

STANDARD FREQUENCY TRANSMISSION IN AUSTRALIA.—H. Stowe. *Q.S.T.*, 11, January, 1927, pp. 34-35.)

SIMPLIFIED S.L.F. AND S.L.W. DESIGN.—O. C. Roos. (*Proc. Inst. Radio Engineers*, 14, December, 1926, pp. 773-780.)

A CALORIMETRIC METHOD OF MEASURING DIELECTRIC LOSSES AT HIGH FREQUENCIES.—G. Owen. (*Journ. Opt. Soc. Amer. and Rev. Sci. Inst.*, 13, December, 1926, pp. 725-726.)

SOME NEW COIL IMPEDANCE DIAGRAMS.—W. Barclay. (*E.W. & W.E.*, 4, February, 1927, pp. 87-92.)

A SHORT-WAVE PRECISION WAVEMETER. (*Q.S.T.*, 11, January, 1927, pp. 43 and 46.)

SUBSIDIARY APPARATUS AND EQUIPMENT.

THE ACOUSTIC PROBLEMS OF MICROPHONES AND LOUD-SPEAKERS. (*E.W. & W.E.*, 4, February, 1927, pp. 106-107.)

Informal discussion at I.E.E. Wireless Section.

A DIRECT RADIO CONTROL RELAY.—R. Kruse. (*Q.S.T.*, 11, January, 1927, pp. 19-21.)

H.T. AND L.T. FROM A 250-VOLT D.C. SUPPLY.—A. Robertson. (*E.W. & W.E.*, 4, February, 1927, pp. 111-113.)

A HIGH VOLTAGE DIRECT CURRENT GENERATOR.—S. Mackeown. (*Journ. Opt. Soc. Amer. and Rev. Sci. Inst.*, December, 1926, pp. 727-729.)

DRY BATTERIES FOR RADIO PURPOSES. (*Electrical Review*, 100, 7th January, 1927, pp. 3-5.)

Some impressions of a visit to the Woolwich works of Siemens Bros. & Co., Ltd., and their methods of manufacture.

EFFECT OF WORKING ON THE PHYSICAL PROPERTIES OF TUNGSTEN.—J. Avery and C. Smithells. (*Phys. Soc. Proc.*, 39, 1, December, 1926, pp. 85-96.)

GENERAL PHYSICAL ARTICLES.

PIEZO-ELECTRICITY OF CRYSTAL QUARTZ.—L. Dawson. (*Physical Review*, 29, January, 1927, p. 216.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1926.

Measurements with a quadrant electrometer of the piezo-electric charge in optically perfect crystal quartz have shown that the different specimens of quartz may produce charges of different magnitude. The piezo-electric charge appeared to be an integral effect over the surface since an exploration of the surface by an approximation to a point contact showed that charges varying in magnitude and sign may be produced on adjacent portions of the surface. The piezo-electric charge increased as the temperature was raised from room temperature to 60° C. and decreased thereafter to 576° C. where it disappears. The cooling curves show a lag. A relation between the pyro- and piezo-electric effects is pointed out. The piezo-electric charges on surfaces variously oriented with respect to the optic axis showed a characteristic distribution hitherto unsuspected and not explainable by simple theory. This characteristic distribution lead to an accurate method for determining the direction of the electric axes of quartz.

NEUE KUNSTGRIFFE IN DER VACUUMTECHNIK (New artifices in vacuum technique).—M. Schirmann. (*Physik. Zeitschr.*, 27, 1st November, 1926, pp. 659-680.)

The first device consists in connecting the vessel to be exhausted to the trunk tube of the pump by means of a narrow tube and sealing off close to the trunk, thus avoiding most of the gas set free from the heated surface of the glass getting into the vessel.

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The second improvement refers to ground glass joints and taps in which the seal is effected without mercury or grease. The inner cone or plug is of metal and the outer surface of the outer cone or barrel respectively is coated with metal, and an electromotive force is applied between the two metal surfaces which draws them together.

THERMAL AGITATION OF ELECTRICITY IN CONDUCTORS.—J. Johnson. (*Nature*, 119, 8th January, 1927, pp. 50-51.)

Ordinary electric conductors are sources of spontaneous fluctuations of voltage which can be measured with sufficiently sensitive instruments. This property of conductors appears to be the result of thermal agitation of the electric charges in the material of the conductor. The effect has been observed and measured for various conductors, in the form of resistance units, by means of a vacuum tube amplifier terminated in a thermocouple. It manifests itself as a part of the phenomenon which is commonly called "tube noise." It is here shown that for the technique of amplification the effect means that the limit to the smallness of voltage which can be usefully amplified is often set, not by the vacuum tube, but by the very matter of which electrical circuits are built.

DEMONSTRATION OF SELENIUM CELLS.—H. Thirring. (*Phys. Soc. Proc.*, 39, 1, December, 1926, p. 97.)

Among the deficiencies naturally inherent in selenium cells are :—

1. The resistance is not a linear function of the intensity of illumination.
2. It has a temperature coefficient.
3. The reaction to light is not instantaneous.

The cells, therefore, have to be used in an arrangement which compensates as far as possible these deficiencies for the given purpose. Experiments were shown illustrating some of these arrangements.

THE AURORAL GREEN LINE 5577. (*Nature*, 119, 29th January, 1927, p. 162.)

A letter from Dr. Keys of McGill University, Montreal, describing evidence for the fact that the auroral green line is primarily due to oxygen, thus confirming the recent work of Prof. McLennan and his co-workers.

A DETERMINATION OF THE DIELECTRIC CONSTANT OF AIR BY A DISCHARGE METHOD.—A. Carman and K. Hubbard. (*Physical Review*, 29, January, 1927, p. 217.)

Abstract of a paper presented at the Chicago meeting of the American Physical Society, November, 1926.

A value of 1.000594 was found for the dielectric constant of air at 0°C. and 760 mm. Hg. pressure.

KATHODENZERSTÄUBUNGSPROBLEME (Problems of cathode sputtering).—A. v. Hippel. (*Annalen der Physik*, 81, 1926, pp. 1043-1075.)

A previous paper (*Ann. d. Phys.*, 80, 672) described a new method for investigating cathode sputtering and showed that sputtered metal particles consist very largely of uncharged atoms. The present paper deals with the theory of cathode sputtering.

KATHODENZERSTÄUBUNGSPROBLEME (Problems of cathode sputtering).—E. Blechschmidt. (*Annalen der Physik*, 81, 1926, pp. 999-1042.)

A paper dealing with the dependence of cathode sputtering on the working conditions, with a plate showing photographs of cathodes after sputtering.

SECONDARY ELECTRON EMISSION PRODUCED BY POSITIVE CAESIUM IONS.—J. Hyatt.

SECONDARY ELECTRON EMISSION FROM MOLYBDENUM.—A. Hull and J. Hyatt.

THE DISTRIBUTION OF ENERGY AMONG ELECTRONS REBOUNDING FROM HELIUM ATOMS.—A. Hughes and L. Jones.

(*Physical Review*, 29, January, 1927, p. 214.)

Abstracts of papers presented at the Chicago meeting of the American Physical Society November, 1926.

MISCELLANEOUS.

