THE

WIRELESS ENGINEER

AND

EXPERIMENTAL WIRELESS

NUMBER 102 VOLUME IX MARCH 1932

A JOURNAL OF

RADIO RESEARCH

AND

PROGRESS

2/6
NET

PUBLISHED BY
ILIFFE & SONS LTD.
DORSET HOUSE TUDOR STREET LONDON E.C.4

WIRELESS

DIRECTION FINDING

and DIRECTIONAL RECEPTION

By R. KEEN, B.Eng. (Hons.)

SECOND EDITION: (1927)

This volume deals with the principles of the subject and the constructional details of direction finding installations, and includes some information concerning aircraft installation. It describes the principles of Direction and Position Finding in this country in such a way that the subject may be grasped easily by engineers tackling this field of wireless work for the first time. Numerous photographs and diagrams are included.

Price 21/- net **By post 21/9**

From leading booksellers or direct from the publishers:

ILIFFE & SONS LIMITED,
DORSET HOUSE, TUDOR STREET, LONDON, E.C.4

W.E.2.

RADIO DATA CHARTS

A SERIES OF ABACS

providing most of the essential Data required in Receiver Design.

By R. T. BEATTY, M.A., B.E., D.Sc.

Reprinted from "The Wireless World."
(1930)

"Radio Data Charts" provide designers of wireless apparatus with a ready and convenient means of solving problems without having recourse to complicated formulæ and mathematics.

By the use of the charts it is possible to tackle all the more familiar problems in radio receiver design; such as, for example, finding the relationship between inductance capacity and frequency, and working out the design of high frequency transformers. All keen experimenters will appreciate this helpful book.

Price 4/6 net. By post 4/10.

(39 CHARTS and more than 50 Diagrams.)

From all leading booksellers or direct from the Publishers.
Published from the Offices of "THE WIRELESS WORLD."

ILIFFE & SONS LTD., Dorset House, Tudor St., London, E.C.4

W.E.11

CLAUDE LYONS, LTD

Head Offices : 76 OLDHALL STREET, LIVERPOOL
London Offices : 40 BUCKINGHAM GATE, S.W. 1

TYPE 403—D SIGNAL GENERATOR,

DUAL RANGE ; 200-600 PLUS 750-2,250 METRES.

For obtaining rapidly and with extreme precision laboratory measurements of Radio Receiver characteristics, a properly designed Standard-Signal Generator may well be described as an essential.

With such a piece of apparatus the research engineer may very rapidly check either new designs or random specimens from the packing room stock-shelves, and assure himself as to their Sensitivity, Selectivity and "Fidelity."

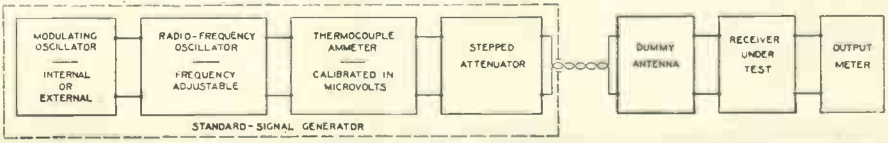
The circuit below gives the fundamental set-up of the necessary apparatus required for critically checking up on the above three essentials of modern receiver design. For the external Power Oscillator we recommend our Type 377-B L.F. Oscillator or our new Type 513-B. Beat-Frequency Oscillator, 10 C.P.S. to 10,000 C.P.S. The Dummy-Antenna is supplied gratis with the 403-D Standard-Signal Generator. The Output Meter may be one of several types we are in a position to deliver ex-stock, the choice being dependent upon the receiver impedance and wattage output characteristics. The special test-leads and plugs are also supplied gratis with the 403-D.

The other main application of the Standard-Signal Generator is its employment on accurate Field-Intensity Measurements. For this class of work a somewhat different set-up is necessary. We shall be pleased to supply full details on application, and also to mail a treatise on Field-Intensity Measurements, which includes a reproduction of an "aerial survey" by the Fairchild Corporation.

Some of our important and well-known British Manufacturers who have found our Type 403-D Standard-Signal Generators of the greatest service in their laboratories include :

The B.T.-H. Co., Ltd. ; Columbia Graphophone Co., Ltd. ; Dept. of Scientific and Industrial Research ; E. K. Cole, Ltd. ; E.&.M.I. Ltd. ; Ferranti Ltd. ; The G.E. Co., Ltd. ; The G.P.O. ; The Gramophone Co., Ltd. ("H.M.V.") ; Kolster-Brandes Ltd. ; L. McMichael, Ltd. ; The National Physical Laboratory ; The Plessey Company Ltd. ; Pye Radio, Ltd. ; R.G.D. (Birmingham) ; Ultra Electric, Ltd. ; Etc.

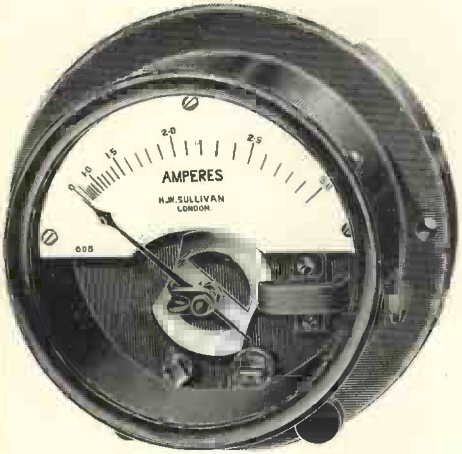
" There must be a reason ! "



HOT-WIRE AMMETERS

FOR ALL FREQUENCIES AND RANGES.

These instruments are constructed in a variety of sizes, from 2¼″ dial to 9″ dial, and in insulating or metal cases.



Freedom from zero creep, from temperature error and from frequency error when used at the higher radio frequencies, are features for which, together with open scale "law" and compact, self-contained design, even for high current ranges, the SULLIVAN hot-wire meter is noted.

As used by—

The British Admiralty, The Air Ministry,
The War Office, Marconi's W/T Co.,
and the leading wireless companies of the world.

PRICES ON APPLICATION.

H. W. SULLIVAN, LTD.
Leo St., London, S.E.15

T.C.C.

—wherever absolute dependability and accuracy are demanded . . . . .

Here is shown an H.F. Condenser at .0002 mfd. to pass 30 amps. at 300 metres plus 10,000 volts D.C.

THE Post Office—the Admiralty—the B.B.C.—the big Cable Companies, and Radio Technicians throughout the World place absolute confidence in T.C.C. In every sphere of the electrical industry will be found T.C.C. because always they live up to their 25 years' reputation for downright reliability and accuracy. That condenser *you* need—for whatever purpose—will be found in the extensive T.C.C. range. Consult T.C.C., the World's premier condenser manufacturers.