RADIO-TELEGRAPHY AND RADIO-TELEPHONY.—L. B. Turner. (*Journ. Inst. Elect. Engineers*, 65, January, 1927, pp. 131-136.)

A review of progress. Reprints (price 2s. 6d. each) are obtainable from the Secretary of the Institution.

DIE BETRIEBS-ZENTRALE DER TRANSRADIO A.-G. FÜR DRAHTLOSEN ÜBERSEE-VERKEHR (Headquarters of the joint-stock company Transradio for wireless communication overseas).—E. Quäck. (*Zeitschr. f. Hochfrequenz.*, 28, pp. 162-167, November, 1926.)

Detailed description of the Transradio Central Office in Berlin, which was completely remodelled in 1925. A plan of the building is shown and photographs of the different rooms for sending and receiving. This company owns the high power stations Nauen and Eilvese, with the receiving stations Geltow and Westerland a. Sylt, which are in regular communication with New York (Radio Corporation of America), Buenos Aires (Transradio Internacional Compania Radiotelegrafica Argentina), Rio de Janeiro (Companhia Radiotelegraphica Brazileira), Abu Zabal (British Government), Malabar (Netherlands Colonial Government), and also in one-way communication with China and Japan.

POLAND—RADIO COMMUNICATION. (*Electrical Review*, 99, 24th December, 1926, p. 1042.)

For communication with foreign countries the Post Office is in possession of four stations : the transatlantic station, built by the Radio Corporation of America, the transmitter comprising two 300kW alternators which can work in parallel on a very good elaborated aerial ; arc transmitters at Cracow and Poznan which only permit of hand-speed working ; and a French alternator station of approx. 6kW at Grudziadz, used mostly for communication with France.

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The last three stations are "extremely inefficient," and are not equipped with modern receivers, and the running expenses of the first station are so high, for the small number of words available for transmission, that special credits have to be voted by the Diet to cover the losses. Only a small part of correspondence which could be transmitted from and received in Poland is going by wireless.

FRANCE—CONTROL PLAN. (*Electrical Review*, 99, 24th December, 1926, p. 1042.)

M. Bokanowski, Minister of Commerce, who recently described the conditions under which French broadcasting is carried on as "anarchic," is stated to have submitted a scheme of control to the Post Office Department. In the *Review* of 7th January, p. 21, it is announced that broadcasting now becomes the prerogative of the State, which will assume possession of all transmitting stations in five years' time, and that meanwhile broadcasting will be controlled by a mixed committee of Government officials, authors, musicians and lecturers, who will supervise operation carried out by authorised private enterprise.

PORTUGAL—NEW WIRELESS TELEGRAPH SERVICE. (*Electrical Review*, 99, 24th December, 1926, p. 1042.)

A direct high-speed wireless telegraph service between England and Portugal was opened on 15th December. It is the first of a number of wireless services which are being established by the Portuguese Marconi Company under a 40 years' concession granted by the Portuguese Government to Marconi's Wireless Telegraph Co., Ltd., to undertake the organisation of a complete wireless telegraph and telephone system to place Portugal in communication with her Colonies, the principal capitals of Europe, South America, and other countries. Stations are being built near Lisbon, in Cape Verde Islands, Madeira, the Azores, Mozambique, and Angola.

TELEVISION. (*Nature*, 119, 15th January, 1927, pp. 73-74.)

An article giving the writer's impressions of the lecture delivered by Mr. Baird on 6th January at the Physical and Optical Society's exhibition, stating that Mr. Baird did not add to the general knowledge by what he said and did on that occasion. In a letter to *Nature* of 29th January, Mr. Baird replies to statements and criticisms contained in the article, the Editor adding a footnote that this further information is precisely the kind which physicists were waiting for.

PREFERRED NUMBERS.—L. Hazeltine. (*Proc. Inst. Radio Engineers*, 14, December, 1926, pp 785-787.)

The Institute of Radio Engineers is taking part in the study of Preferred Numbers and their application, and would welcome comments by radio engineers.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto - Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPRECOJ DE CIRKVITOJ.

KELKAJ NOVAJ DIAGRAMOJ DE BOBENAJ IMPEDANCOJ.—W. A. Barclay.

La artikolo traktas pri la aplikado de la enliniiga principo al la kalkulado de reaktancaj kaj impedancaj valoroj en alternkurentaj cirkvitoj. Kelkaj utilaj ekzemploj estas bone ilustritaj per serio de diagramoj montrantaj la konstruadon por induktaj kaj kapacitaj reaktancoj, resonancon, k.t.p.

SIMPLAJ RESONANCAJ KURVOJ KAJ ILIA MODIFO PER VALVAJ CIRKVITOJ.—Prof. E. Mallett.

La aŭtoro priskribas vektoran traktadon de simplaj resonancaj kurvoj. Pere de la traktado, la resonanca kurvo estas antaŭdirebla en okazoj, kie estas nur unu agordita cirkvito, kiu povas esti kunigita al valvo kun aŭ sen reakcio. Alternative, per resonanca kurvo eksperimente obtenita per variigo de la frekvenco, la efektiva velkada faktoro de la cirkvito estas trovebla. La kondiĉoj por la konservado de osciladoj per valvo estas ankaŭ kalkuleblaj.

La traktado estas dividita laŭjene :—

1. Seria impedanco—resonancaj kurvoj kaj cirkloj—cirkla kaj rektlinia konstruado por trovi velkadan faktoron.

2. Paralela resonanco—agordita anoda cirkvito—kondiĉoj por oscilado—anoda spilo.

3. Oscila cirkvito konektita al krado—kondiĉoj por oscilado.

RICEVADO.

LA AGADO DE AMPLIFIKATOROJ—P. K. Turner.

Unue la aŭtoro ilustras kaj diskutas kurvon por trivalva aparato mezkvalita, la frekvencaj abscisoj estante laŭ oktavoj de tonalteco, dum la ordinatoj estas amplifitaj. Oni sugestas, ke pro tio, ke la diferenco de impreso farita ĉe l'orelo per du

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nesamaj volumoj de sono estas afero de ilia proporcio, pli ol iliaj absolutaj valoroj, la ordinatoj devus ankaŭ esti efektive logaritmaj, ekz., esprimitaj laŭ "Sendaj Unuoj," kiel je la telefona praktikado. Tiel taksite, la agadon de la amplifikatoro aludita, oni montras plibonan ol unue sugestitan. Similaj kurvoj estas poste donitaj por du aliaj amplifikatoroj, unu, Burndept Ethophone III., Marko IV., kaj la alia, laboreje konstruita rezistance kuplita aparato, ĉiu kun tri valvoj. La unua donas skalon de 70 ĝis 4,000 cikloj kun 25-procenta falo, kaj 30 ĝis 7,000 cikloj kun 50-procenta falo, dum la lasta donas 30 ĝis 7,000 ciklojn kun nur 25-procenta falo.

La metodo de mezurado estas ilustrita kaj diskutita.

Alta-Tensio kaj Malalta-Tensio pere de 250-volta Kontinukurenta Provizo.—A. Robertson.

La aŭtoro priskribas kaj ilustras la utiligadon de elektraj ĉeftuboj de 250-volta Kontinua Kurento por filamenta varmigado kaj alta tensio. Por unuvalva aparato oni montras la ĉeftubojn uzitajn senpere por filamenta provizado, dum por trivalva aparato, varianta baterio estas ilustrita. Sokaj kaj glatigaj aranĝoj estas ankaŭ diskutitaj, kaj nova speco de transformatoro estas priskribita, utiliganta la ŝanĝon de kurento ĉe la pozitiva kaj negativa membroj de la filamento kiam la anoda cirkvito estas energiita.

SUBGRADA EKIPAĴO KAJ MATERIALOJ.

La Desegno de Heterodina tipo de Malalt-Frekvenca Generatoro.—H. L. Kirke.

La generatoro priskribita estas de la tipo, kiu uzas la radio-frekvencajn oscilatorojn por produkti aŭdeblan baton, kiun oni povas variigi por ampleksi la bezonitan skalon de aŭd-frekvenca elmeto.

La du oscilatoroj funkcias je ĉirkaŭ 4,000 metroj, unu estante variebla, kaj la alia fiksita laŭ frekvenco. Iliaj elmetoj estas kondukitaj al rektifikatoro, kaj la rezultanta malalta frekvenco estas pasigita tra taŭga amplifikatoro. La amplifikatoro estas kuplita rezistec-kapacite, kun altfrekvencaj ŝokbobenoj kaj paralelaj kondensatoroj en ĉiu kupla ŝtupo, inter la kupla kondensatoro kaj krado. La kontrolo de volumo estas donita de potenciometroj ĉe du el la ŝtupoj.

La generatoro provizas maksimuman elmeton de 0.5 vato, kun frekvenca skalo de 50 ĝis 10,000 cikloj. La elmeto estas konstanta super la tuta frekvenca skalo, kaj donas ondan formon proksimiĝantan je sinusa ondo.

Retroglitebla unuo estas utiligita por mezuri la elmeton.

En la artikolo, la teorio de la generatoro estas diskutita, kaj la desegno de la oscilatoroj kaj amplifikatoro priskribita kaj ilustrita per diagramoj kaj ilustraĵoj. Oni donas ankaŭ notojn pri normigado, konstanteco de frekvenco, kaj ponta metodo de frekvenca mezurado.

La Akustikaj Problemoj de Mikrofonoj kaj Laŭtparoliloj.

Raporto pri neformala diskutado pri la ĉisupra temo, tenita ĉe la monata kunveno de la Senfadena Sekcio, Institucio de Elektraj Inĝenieroj, je 5a Januaro, 1927a.

La diskutadon malfermis S-ro. G. H. Nash, kaj daŭrigis S-roj. B. S. Cohen, P. P. Eckersley, C. F. Phillips, kaj aliaj.

DIVERSAĴOJ.

Matematikoj por Senfadenaj Amatoroj.—F. M. Colebrook.

Daŭrigita el antaŭaj numeroj.

La nuna parto traktas pri la kontinueco de Funkcioj kaj Limoj, la Funkcio

$$y = 10^{\frac{1}{x-1}} + 1$$

estante pritraktita detale laŭ ambaŭ vidpunktoj.

Aferoj Senfadene Interesaj ĉe la Ekspozicio de la Fizika Societo.

Oni donas mallongan raporton pri aferoj interesaj laŭ senfadena vidpunkto ĉe la Deksepa Ĉiujara Ekspozicio de Aparataro, tenita de la Fizika Societo kaj Optika Societo ĉe la Imperia Kolegio, South Kensington, Londono, je la 4a, 5a, kaj 6a Januaro 1927a.

Libro-Recenzoj.

Jen grava recenzo (de D-ro. D. W. Dye) pri "Radio-Frekvencaj Mezuraj: Manlibro por la Laborejo kaj Lernolibro por Altgradaj Studentoj," de E. B. Moullin, M.A.

Kvar aliaj verkoj estas ankaŭ recenzitaj de Prof. G. W. O. Howe.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato) kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

ERRATUM.

Radio Frequency Measurements.—The expression on page 109, col. 1, of the February issue, should read

$$\frac{\sqrt{I^2_{res} - I^2}}{I^2}$$

instead of as there shown.

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Correspondence.

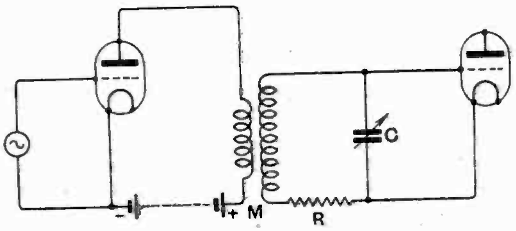
Letters of interest to experimenters are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Plate-Current, Plate-Voltage Characteristics.

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

SIR,—Mr. Holt Smith disagrees with the statement in my article that "For amplifiers using tuned circuits, maximum amplification occurs when the output power is a maximum for a given amplitude of grid voltage," and goes on to state that if the resistance of the tuned circuit is zero, then we get maximum amplification with minimum output.

Mr. Holt Smith apparently has not noticed the typical diagram I gave for a tuned circuit amplifier, and which I reproduce here. It is only with such a type that the effective load of the tuned circuit in the plate circuit can be varied efficiently.



If R = series resistance of tuned circuit.
M = mutual inductance between grid and plate coil.
$\omega = 2\pi \times$ frequency in use.

Then with the grid circuit in tune the resistance this circuit provides in the plate circuit, through the mutual inductance M, is $\frac{M^2\omega^2}{R}$ and can be made equal to the A.C. plate resistance, thus ensuring maximum power output for a given input. This power is delivered to the tuned circuit, and will obviously give the maximum voltage across it.

If the resistance of the tuned circuit is reduced to zero as Mr. Holt Smith suggests, theoretically an infinite step-up could be obtained. In practice, even with the lowest resistance coil, we have to be content with a much more modest value.

Much could be written from the practical point of view as regards the step-up obtainable at various wavelengths, but enough has been said to defend the original statement. The article was on plate-current, plate voltage curves, and circuits could only be touched on very lightly if the article was to be kept to a reasonable length. E. GREEN.

That Audio Transformer Problem.

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

SIR,—The problem of the audio-frequency transformer is one which concerns all of us in a greater or less degree, and I trust that this, I fear rather lengthy contribution, mainly in answer to the letters of your correspondents Messrs. Albert Hall and C. Holt Smith appearing in your January issue, will be acceptable in full.

The contents of my letter in your November issue have not apparently been properly appreciated. As stated, it was not possible to give a complete explanation, and the letter was largely only a statement of the case. So far as it goes, its contents are quite correct.

Now, sir, I have, I hope, this opportunity of making matters somewhat clearer.

When variations and maxima of quantities of any kind are under consideration it is most necessary to keep clearly in mind the postulated basis over which these variations are supposed to occur. Thus, Mr. Albert Hall has not in his letter—see particularly his unfortunate last sentence—understood that the general principle concerning primary impedance in relation to that of the valve was as stated, on the basis of a given frequency. The figures which he quotes, far from giving me a "problem to solve," are, so far as they go, in agreement with the principles to which I refer below.