T.C.C.
ALL-BRITISH
CONDENSERS

The Telegraph Condenser Co., Ltd., Wales Farm Road, N. Acton, W.3

The WIRELESS ENGINEER
and EXPERIMENTAL WIRELESS

A Journal of Radio Research & Progress

Editor
HUGH S. POCOCK

Technical Editor
Prof. G. W. O. HOWE D.Sc., M.I.E.E.

VOL. IX No. 102

MARCH 1932

CONTENTS

Published Monthly on the first of each month
SUBSCRIPTIONS Home and Abroad: One Year 32/-, 6 Months, 16/-. Single Copies, 2/8 post free

Editorial Offices
116-117 FLEET STREET, LONDON, E.C.4 Telephone: City 9472 (5 lines)

Advertising and Publishing Offices
DORSET HOUSE, TUDOR STREET, LONDON, E.C. 4
Telegrams: "Experiwyr Fleet London" Telephone: City 2846 (15 lines)

Branch Offices

COVENTRY	BIRMINGHAM	MANCHESTER	GLASGOW
19, Hertford Street	Guildhall Bldgs. Navigation St.	260 Deansgate	26B Renfield Street, C2.
Telegrams: "Cyclist, Coventry."	Telegrams: "Autopress, Birmingham"	Telegrams: "Iliffe, Manchester"	Telegrams: "Iliffe, Glasgow"
Telephone: 5210 Coventry	Telephone: Midland 2970 (3 lines)	Telephone: City 8970 (4 lines)	Telephone: Central 4857

The Editor invites the submission of articles with a view to publication. Contributions which are not exclusive should be so described when submitted. MSS. should be addressed to the Editor, "The Wireless Engineer and Experimental Wireless," Dorset House, Tudor Street, London, E.C.4. Especial care should be taken as to the legibility of MSS. including mathematical work.

THE
WIRELESS
ENGINEER
AND
EXPERIMENTAL WIRELESS

VOL. IX. MARCH, 1932. NO. 102.

The Field in the Immediate Neighbourhood of a Transmitting Aerial.

TWO papers on this subject have appeared almost simultaneously; one, entitled "Measurements in the neighbourhood of a broadcast transmitter," by Hans Zickendraht, dated 28th November, 1931, was published in the January number of *Helvetica Physica Acta*; the other, entitled "The spreading of electromagnetic waves from a Hertzian dipole," by Ratcliffe, Vedy and Wilkins, dated 23rd November, 1931, was read and discussed before the Wireless Section of the Institution of Electrical Engineers on 3rd February. Both papers give a theoretical discussion of the nature of the field in the immediate neighbourhood of the aerial, followed by a description of experiments designed to check the accuracy of the theoretical formulae. In the former case the work was done at Basle and in the latter case at Cambridge. In both cases an oscillating dipole forms the starting point of the theoretical development.

The Five Components of the Field.

If two equal and opposite electric charges, $+q$ and $-q$ are separated by a distance h, as in Fig. 1, the electric field E_3 at a point such as P, that is, the force on a unit positive charge at P, is downwards and equal to $\frac{qh}{r_1^3}$. If we agree to call E positive when it is directed upwards, and assume that h is very small compared with r, then $E_3 = -qh/r^3$. If q or h follows a sine law, then E_3 will do the same, but not quite in phase because of the time taken for any change in q or h to be communicated to P. The effect at P will lag behind the cause at the dipole by an angle $2\pi(r/\lambda)$. This angle $2\pi r/\lambda$ occurs very frequently in all the formulae and Zickendraht calls it z. Hence if $q = \hat{q} \sin \omega t$, $E_3 = -\frac{\hat{q}h}{r^3} \sin(\omega t - z)$. We have used the suffix 3 to indicate that this component of the total electric force varies inversely as the cube of the distance.

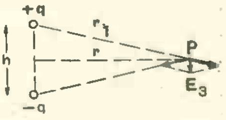


Fig. 1

If we assume that the variation of the charges is due to a current i in a wire joining them, the current being reckoned positive when flowing upwards, then $i = \frac{1}{c} dq/dt$ and if $q = \hat{q} \sin \omega t$, then $i = \frac{\omega \hat{q}}{c} \cos \omega t$, where $c = 3 \times 10^{10}$ and is introduced because q and i are expressed in electrostatic and electromagnetic units respectively. Putting $\hat{\imath} = \frac{\omega\hat{q}}{c}$ we have $E_3 = -\frac{c\hat{\imath}h}{\omega r_1{}^3}\sin(\omega t - z)$.

A current i flowing in the conductor of length h would produce at the point P a magnetic force $H_2 = \frac{2i}{r}\cdot\frac{h/2}{r_1}$. If the distance r is very small compared with h, this reduces to $\frac{2i}{r}$, the well-known formula for the field near an infinitely long wire, whereas if h is small compared with r, it reduces to $\frac{ih}{r^2}$. If the current varies according to a cosine law, H_2 will do the same, but with a lag of $2\pi r/\lambda = z$. Hence if r is large,

$$H_2 = \frac{\hat{\imath}h}{r^2}\cos(\omega t - z)$$

where H is reckoned positive when directed away from us at any point such as P on the right-hand side of the dipole.

Now, although these elementary considerations have given us correctly two of the five components which a complete analysis of the problem shows to be present in the electromagnetic field, it must be pointed out that we tacitly assumed the propagation of the fields through space at the velocity c and that we ignored the fact that this implies the interaction of electric and magnetic fields. The current in the wire of length h must be accompanied by displacement currents in the surrounding medium which we neglected. The complete solution of the problem, which forms the basis of both the papers referred to above, shows that the resultant electric field at any point in the equatorial plane through the centre of the dipole may be analysed into three components, varying inversely as the first, second, and third powers of the distance, whilst the resultant magnetic field contains only two components varying inversely as the first and second powers of the distance. Why the other electric field is not associated with an inverse third power magnetic field, although it involves the retarded moment of the dipole and consequently also the velocity c, has always seemed to us somewhat of a mystery. The formulae for the resultant fields are:

$$E = E_3 + E_2 + E_1$$

$$= \hat{\imath}h\left\{-\frac{c}{\omega r^3}\sin(\omega t - z) - \frac{1}{r^2}\cos(\omega t - z) + \frac{\omega}{cr}\sin(\omega t - z)\right\}$$

$$H = H_2 + H_1 = \hat{\imath}h\left\{\frac{1}{r^2}\cos(\omega t - z) - \frac{\omega}{cr}\sin(\omega t - z)\right\}$$