The basic principles of this problem, inclusive generally of *all* effects occurring in transformers, are:—

1. For varying degrees of primary winding fineness in a given winding space (excluding capacity effects for the moment only) the maximum inductive voltage per turn *for any one frequency*, and therefore the maximum voltage of a given secondary winding, occurs when the winding fineness is such that the impedance is (approximately for iron) *equal* to that of the valve.

That is certainly true, and as indicated by Mr. Holt Smith, readily capable of proof when winding self-capacity may be neglected.

It is also true of the combined impedance in the most important case and true in a modified form in another (constant parallel capacity) when self and/or additional parallel capacity is taken into account, but to this I shall again refer when discussing the letter from Mr. Holt Smith.

Hysteresis and eddy current effects are included in these statements.

2. The *magnitude of this maximum* effect increases with the frequency though in the case of constant parallel capacity it ultimately decreases again due to the required value of the tuning capacity becoming reduced, as a result of hysteresis and eddy currents.

3. With any *given windings* the amplification, *i.e.*, inductive voltage per turn, increases with the frequency up to a point, after which it falls mainly due to capacity effects, but at any one frequency for which the primary impedance, with or without parallel capacity, is materially greater than that of the valve, the amplification at that frequency could be increased by reducing the impedance of the winding or combination to the region of equality, provided in the latter case the change is effected by reducing the impedance of the winding, which is the same as saying that the combination does not at any time give a condenser effect.

4. With a given secondary of highest number of turns reasonably possible, maximum volt amplification occurs when the effective primary, *i.e.*, the

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primary inclusive of the capacity effects of secondary, eddy currents and hysteresis, is *tuned* by self plus added capacity to the given frequency, the fineness of the primary winding being such that the *impedance of the combination* is *equal* to that of the valve.

It is not possible for me to consider here Mr. Hall's figures in detail, but it will readily be seen that they do not contradict these principles.

In reference to Mr. Hall's second paragraph and to the last sentence of his third, I trust that after perusal of this letter he will himself be better able to understand this matter. The remainder of his third paragraph with " release " substituted for " produce " is agreed to, but is surely too elementary to have been included in this discussion.

Mr. Holt Smith's observations on this problem, though not incorrect so far as they go, are to some extent misleading. Naturally, if we could have a transformer with a constant ratio and with no capacity effects, we should want the highest possible impedance ; in fact, it is only the case of the choke, with its gradual approach to an asymptotic maximum. But then he appears to agree that that is not a practical case.

The transformer problem is fundamentally different. We have a secondary of the maximum number of turns which is practically possible, which has resistance and self-capacity. We have so to excite the core as to obtain at the given frequency maximum induced effect in that secondary. It is a case of producing maximum volt-amperes in the primary winding space at our disposal, not maximum volts, and it is the $\mu \times m$ of the valve which counts, not the μ alone.

His point, which is " at variance with my rule," is correct. But I did not lay down a rule ; I stated that the basic principle of equality of primary and valve impedance for maximum amplificaton was not incorrect, and that that of the utmost possible primary impedance was, which is true. If Mr. Holt Smith will apply pen to paper once again, he will discover that the absolute maximum effect in his more practical case occurs when the primary is tuned *and* of equal impedance with the valve at the same time. For given windings, the optimum is obtained when the primary is *tuned* by parallel capacity (total current in phase). Then, for the tuned condition and varying primary, optimum is again obtained when impedance of combination *equals* that of valve. So he will see that the reason he increases the amplification by increasing the impedance away from the valve is that he is approaching the tuned condition from the wrong side, so to speak. Nevertheless the principle of equality is correct for the absolute maximum.

If we take, as he has done, the case of a constant capacity, it is true that the optimum does not occur when there is equality, but there is still a true (not asymptotic) maximum which occurs in this case when the impedance of the combination bears a definite ratio—not very far removed from unity for small capacities and/or frequencies—to that of the valve.

This principle of equality of primary impedance and valve for maximum amplification at a given frequency is thus, after all, a general principle and *not* an error. It need not be taken with a " pinch of salt," and Mr. Hall is simply wrong when he says that it is " an erroneous idea." On the other hand, the notion held by Mr. I. A. J. Duff, and which has been thrust on the radio public as the " truth " in certain recent advertisements from another source, that the primary should be of the utmost possible impedance, is definitely erroneous, and is one which, carried out practically to its technically, as distinct from commercially, possible extent, leads to an incorrect transformer.

The equality principle is correct for the absolute maximum in all cases, inclusive of *all* effects, but because we have to apply it at lower and lower frequencies, in order to bring in lower and lower notes, the erroneous idea has arisen that we require intrinsically the highest possible primary inductance, which is not the case.

Nevertheless, as I have amply proved experimentally, it is true that we want higher values than are found in many transformers.

E. Fowler Clark,
B.Sc., B.A., A.M.I.E.E.

The Performance of Amplifiers.

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

Sir,—I have read with interest your editorial note in the issue for February, referring to my short article in the same issue. In the last paragraph of this editorial note you express an objection to the procedure adopted during the tests, and (although I may be unduly sensitive) this paragraph gave me the impression that you felt that perhaps this method had been deliberately adopted to favour some particular point of view ; you refer to it as a " peculiar procedure," and go on to say that the tests " would have been more convincing " if certain other measures had been adopted.

Perhaps you will allow me to explain that these tests were undertaken primarily to measure the performance of the audio-frequency side of the sets in question. I quite agree with the remark that tests made on a radio-frequency voltage modulated with a pure sine wave would have been more convincing, but I have no hope of making really satisfactory tests on these lines for some months to come : I find it is extremely difficult, with the apparatus available to me, to devise any method by which I can modulate an R.F. oscillator, in which the output of such oscillator is exactly known, and in which, further, the radio-frequency amplitude is modulated in a strictly linear manner. It is obvious that if this last requirement is not fulfilled, the envelope of the radio-frequency output will not be a pure sine wave. However, perhaps later on I may be able to get over this difficulty.

In any case, tests so conducted introduce several other factors into the performance of the receiver, notably the favouring of low frequencies, caused by the selectivity of the radio-frequency side of the set.

Granted that it was necessary to feed the set with audio-frequency voltage, it would, of course, have been possible to deal with the set only as from the grid of the first L.F. valve. This, however, would have failed to show up the frequency response characteristic of the coupling between the detector and the first L.F. valve. As this is an essential part of the L.F. side of the set, I considered it quite necessary to include it. It would, of course, have

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been quite unjustifiable to remove the detector valve and feed in the audio-frequency E.M.F. in place of it, as this would have changed the response characteristic of the coupling in question. It therefore seemed to me obvious that the L.F. energy should be fed in at the grid of the detector valve, which is in actual fact the closest approximation possible in the circumstances to the normal action of the set. Had I left the valve with its grid positive, it would, of course, have set up such waveform distortion that the set would not have been amplifying a pure sine wave. It was therefore necessary to make the grid slightly negative. The grid condenser and leak were not removed, but of course as the grid is maintained negative the leak carries no current. The net effect was to diminish slightly the anode current of this valve, though not so much as would be expected, for although the grid had been previously connected to filament positive, the drop across the leak brought the grid very nearly to zero potential. An investigation was made to see whether there was any change in the anode A.C. resistance of the valve, due to working on a different part of the characteristic, but this was found to be negligible.