An aerial consisting of a vertical wire with a large capacity at the top and earthed at the lower end may be regarded as the upper half of a giant dipole, and the point P in Fig. 1 would be a point on the ground. The formulae just given for E and H assume that the distance r is large compared with h, and by working at a long wavelength this can still be the case, although r may be but a fraction of a wavelength. If one approached very close to the aerial the formulae would not hold, for the aerial would be equivalent to an infinitely long conductor and would produce a magnetic force inversely proportional to the distance, and not to the square of the distance; similarly the electric force would be approximately constant anywhere directly under the aerial. In both the papers experimental results are given, but the Swiss measurements were made on an actual broadcast transmitter under very unfavourable conditions and the results are consequently only very approximate as a check on the theory; but the Cambridge experiments were done with great care under favourable conditions, using a wavelength of 1,000 metres and an aerial only 4.15 metres high. It was possible, therefore, to work at distances down to about 10 metres, that is, 0.01 of the wavelength, before the difference between r and r_1 (Fig. 1) became appreciable. It is satisfactory to know that the experiments confirmed the theory within the limits of accuracy of the tests, that the time-honoured method of regarding the aerial as a dipole, with an effective height above the ground equal to the total height reduced in the ratio of the average current along it to that at the foot, gives strictly accurate results, and that an earthed aerial can be regarded as the upper half of a dipole, its image in the earth acting as the lower half. The authors seem rather surprised at this last result, and suggest in the concluding paragraphs of this paper that theory indicates a different result. This concluding part of their paper is not so satisfactory as the earlier portion. We are not sure that it is correct to think of the image as due to the reflection at the surface of the ground of the direct wave from the aerial. The image forms a part of the radiating system. The current distribution, the magnetic field, and the electric field approximate to those of a dipole of which the earth's surface forms the equatorial plane, the degree of approximation depending on the nature of the ground.

The authors give, however, a very complete and satisfactory explanation of some hitherto unexplained peculiarities which Barfield and Munro found in measuring the effect on the main field of the re-radiation from a tuned receiving aerial, a problem which was discussed by Rüdenberg in 1908 (*Ann. d. Physik*, Vol. 25, p. 464).

In order to illustrate the manner in which the magnitude and phase of each of the five component fields vary within the first wavelength, we shall take as an example an aerial 5 metres high, assumed to have such a large capacity at the top that it may be regarded as the upper half of a dipole with $h = 10$ metres. We shall assume that it is energised at a frequency of 300,000 ($\lambda = 1{,}000$ metres) and that the current in the aerial has a maximum value of 1 ampere (0.1 e.m. unit). At the moment of zero current the charge will be

$$\hat{\imath}\, c/\omega = 0.1 \times 3 \times 10^{10}/2\pi \times 3 \times 10^{5} = 10^{4}/2\pi.$$

If this is assumed to be concentrated at the top of the aerial it is easily seen that the electric field at the foot of the aerial is 0.01275 units. By substituting the values of i, h, and ω in the formulae for the component fields we obtain the following results :—

Distance from aerial in metres.	E_3.	$E_3 r^3$.	H_2 and E_2.	$H_2 r^2$.	H_1 and E_1.	$H_1 r$
1	0.012	0.012	2×10^{-3}	0.2×10^{-2}	—	—
10	1.14×10^{-3}	1.14	8.95×10^{-5}	0.895×10^{-2}	5.6×10^{-6}	5.6×10^{-5}
100	1.59×10^{-6}	1.59	1×10^{-6}	1×10^{-2}	6.28×10^{-7}	6.28×10^{-5}
500	1.275×10^{-8}	1.59	4×10^{-8}	1×10^{-2}	1.26×10^{-7}	6.28×10^{-5}
1000	1.59×10^{-9}	1.59	1×10^{-8}	1×10^{-2}	6.28×10^{-8}	6.28×10^{-5}

In forming the products $E_3 r^3$, etc., r has been expressed in metres. For distances of 10 metres and less the aerial can no longer be regarded as a point source, and E_3 and H_2 have been calculated from the quasi-static formulae, taking into account the extent of the dipole. This accounts for the fact that $E_3 r^3$, $E_2 r^2$ and $E_1 r$ are no longer constant for distances of 10 and 1 metre, measured, of course, to the foot of the aerial. By using a small aerial and a long wave-length, however, one approaches within $\lambda/20$ of the aerial before this effect becomes appreciable.

The phases of the various components at any moment change at the same rate as one recedes from the aerial, all going through an angle 2π in the distance λ, but leaving the aerial with the phases shown in the following diagram.

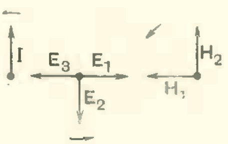


Fig. 2.

This shows the phases of the various fields at the aerial when the aerial current is a positive maximum ; it also represents the phases 1,000 metres away at the same moment. For other distances the vectors must be retarded by a suitable amount ; thus, at a distance of $\lambda/4$ from the aerial, they must all be rotated 90° in a clockwise direction.

Close to the aerial E_3 and H_2 are the predominant fields, the former being 90° ahead of the current and the latter in phase with it. As the distance increases, E_1 first counteracts E_3, leaving E_2, and then E_1 becomes predominant. The electric field at a great distance is therefore in opposite phase to what one would have expected from the field near the aerial. The magnetic field undergoes a somewhat similar change but only through 90°, so bringing the magnetic and electric fields, which left the aerial in approximate quadrature, into phase or phase opposition, depending on the convention adopted as to sign.

By compounding the component forces in the above table, the following results are obtained for the resultant values of E and H.

Distance from aerial in metres.	E.	H.
10	1.14×10^{-3}	0.9×10^{-4}
100	1.39×10^{-6}	1.18×10^{-6}
500	1.2×10^{-7}	1.32×10^{-7}
1000	6.2×10^{-8}	6.4×10^{-8}

These are plotted to logarithmic scales in Fig. 3. Over the first 10 metres E is roughly ten times H, but at 100 metres they have become approximately equal, H being slightly greater than E from about 110 metres, the two curves gradually merging into one.

G. W. O. H.

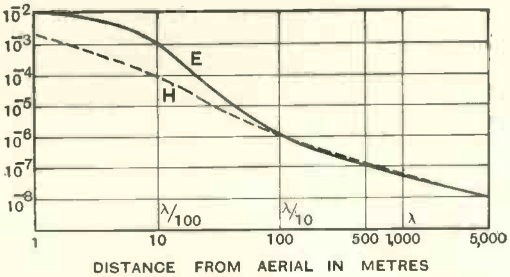
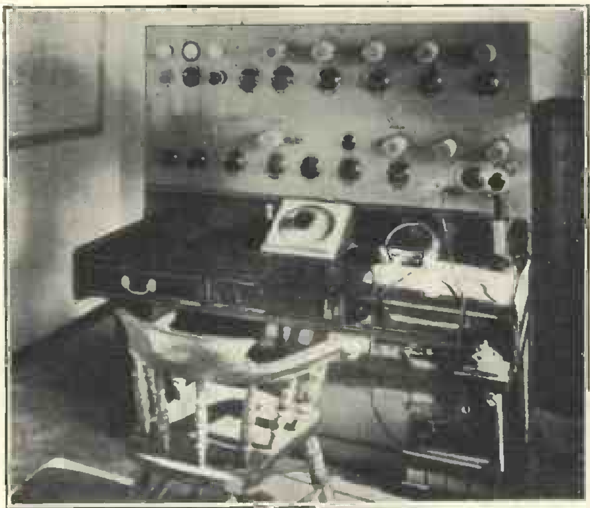


Fig. 3.—*Full line—amplitude of electric field in e.s. units. Dotted line—amplitude of magnetic field in e.m. units.*

Radio Guidance for Aircraft.

Marconi-Adcock Station at Pulham.

To overcome "night effects" in the radio location of aircraft the first Marconi-Adcock D.F. station has recently been erected at Pulham, Norfolk. The system consists of four wooden masts, one at each corner of a square, each containing a vertical aerial. At its base each aerial is connected to a horizontal feeder, which is contained in, but insulated from, a copper tube earthed at frequent intervals along its length. Each feeder is led to a normal radiogoniometer and receiver. Being completely screened, it is impossible for the horizontal members of the aerial system to be influenced by abnormally polarised waves. The receiver itself is also very completely screened to prevent any direct pick-up in the numerous circuits.



The upper photograph shows the Marconi-Adcock D/F receiver installed at Pulham. The general view seen in the lower picture clearly shows the disposition of the four wooden masts carrying the vertical aerials.

Distortion in Screen-grid Valves.*

With Special Reference to the Variable Conductance Type.

By R. O. Carter, M.Sc., A.C.G.I., D.I.C,

(Research Laboratories of the General Electric Co., Ltd., Wembley, England.)

WHILE conditions for distortionless working of low-frequency amplifiers have been studied carefully for many years, with consequent improvement in the standard of quality of radio sets, distortion in the high-frequency valves has received scant attention, and has generally been assumed to be negligibly small. In fact, provided a set was not made too selective, either by the use of reaction or by the use of too efficient coupling coils, it was usually taken for granted that no distortion would take place, and attention was turned to considerations of stability and high amplification.

Within the last twelve months, however, a considerable amount of work has been done on this subject, which has shown that, under certain conditions, the distortion introduced may be quite large, especially when the gain of the amplifier is controlled by variation of grid bias on the H.F. valves. As this is probably in many ways the best method of gain control, it is highly desirable to know the conditions which must be fulfilled if quality is to be unimpaired.

The present article describes some measurements made to determine the limits for distortionless operation both of a standard type of screen-grid high-frequency amplifying valve and also of a special type, commonly known as the "Variable-Mu Tetrode," developed expressly for use as a variable-bias gain control amplifier. This was first introduced by Ballantine and Snow, in America.†

Causes of Distortion.

Before proceeding farther, it is worth while to consider the conditions which produce distortion in a high-frequency amplifier, since they differ in several important respects from the low-frequency case.

Suppose that an unmodulated sinusoidal radio-frequency voltage is applied to the grid of a valve having a grid volt-anode current curve of the form shown in Fig. 1(*a*), and suppose that the valve is biassed to the point *A*. Suppose further that there is no load in the anode circuit. Then since the curve is not linear, a certain amount of anode-bend rectification will take place, and the mean anode current will rise. The wave-form of the anode current will be of the form shown in Fig. 1(*c*). After subtracting the D.C. component (the mean anode current) this wave contains a fundamental of the same frequency as the input frequency, and a range of harmonics of this frequency. Being a dissymmetrical wave,

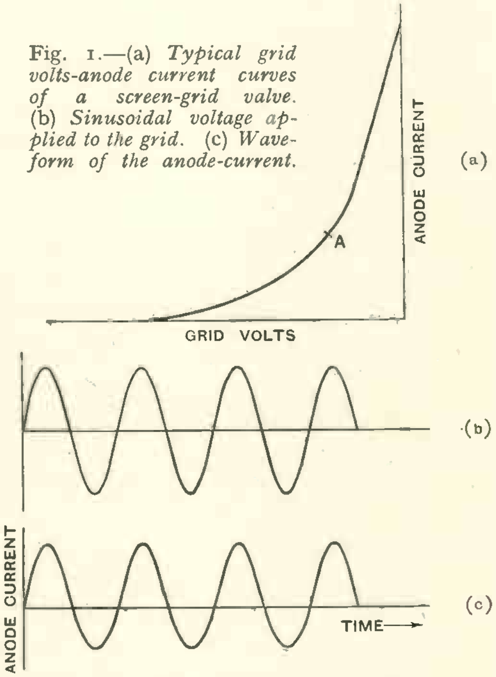


Fig. 1.—(a) *Typical grid volts-anode current curves of a screen-grid valve.* (b) *Sinusoidal voltage applied to the grid.* (c) *Wave-form of the anode-current.*

---

* M.S. received by the Editor, September, 1931.

† Proc. *I.R.E.*, December, 1930.

it will, as a rule, contain a large second harmonic. Now the impedance at resonance of a tuned anode or transformer coupling will, in the case of a screen-grid valve, be generally much less than the anode A.C. resistance of the valve itself, so that the magnitude and wave-form of the anode current will be inappreciably affected by the load in the anode circuit. Whereas, however, a current of the resonant frequency will develop quite a large voltage across the tuned circuit, currents of a frequency far removed from resonance will produce practically no voltage since the impedance of the tuned circuit at these frequencies is so low. Expressed more simply, we may say that the selectivity of the tuned coupling circuit prevents all components of the anode current except those at or near the resonant frequency from being amplified. Consequently, the voltage applied to the grid of the next valve will be practically a pure sine wave of the same frequency as the input to the first valve. As the amplitude of the input is increased, however, the anode current will sweep over more of the curved part of the characteristic, and the distortion of the anode *current* waveform will be greater. Provided the input is fairly small, the effect will be merely to increase the harmonics in the anode current, and the fundamental component (and therefore he voltage applied to the next valve) will still be proportional to the input voltage, being, in fact, the same as if the characteristic were linear and had the same slope as the tangent at the operating point *A*. When the amplitude of the input is sufficient to sweep on to a part of the curve with a considerably steeper slope, the fundamental component of the anode current increases more rapidly than the input, and the relation between input voltage and output voltage ceases to be linear. Consequently the input-output curve of such a valve when working at a fixed bias point is of the form shown in Fig. 2. The input at which the curve ceases to be linear will depend on the rapidity of the curvature of the static characteristic, being less the greater this curvature is.