I regret very much that I did not go into this point more fully in the article itself, but, frankly, it appeared to me to be such an obvious matter as to need no explanation.

With regard to the last few lines of the editorial note, in which you are interested in the possible cause of the bad response curve of the set shown in Fig. 1, this was simply due to the fact that the set had two transformer coupled stages, in which the transformers were not very well designed, and, moreover were not particularly well suited to the valves specified. If you take the square root of the ordinates in Fig. 1, or half the ordinates in Fig. 2, you will get a rough approximation to the curve of one of these transformers, and you will at once perceive that it is typical of a transformer of indifferent design.

Blackheath, S.E.3. P. K. TURNER.

Quartz Crystal Stabilisation of Transmitters.

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

SIR,—In my article on quartz crystal-controlled transmitters in the December issue, the tuned-plate, tuned-grid circuit is used throughout. This circuit oscillates without magnetic coupling due to the feed-back through the valve capacity. I have recently found that with some valves the feed-back is so great that it causes over excitation of the grid. As the synchronising effect required is inversely proportional to the grid excitation it is evident that the range of synchronisation can be considerably increased in this case by reducing the grid excitation. This can be simply effected by partial neutralisation (by taking a tap from a point below the low potential side of the plate inductance, through a condenser to the grid of the valve in the usual manner). The adjustment is not critical as complete neutralisation is not desired. The efficiency of the circuit is also increased by this procedure.

N.W.7. C. W. GOYDER, G2SZ.

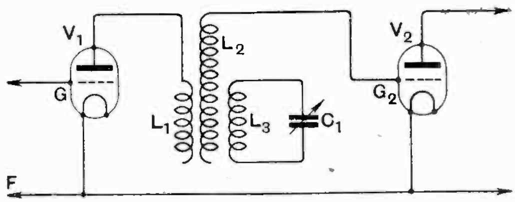
Some Recent Patents.

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

A HIGH FREQUENCY AMPLIFIER.

(*Application date, 12th August*, 1925. *No.* 261,088.)

A form of intervalve coupling for high frequency amplification is described in the above British Patent by Radio Patents Corporation and W. Dubilier, one arrangement of the invention being shown in the accompanying illustration. Signal voltages are applied between the grid *G* and filament *F* of the valve V_1, the anode circuit of which contains an inductance L_1, comprising the primary coil of a high frequency transformer. One end of the coil L_1 is connected to the anode, of course, while the other end is connected to the high tension battery, which is not shown. The secondary winding comprises an inductance L_2 having a very much larger number of turns than the inductance L_1, and is connected between the grid G_2 of the valve V_2, and the common filament lead *F* of the grid bias battery. Coupled to L_1 and L_2 is another inductance L_3, tuned by a condenser C_1, the oscillatory circuit L_3 C_1 being in resonance with the frequency of the oscillations to be amplified. The specification states that this arrangement results in an amplification which is sometimes 50 per cent. greater than the more normal form of high frequency transformer. A similar arrangement can be applied to an aerial circuit, where the inductance L_1 comprises the aerial tuning coil,



and the inductance L_2 is connected to the grid-filament circuit of the first valve, the closed circuit L_3 C_1 being coupled to the inductance L_2 as before.

ELIMINATING HUM.

(*Application date, 27th January*, 1926. *No.* 262,979.

Most methods of eliminating ripple in rectified A.C. supply for receiving sets consists in introducing a filter system into the rectified power supply which is applied to the valve. A method is claimed by

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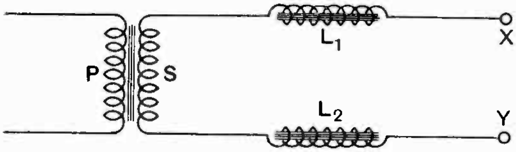
W. E. H. Humphrys in the above British Patent, which consists in introducing chokes into the output of the receiver. A convenient method of carrying this into effect is shown in the accompanying illustration, where an output transformer comprising a primary winding P and a secondary winding S

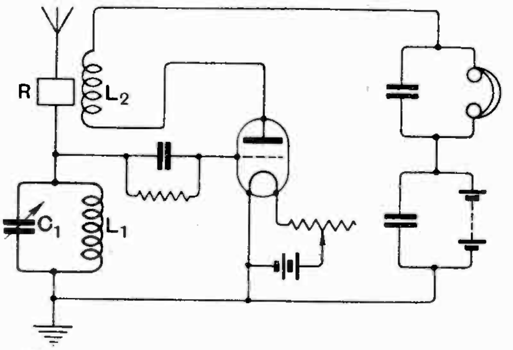


is connected in the anode circuit of the last valve. The telephones or loud speakers are connected at XY, *i.e.*, across the secondary of the transformer, but in series with the two leads from the secondary are two chokes L_1 and L_2, which offer considerable impedance to currents of frequencies of the orders of those due to the ripple.

CONSTANT REACTION CONTROL.

(*Application date*, 6*th October*, 1925. *No.* 263,560.)

A method of obtaining constant reaction control is described by M. A. Robinson in the above British Patent. The accompanying illustration should make the invention quite clear, the main feature being the inclusion of a resistance in the aerial circuit. A single valve receiver is shown in the diagram, the input comprising a tuned circuit L_1C_1 connected between the grid and the filament, the usual condenser and leak being included for rectification, while a reaction coil L_2 is coupled in fixed relationship with the inductance L_1, the telephones and high tension battery being connected

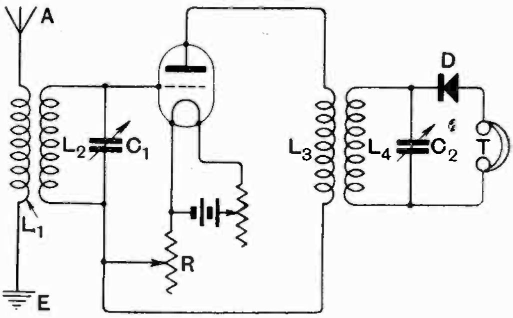


in the normal manner. It is well known that if the aerial is connected to the grid the amount of regeneration existent in the system will vary with the capacity existing between the grid and the filament, *i.e.*, with the position of the tuning condenser. The aerial system, which one can regard as a combination of inductance and capacity, and, of course, resistance, materially affects the tuned circuit L_1C_1. If, however, a resistance such as that shown at R is included between the aerial and the grid or high potential end of the input circuit, its effect on the tuned circuit L_1C_1 will not be so great. It is stated in the invention that by suitably adjusting this resistance it is possible to obtain a fairly constant degree of reaction or regeneration throughout the whole tuning range irrespective of the position of the tuning condenser C_1. Whether this effect is fulfilled or not is very materially influenced by the constants of the remainder of the circuit, this being pointed out in the specification.

STABILISING VALVE AMPLIFIERS.

(*Convention date* (*U.S.A.*), 13*th October*, 1924. *No.* 241,185.)

A method of stabilising valve amplifiers depending upon coupling back potentials produced across a resistance in the anode circuit into the grid circuit is described in the above British Patent by R. E.