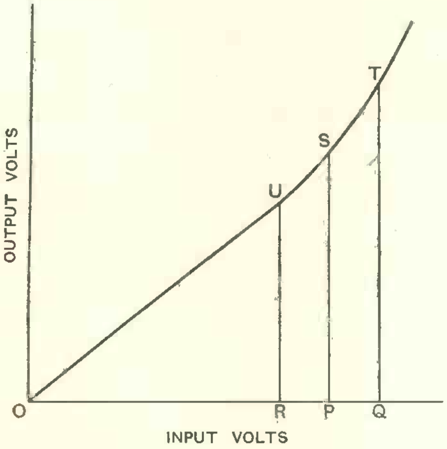


Fig. 2.

If now the input radio-frequency is modulated at audio-frequency, as shown in Fig. 3(*a*), the anode current wave-form will be of the form shown in Fig. 3(*b*).

This wave will contain :—

(*a*) a D.C. component,

(*b*) an A.C. component of the modulation audio-frequency together with a range of harmonics,

(*c*) a component of the input radio-frequency with side-bands,

(*d*) a range of harmonics of the input radio-frequency, each with side-bands.

The only components which are amplified by the tuned coupling are those in (*c*), all the others being too far removed from resonance. It would be perfectly possible to plot out the anode current wave-form from the static curve, to analyse this in a Fourier series, and retain the desired terms. For a large input, the sum of these desired components (which is the wave-form of the voltage applied to the grid of the next valve) is of the form shown in Fig. 3(*c*). Such an analysis is, however, very laborious, and it is impossible by this method rapidly to determine distortion limits or to compare different valves.

Considering for a moment the input wave of Fig. 3(*a*) as a radio-frequency, the amplitude of which is varying, it will be seen that as the amplitude varies, the operating point on the curve of Fig. 2 will move up and down. For example, if the unmodulated input amplitude is *OP*, and it is modulated, say, 20 per cent., the peak amplitude will be *OQ*, and the "trough" amplitude *OR*. Since the selectivity of the tuned anode-circuit is low enough to amplify the side-bands without appreciable distortion, the output voltage will follow the input amplitude in the same way as when taking the "semi-static" curve of Fig. 2. Since it is fashionable nowadays to talk in terms of "decrement" instead of selectivity, we may say alternatively that the decrement of the tuned circuit is low enough for it to respond faithfully to change of amplitude, provided the change is not more rapid than the highest audio-frequency the set is designed to pass. From the curve of Fig. 2 we can therefore plot the output voltage wave for any desired input and depth of modulation. It will be seen that the shape of the "envelope" of the output wave of Fig. 3(*c*) is no longer sinusoidal; this means that the carrier is modulated with harmonics of the input modulation frequency as well as with the fundamental.

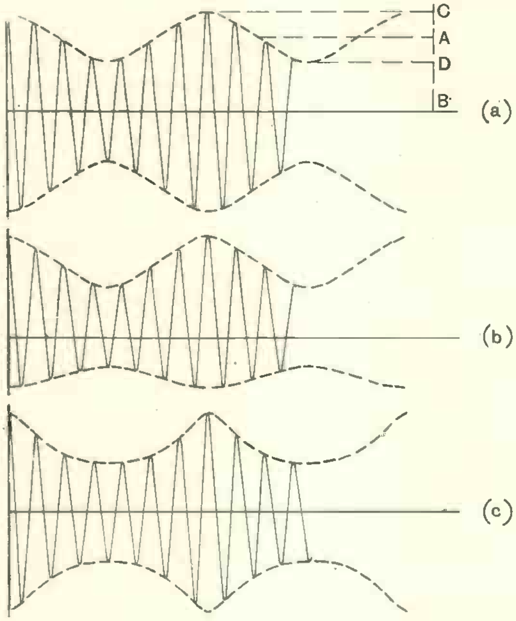


Fig. 3.

But, in addition, it will be seen that the percentage modulation has increased. The percentage modulation of the input wave of Fig. 3(*a*) is given by $\frac{CD}{2AB} \times 100$. The percentage modulation of the output wave is rather a vague term, since harmonics of the original modulation frequency are introduced. The percentage modulation of the fundamental could be found by analysing the envelope into its fundamental and harmonics. Provided the curvature of the input-output curve is not rapid, however, the deviation of the envelope from sinusoidal will not be great, and the depth of modulation can be taken as approximately equal to

$$\frac{\text{amplitude at peak minus amplitude at trough}}{2 \times \text{amplitude with unmodulated input}} \times 100$$

Referring to Fig. 2, this is seen to be equal to

$$\frac{QT - RU}{2PS} \times 100$$

If the input percentage modulation is m and the output percentage as defined above is m', then the percentage rise in modulation is

$$\frac{m' - m}{m} \times 100$$

This rise must not be allowed to become large, since, quite apart from the harmonics introduced in the envelope, which will reappear in the audio output of the detector, the distortion of the detector itself will be increased when the depth of modulation is increased, unless the detector is perfectly linear.

The amount of harmonics due both to envelope distortion and detector distortion for a given amount of modulation rise will depend on the characteristic of the actual valve and of the detector, but it is suggested as a rough rule for comparison between different valves that a rise of 20 per cent. in depth of modulation would usually correspond to quite small envelope distortion, and very little increase in detector distortion, except at very large peaks of modulation (80 per cent. or more).

More specifically, a rise from an initial value of 20 per cent. to a value of 24 per cent. (as defined above) has been taken as the tentative limit of operation and basis of comparison.

It might be objected that, since the envelope is no longer sinusoidal, the mean value of the radio-frequency amplitude will be greater than the amplitude for unmodulated input, and hence the modulation rise as calculated above is too high. This is quite correct, but the error will only be appreciable when the envelope departs considerably from sinusoidal; but in this case the distortion is worse, so that there is no disadvantage in obtaining a pessimistic result. The true mean radio-frequency amplitude is in any case an indefinite quantity which can only be determined by analysing the envelope in each individual case. Since the object is rather to determine a rapidly calculable criterion of distortion, the definition adopted appears to be the most serviceable.

A short description of the method of measuring the input-output curves of a valve may perhaps be of interest. The valve under test was mounted in a screened box, the anode circuit being screened from the grid circuit, so that the feedback was reduced to the small amount between anode and grid in the valve itself. The input was supplied from a small radio-frequency oscillator, the output of which was passed through a tapped resistance, the value of which was accurately known at radio-frequency. The current passing through the resistance was measured by a thermo couple. By connecting grid and cathode across a known amount of resistance, and suitably adjusting the current, any desired voltage could be applied to the grid. For large input voltages the resistance method had to be discarded, and a tuned circuit was used instead. The voltage was then measured by a valve voltmeter. The output voltage of the valve under test was also measured by a valve voltmeter. Measurements were not taken above the input level at which grid-current started, so that distortion of the input wave when using the tuned circuit was not present. It was not thought worth while to investigate conditions when grid current flowed, since the distortion will usually be bad in any case, and the amplification is reduced, due to the damping of the tuned circuits. The distortion limit may therefore be regarded as determined by the modulation rise or by grid current, whichever commences first.