Manufacturing Co. and Boyd Phelps. The basic idea of the invention can be gathered by referring to the accompanying diagram, which shows a valve amplifier followed by a crystal rectifier. Here the aerial circuit comprises an aerial A, earth connection E, and an inductance L_1 coupled to an inductance L_2 tuned by a variable condenser C_1. The anode circuit contains a high frequency transformer $L_3 L_4$, the secondary of which is tuned by a condenser C_2. The amplified potentials produced across the secondary of the transformer are rectified by a crystal detector D in series with the telephones T. The usual filament and anode batteries are shown. Instead of connecting the negative terminal of the high tension battery and the lower end of the grid circuit directly to the filament, connection is made through a resistance R. Since the resistance R comprises part of the anode circuit, a portion of the potentials produced in this circuit will naturally occur across the resistance, but since this resistance is also in the grid circuit the potentials produced across it will be transferred to the grid of the valve. But as the anode and grid potentials are substantially 180 degrees out of phase, the potential which is applied to the grid from the anode circuit will oppose that applied to the grid from the signal voltage, or whatever may be exciting the valve. Thus it will be seen that if there is a tendency for continuous oscillations to be sustained by the valve acting as a generator—due, perhaps, to stray magnetic or capacitative coupling—by suitably adjusting the resistance value sufficient opposition phase voltage can be introduced into the grid circuit to cause cessation of oscillation. It must be remembered, of course, that a valve connected in this manner, while being stable in operation, tends to lower the amplification, since

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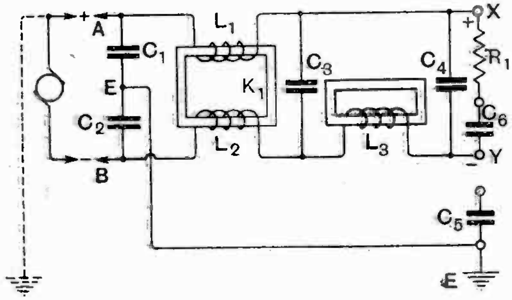
the amplification of all voltages applied to the grid of the valve will be somewhat diminished. The specification is detailed, and contains several multi-valve circuits embodying this principle.

SMOOTHING DIRECT CURRENT SUPPLY.

(*Convention date* (*U.S.A.*), *24th October*, 1924. *No.* 241,944.)

Some very broad claims are made in the above British Patent, granted to the Dubilier Condenser Company (1925), Limited, and H. W. Houck, for an arrangement of smoothing circuits in combination with a direct current supply for receiving sets. The smoothing circuit is shown in the accompanying illustration, and should be readily understood. The direct current mains are introduced at A and B, which are positive and negative respectively. Across the mains are two condensers C_1 and C_2 a centre point earth being taken at E. The two mains are then passed through chokes L_1 and L_2 arranged on a common core K_1, the two chokes then being shunted by a third condenser C_3, another choke L_3 being included in the negative lead, and another condenser C_4 being placed on the other side. The earth connection to the set is taken through a safety

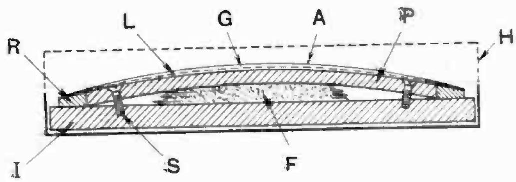


condenser C_5. The main supply is taken across X and Y, these representing respectively the positive and negative terminals of the smoothed output. A lower voltage for working the detector valve of the receiving system is derived from a series resistance R_1 and a by-pass condenser C_3. The filter system briefly described is a double π filter with a centre point earth to the integrating condenser, and chokes in both limbs of the first π and a choke in one limb of the second π.

A CAPACITY MICROPHONE.

(*Application date*, *21st December*, 1925. *No.* 263,300.)

A very interesting form of condenser microphone is described by P. G. A. H. Voight in the above British Patent Specification, the accompanying illustration showing one form of the microphone. The two electrodes consist of a heavy rigid plate and a very light moving foil area. The heavy electrode consists of a metal plate P which is clamped with felt or similar material F, the plate being screwed to another insulating plate I by screws S. Alternatively, it may consist of some non-resonant substance coated with a metallic film if the substance happens to be non-conducting. The other electrode consists of very thin aluminium foil A, about 1/2000 inch thick. This is separated from the back electrode P by a layer of air G which acts as a cushion. In order to prevent any short circuit occurring between the two a layer of silk L is interposed. The specification states that the mass of the aluminium foil, together with the resiliency of the gas layer, produces a resonant



system, but with foil of the thickness stated, and an air cushion of about 1/32 inch the natural frequency is of the order of 16,000 cycles per second. Another interesting point is that as the air cushion is likely to be of varying thickness the diaphragm will not be resonant as a whole, but tend to have various natural frequencies at various parts of the surface. Referring again to the illustration, in one modification of the invention the foil is stuck to a ring R which, in turn, is fixed to the insulating plate I. In order to protect the microphone from stray capacity effects a metal screen is used, as at H. Another modification of the invention lies in the use of two foil areas instead of one foil and a rigid back plate. The specification, while short, is exceedingly detailed, and contains a great amount of useful information and minor points regarding the successful operation of the microphone. For example, it is stated that the air must be perfectly dry to prevent leakage, and means can be provided for sealing the air into the microphone, or else allowing it to be free and providing calcium chloride for absorbing the moisture. It is stated that silent working can frequently be obtained by connecting a battery between the electrodes. It is stated that this probably causes the moisture to decompose, thus restoring the insulation between the two electrodes.

AN INTERESTING RECEIVER.

(*Application date* (*U.S.A.*), *26th May*, 1925. *No.* 252,691.)

A rather interesting receiver is described in the above British Patent by the Hazeltine Corporation and W. A. MacDonald. The invention broadly consists in using a multi-valve radio frequency amplifier with an untuned aerial circuit, the aerial being connected to the grid of the valve, an untuned circuit being connected to the input of this valve. In the accompanying illustration an aerial A is connected to the grid G of the valve V_4, the anode circuit of which contains the primary L_1 of a transformer L_1 L_2, the secondary being tuned by a condenser C_1. This secondary is connected to the grid of the first ordinary amplifying valve V_1. The valve V_2 acts as another radio frequency amplifier, and is coupled to the valve V_1 by means of a neutralised centre-tapped secondary transformer. A similar transformer is connected to the output of