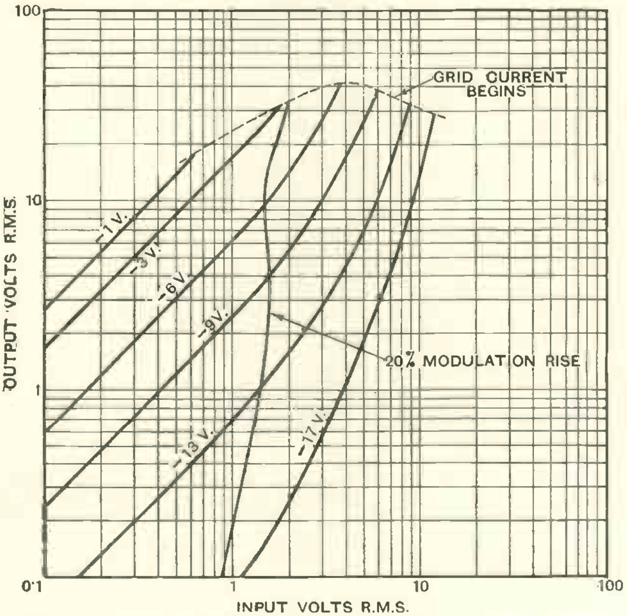


Fig. 4.—*Input-output characteristics of M.S.4 valve. Curves taken at* $V_a = 200$, $V_s = 60$ *volts.*

The results of a series of measurements of this type made on an Osram M.S.4 and V.M.S.4 (the latter a variable-conductance screen-grid valve) are shown on Fig. 4 and 5. The 20 per cent. " modulation rise " point on each curve was determined by trial and error in the manner explained in connection with Fig. 2.

The curves of mutual conductance against grid bias for the same valves are shown on Fig. 6. It will be seen that the rate of change of mutual conductance of the V.M.S.4 is much less than that of the M.S.4, which means that the curvature of its grid volts-anode current curve is less. This is the reason for its greater input-handling capacity, especially at large values of grid bias. As the amplification is nearly proportional to the mutual conductance, the reduction of amplification due to any increase of grid bias is given by the corresponding reduction of mutual conductance.

For example, in the case of a set having a single H.F. stage using a V.M.S.4 valve, suppose a weak station gives suitable distortionless volume when the grid bias on the V.M.S.4 is − 1 volt. If now a strong station is tuned in which gives ten times the radio-frequency voltage on the grid of the first valve, the amplification (and therefore the mutual conductance) must be reduced to a tenth. To obtain this the grid bias must be increased to 12 volts, which reduces the mutual conductance from 1000 micromhos to

100 micromhos. It is useful to plot a curve showing the mutual conductance required at any value of R.F. input to give a standard output to the detector valve for any particular intervalve coupling.

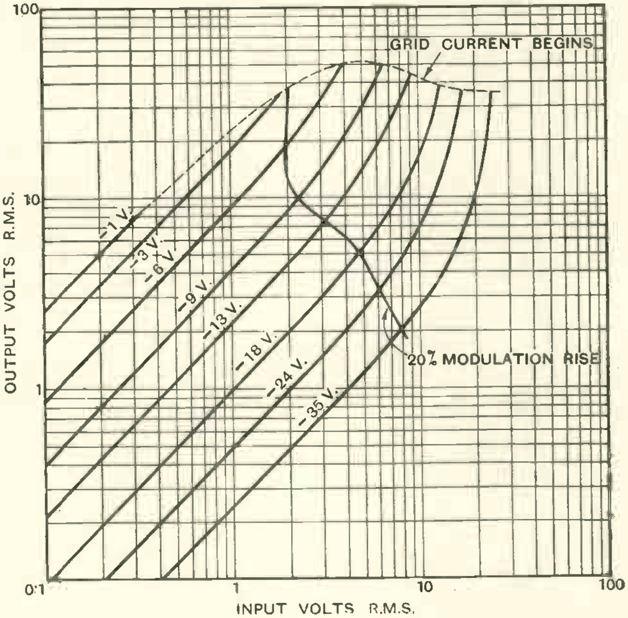


Fig. 5.—*Input-output characteristics of V.M.S.4 and M.S.4 valves. Curves taken at* $V_a = 200$, $V_s = 60$ volts.

For example, if a detector requires an input of 2.0 volts R.F. for efficient operation, and if the transformer coupling the H.F. valve to the detector has a voltage ratio at resonance of 1.6, and the effective impedance of the primary circuit with the secondary tuned and the detector connected and operating is 10,000 ohms, then the input to the H.F. valve to give this required output is given by

$$V_1 = \frac{2.0 \times 10^6}{10{,}000 \times 1.6 \times g_a} = \frac{125}{g_a}$$

where g_a is the mutual conductance in micromhos, V_1 is the R.F. input voltage to the grid of the H.F. valve, or $g_a = \frac{125}{V_1}$.

The value of g_a for any value of V_1 for these conditions is given by the line *AB* on Fig. 7. The values of input for 20 per cent. modulation rise, obtained from Figs. 4 and 5, are also shown. These enable a fair comparison between the valves to be made. It will be seen that for a mutual conductance of 10 micromhos the input to the V.M.S.4 may be as much as 7.8 volts before 20 per cent. modulation rise is reached, whereas the M.S.4 reaches the same limit at 0.93 volts.

A still better comparison is obtained by considering the practical case represented by the line *AB*. This cuts the curve for the V.M.S.4 at a value of 6.4 volts input, at which point the mutual conductance is 20 micromhos. Hence, provided a signal does not produce a greater voltage than 6.4 on the grid of the H.F. valve, the amplification can always be adjusted by a suitable choice of grid bias, to give the correct output to the detector valve for efficient operation, without thereby approaching the distortion limit in the H.F. valve. The line *AB* will be seen to cut the curve for the M.S.4 at a value of 1.6 volts input, and therefore if this valve were used in the set, this is the maximum input which could be handled without distortion. This is fairly high for an ordinary screen-grid valve, and many types will not handle more than a fraction of this input. As it is quite usual to obtain about three or four volts of R.F. on the first valve, from a strong local station, even with fairly loose aerial coupling and a not very efficient aerial tuning coil, it will be seen that the M.S.4 would not, in these circumstances, provide quite sufficient range of control, and the local station could not be received without distortion, unless the input from the aerial was reduced. If the grid bias on the H.F. valve is left at its normal value, and volume control obtained by controlling the aerial input, the amplifier is always working at full gain, and consequently amplifier noises which are introduced in the first valve always receive full amplification, and are as troublesome on the local station as on a weak station. This difficulty is usually circumvented by using a combination of both methods—generally in the form of an aerial input control mechanically coupled to a grid bias potentiometer.

By using the V.M.S.4 the aerial input control can be dispensed with, and all the necessary gain control obtained by varying the grid bias. The actual limiting input will vary slightly with the type of coupling to the detector and with the input required by the detector for efficient operation ; but unless the coupling is very inefficient the limit will generally exceed 5 volts, which is sufficient for most localities and aerial systems.

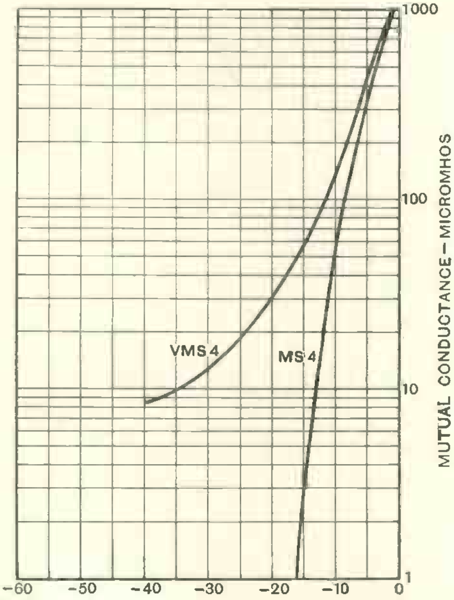


Fig. 6.—*Curves of mutual conductance against grid bias for V.M.S.4 and M.S.4 valves.*

Where two H.F. stages are employed, the input to both stages must be considered, in order to determine the limit of operation. The input to the first valve can be expressed as follows :

$V = \frac{V_1 K}{g_a}$ where V_1 is the input to the 2nd valve.

V is the input to the 1st valve.

K is a constant depending on the coupling transformer, and calculated as previously explained.

As an example, suppose that two similar valves are used in the H.F. stages, and that common grid bias is employed, and suppose that K is equal to 40. Suppose the characteristics of the second H.F. valve couplings and the detector are the same as in the previous case considered.

Then since

$$V_1 = \frac{125}{g_a},\ V = \frac{40 \times 125}{g_a^2} = \frac{5000}{g_a^2}$$

Plotting V against g_a, we obtain the line CD. This cuts the distortion curve for the V.M.S.4 at a value of g_a of 31 micromhos. Since the second valve does not distort until a value of 20 micromhos is reached, the first valve will determine the maximum aerial input which can be handled. In the case of the M.S.4 it will be seen that the second valve determines the limit, since AB cuts the curve for the M.S.4, at a greater value of g_a than does CD. As the V.M.S.4 will handle such a large input, the first valve will as a rule determine the distortion limit in sets using this type. Actually, slightly more input could be handled by grading the grid bias, so that the first valve received rather more than the second. The distortion analysis for any such case can easily be made with the aid of Figs. 4, 5 and 6. A description of the performance of the V.M.S.4 in a typical set has been given in a previous article (*Wireless World*, 9th and 16th Sept., 1931). As a matter of interest, the static grid volts-anode current curves for the V.M.S.4 and the M.S.4 are also shown (Fig. 7). They indicate clearly the smaller curvature of the V.M.S.4 characteristic, which is obtained at the expense of increased anode current. If the same initial mutual conductance is to be maintained, however, this is unavoidable.

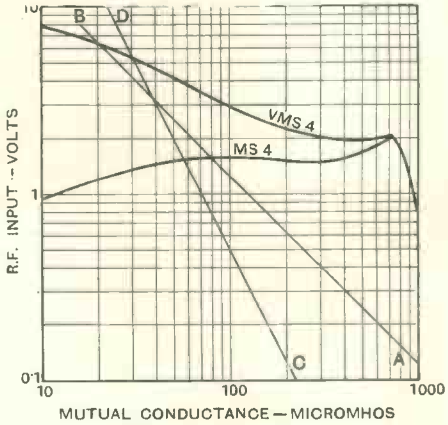


Fig. 7.—*Curves showing input to give 20 per cent. modulation rise for V.M.S.4 and M.S.4 valves.*

The V.M.S.4 is very similar in construction to the M.S.4, except as regards its control grid. In the ordinary type of valve, the wires of the control grid are uniformly spaced ; in the V.M.S.4, some of the wires are more widely spaced than the remainder. The effect of this can be seen from Fig. 8. Considering only one pair of widely spaced wires to be present, the valve may be regarded as made up of two valves in parallel—one having a normal characteristic, such as shown by the curve *AB* and the other having very short electrodes (cathode, grid and anode) and widely spaced control-grid wires. This will have a characteristic such as shown in *CD*, the tailing effect being due to the wide spacing of the grid and the small anode current to the shortness of the electrodes. The two in parallel give the combined curve *EF*. By suitably adjusting the number and separation of the widely spaced wires, the characteristic can be made to conform to almost any requirements. If the " tailing " effect on the characteristic is increased, it is possible to obtain a valve which will handle almost any desired amplitude of input ; but the grid bias required becomes very large. In a practical design, a compromise must necessarily be made.

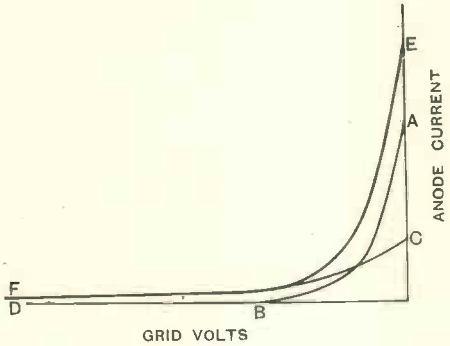


Fig. 8.

BOOK REVIEW.

A Dictionary of Electrical Terms.

By S. R. Roget, M.A., A.M.Inst.C.E., A.M.I.E.E.

Pp. vii + 396. Pitman & Sons, 1931. 7s. 6d. net.

This useful publication, now in its second edition, aims rather at giving explanations than definitions, although, as might be expected where so wide a field is covered, many of the explanations err on the side of brevity. In his preface the author eschews any idea of standardising the meanings attaching to various expressions in current electrical use, though he admits the need for official sanction of some sort for the multiplicity of terms which are being added almost daily to our vocabulary. It is beyond question that too many technical terms are being introduced without prior enquiry as to whether any meaning is already attached to them. In this respect the present volume is likely to render useful service.