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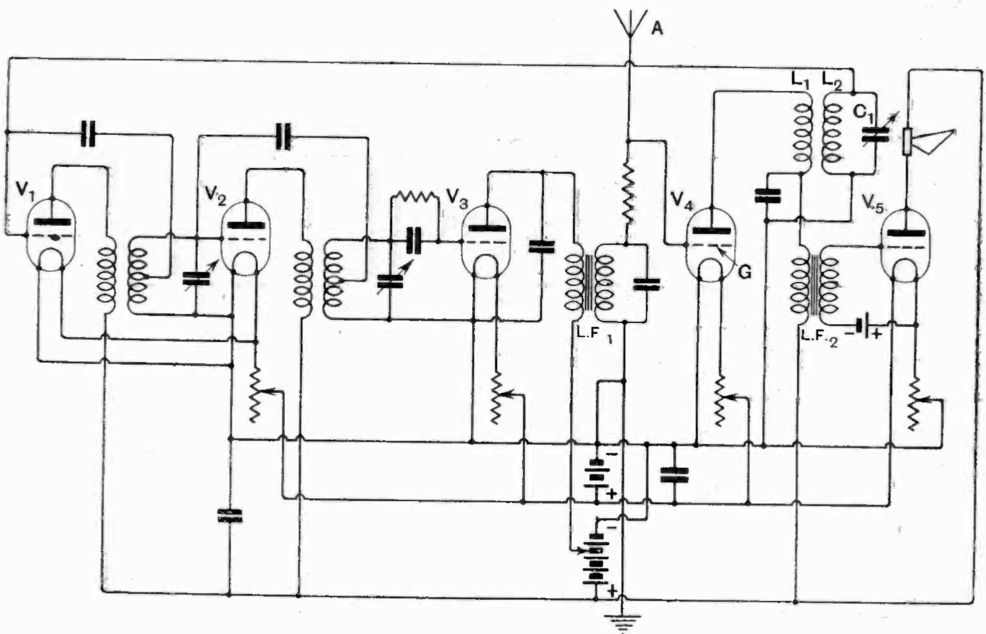
the valve V_2, and the amplified oscillations occurring across the secondary of this are rectified by the valve V_3. As this part of the circuit is entirely normal it will not be described in detail. The output of the detector valve contains a low frequency transformer LF_1. The secondary of this transformer is connected to earth and the grid of the valve V_4, which also acts as a low frequency amplifier, the low frequency output of which is coupled by another transformer LF_2 to the grid filament circuit of the last valve V_5 which operates the loud-speaker. In order to prevent high frequency oscillations being short-circuited to earth through the shunt capacity across the first low frequency transformer a resistance R is inserted as shown, *i.e.*, in series with the grid connection to the special dual amplifying valve V_4. This resistance R will not materially affect the magnitude of the low frequency voltages applied to the grid of the valve V_4, but will effectively prevent the transference of any high frequency currents from the aerial. It is claimed that this circuit while oscillating will radiate only to a very small extent, because the high frequency oscillations can only pass to the aerial through the inter-electrode capacity of the valve V_4, and, moreover, since the aerial circuit is substantially aperiodic it will not tend to radiate very strongly.



ELIMINATING FADING.

(*Convention date* (*U.S.A.*), 19*th June*, 1925. *No.* 253,934.)

Marconi's Wireless Telegraph Company Limited, and H. O. Peterson also describe in the above British Patent a method of eliminating the effect of fading by using a number of receiving stations arranged along a line joining the main desired point of reception and the transmitter. It is pointed out that at various distances along this line the received signal voltages from the earth wave and the reflected wave will be of varying magnitude and varying phase. The invention consists in receiving signals from a number of stations and combining the whole in a common output circuit. One form of the invention is shown in the accompanying diagram. Three stations are shown at A, B, and C, the arrangement of the apparatus being identical in each case. The stations are connected by two lines L_1, and L_2. The arrangement of the system of the station A only will be described briefly, since the others are similar. The aerial circuit comprises a capacity C_1 and an inductance L_1. This is coupled to a modulating system of a known type, consisting of valves V_1 and V_2 and balanced input and output circuits, which will not be described in detail, since readers are no doubt familiar with this modulating system, it being similar to that used in side band transmission. The output from the valve arrangement V_1 and V_2 is transferred to a valve V_3, which acts as a detector, and is provided with a low frequency output transformer T, feeding the line L_2. A source of audio frequency, or radio frequency modulated at an audio frequency is shown at G, and feeds the line L_1 through a transformer H. The line L_1 is connected through a transformer K, the secondary of which is connected to earth and the mid point of the modulating system. Normally, when no signal voltages are being received by the aerial system the audio frequency component derived from the line L_1 will give rise to no audio frequency currents in the valve V_3, and therefore

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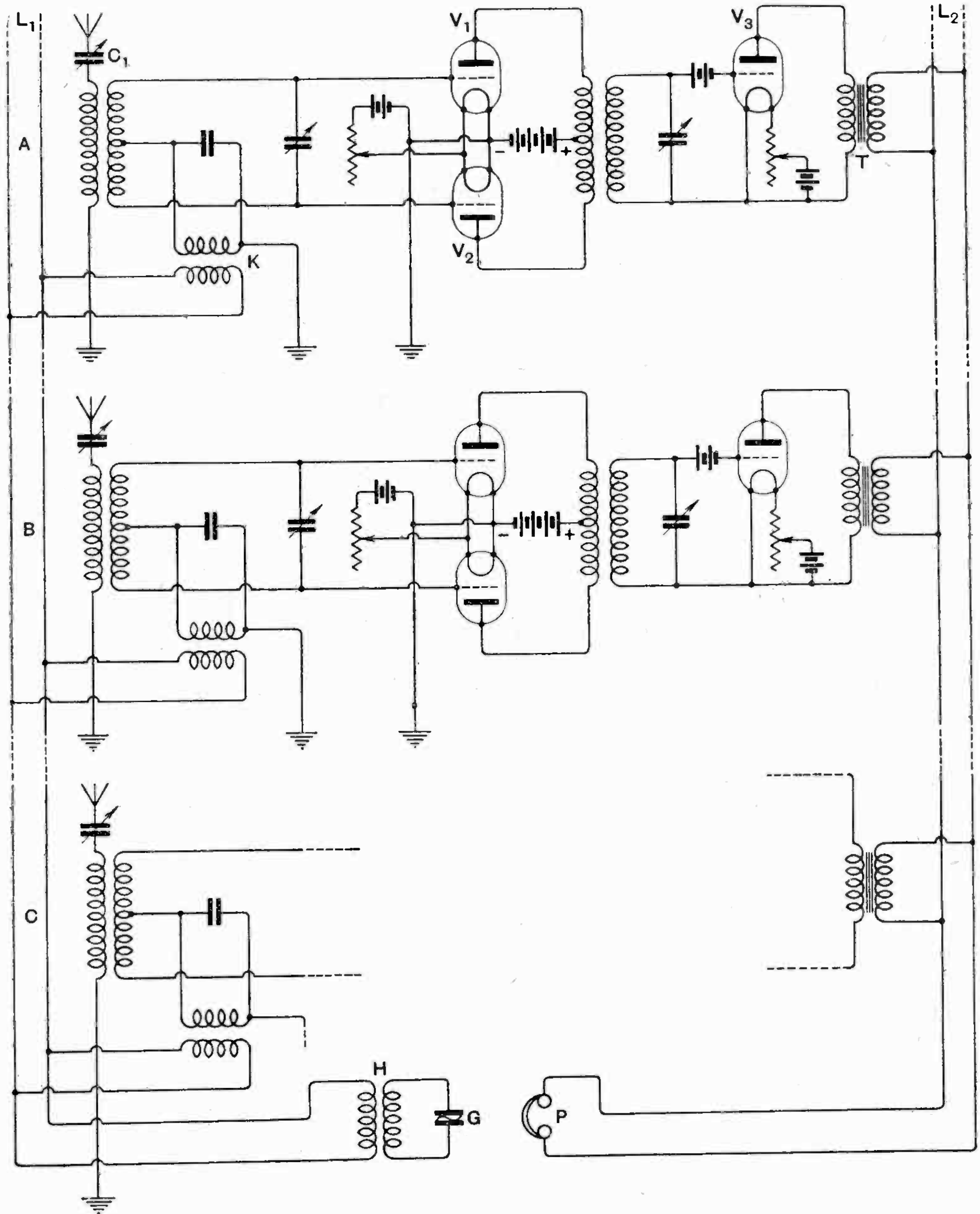
no effect will be obtained in the line L_2 which feeds the telephones *P*. When, however, signal voltages arrive their effect is combined with the audio frequency component fed from the line L_1, with the result that voltages are produced across the line L_2, and operate the telephones *P*. The same sequence of operations occurs with all stations feeding the line L_2, with the result that a fairly constant signal is obtained in the telephones *P*, which is derived from the various signal voltages as they occur along the line. The greater the number of stations used, which, of course must be suitably disposed, the more constant will be the reception.



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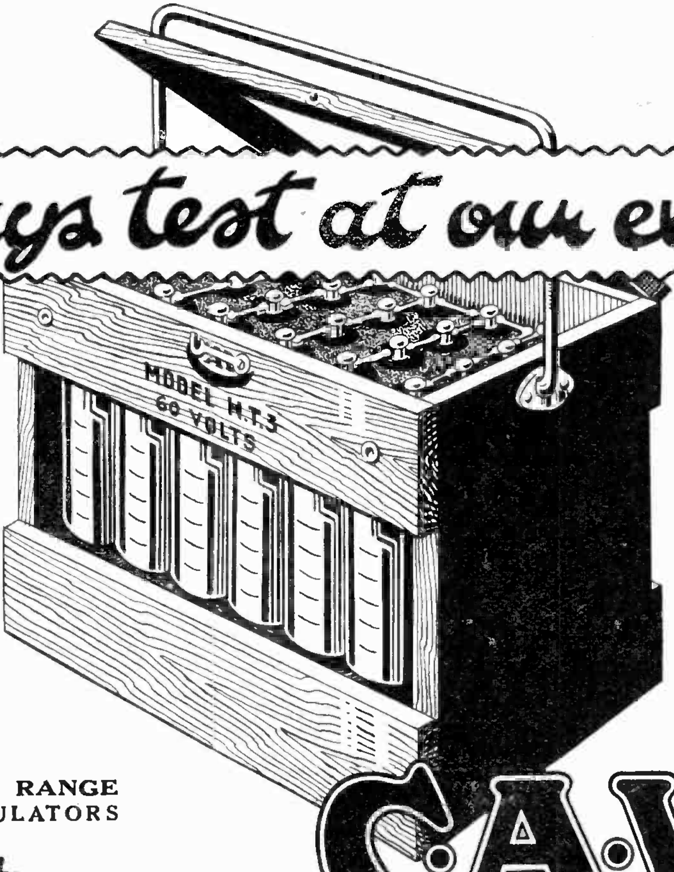

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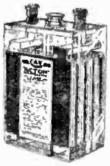

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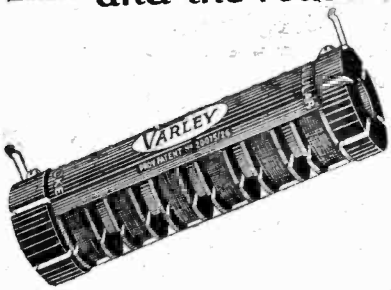

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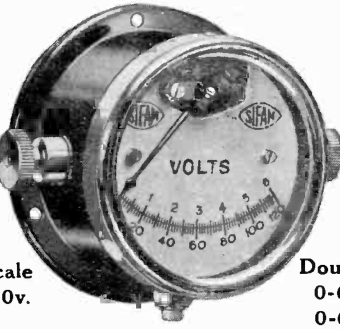

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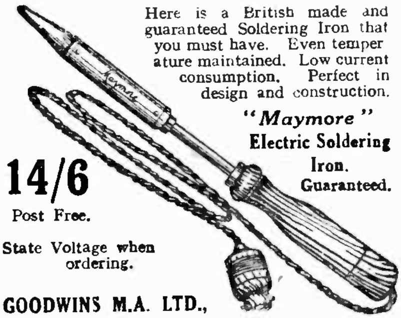

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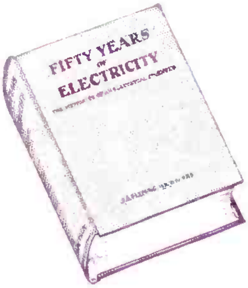

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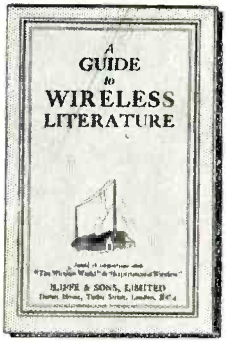

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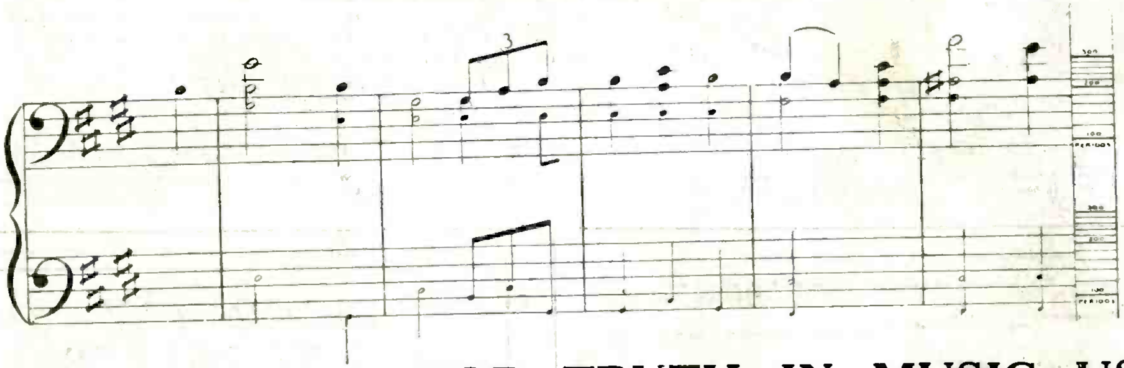

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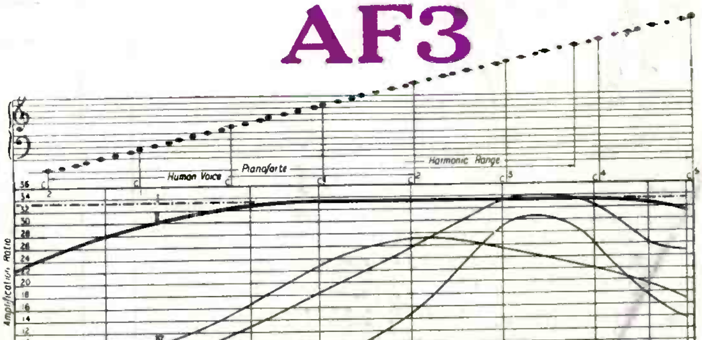

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