Being primarily compiled to cover the whole field of electrical engineering, some omissions from the wireless standpoint are perhaps inevitable. There is, for instance, no mention of *Band-Stop Filters*, nor of the *Stenode*. *Decoupling* is not mentioned, and the reader is not referred to *Anti-Motorboating Device*, under which head it is dealt with. The system of cross-referencing is peculiar ; thus, under *Anode Circuit, Tuned*, we were referred to *Tuned Plate Circuit*, on consulting which we were further referred to *Tuned Anode Circuit*. Again, *Lightning, Ball*, instructs the reader to consult *Ball Lightning*, only to be told to see *Globular Lightning*. A merry game, but out of place in a serious work.

On the whole the wireless "explanations" convey an impression that they might have been considerably improved had they been submitted to more careful editing. Thus, the formulae quoted under *Reactance* and *Impedance* are only true for series combinations ; the definition of *Atom* omits the electrons at the nucleus, while *Hertzian Waves* are not, as stated, limited to those above 10 metres for wireless communication. One or two misprints were noted. For instance, under *Impedance Triangle* the word "inductance" should read "impedance," while *Moullin* should appear as here spelled. Under *Natural Frequency* the formula should be $1/2\pi\sqrt{LC}$.

Apart from such blemishes there is much that is instructive and useful in this book. For instance, the explanation of *Potential Difference* should prove of interest to the beginner, while the author's distinction between *Selectance* and *Selectivity* should give thought to those who are curious in such subtleties.

W. A. B.

On the Influence of Valve Resistance in Oscillation Generators.*

By N. W. McLachlan, D.Sc., M.I.E.E., F.Inst.P.

1. Triodes.

THE frequency of a triode oscillator operating on a family of infinite linear characteristics without grid current is given by the well-known expression† :—

$$\omega^2 = (1/LC)\{1 + R/\rho) - [CR + L/\rho - gM)]^2/4LC\} \quad .. \quad (1)$$

this being derived from the differential equation

$$\{D^2 + D\,CR + L/\rho - gM]/LC + (1 + R/\rho)\}i = 0 \quad .. \quad (2)$$

When the D term is zero the oscillation can just be maintained once it is started, provided there is no additional energy loss. Under this condition the amplitude is constant and the frequency is given by,

$$\omega^2 = (1/LC)(1 + R/\rho) \quad .. \quad .. \quad (3)$$

When the D term is negative the oscillation builds up at a frequency determined by (1), and its value is slightly less than that given by (3).

It is almost impossible in practice to satisfy the constant amplitude condition rigorously, and one usually depends upon slight curvature of the characteristics, *i.e.*, variation in ρ and g to limit the extent of the oscillation. Consequently the value of the D term squared is not zero, and the frequency is altered slightly from that given by (3).

Instead of solving a differential equation, the bare maintenance condition and the corresponding frequency can be found by putting the circuital impedance in the form $a + jb$. Equating a and b to zero gives the required result. In this way we find $\omega^2 = 1/LC(1 + R/\rho)$, *i.e.*, (3) above. But in this expression for ω^2 the square of the D term is missing, since by hypothesis (bare maintenance condition) it is zero. Moreover, formulae deduced by the $a + jb$ method do not fully indicate the influence of variations of ρ on the frequency.

Suppose an oscillator is adjusted to

$$\omega^2 = (1/LC)(1 + R/\rho)$$

and $\phi = 0 = (CR + L/\rho - gM)$
$= CR + 1/\rho(L - \mu M)$

what happens if ρ varies? When ρ increases ϕ becomes positive and the oscillation ceases, whilst a reduction in ρ makes ϕ negative with a consequent growth in amplitude and alteration in frequency.

When the oscillation is powerful, and appreciable curvature of the valve characteristics is involved, expressions (1) and (2) are inapplicable.

By using the $a + jb$ method Prof. E. Mallett‡ has shown that (1) reduces to $\omega^2 = 1/LC$ when an inductance $L' = L$ is connected between the anode and the tuned circuit. From this he concludes that the frequency is independent of the valve. As we saw in the preceding case, $\omega^2 = 1/LC$ only holds when $\phi = 0$. When this is not the case, due to variation in ρ, the expression for ω^2 contains additional terms which are not divulged by the $a + jb$ analysis. With $L' = L$, ϕ_1 becomes $CR(\rho + R') + L - \mu M$. Clearly, if $\phi_1 = 0$, an increase in ρ will extinguish oscillation, whilst a decrease in ρ will alter the frequency due to the missing terms in the frequency equation not being zero.

In Prof. Mallett's experimental results there are two discrepancies. (*a*) Insertion of resistance in the oscillatory circuit, in the absence of L', lowered the frequency instead of raising it, as would be expected from (3); (*b*) the value of L' for constant frequency was not L but 0.18 L. As we indicated above, the valve must be set to $\phi = 0$ for (*a*) and (*b*) to be realised. Since addition of resistance did not suppress oscillation, ϕ must have been negative, and the oscillator was not working under the conditions postulated in Prof. Mallett's analysis. It

---

* MS. received by the Editor, August, 1931.

† Throughout the paper the formulae are written so that the negative mutual inductance M and the negative resistance ρ (Sections 2, 3, 4, 5) are taken numerically positive.

‡ *Journal I.E.E.*, Vol. 68, p. 578, 1930.

follows, therefore, that deductions from his frequency equation must be erroneous, and no *general* proof has been given that an inductance L' will counteract variation in the valve parameters. What Prof. Mallett finds is this:—When an inductance $L' = 0.18L$ is connected between the anode and tuned circuit of a certain valve oscillator working with appreciable variation in ρ throughout a cycle, a variation in anode voltage from 270 to 300 causes no change in frequency. It appears that curvature of the characteristics had something to do with the problem. If an impedance large in comparison with ρ were used in place of $0.18L$, the influence of variation in ρ would be reduced considerably. This, however, was not Prof. Mallett's method of solution.

2. Screened-grid Valves.

The case of the screened-grid valve as an oscillator is of particular interest to me, since it is used in my modulated C.W. wavemeter.* In (1) if $M = 0$ and ρ is negative† we obtain for the circuit of Fig. 1 *a, b,*

$$\omega^2 = [1/LC - 1/4(R/L + 1/C\rho)^2]^{\frac{1}{2}} \quad .. \quad (4)$$

an expression which holds when the oscillation is building up on an infinite ideal characteristic.

The maintenance condition is $R/L = 1/C\rho$ which gives

$$\omega^2 = (1/LC - R^2/L^2) \quad .. \quad .. \quad (5)$$

an *expression* which is quite independent of the valve resistance. One might be tempted to infer that the frequency is now independent of the valve. Hence the latter can be removed without effect !

But since $R/L = 1/C\rho$ we have

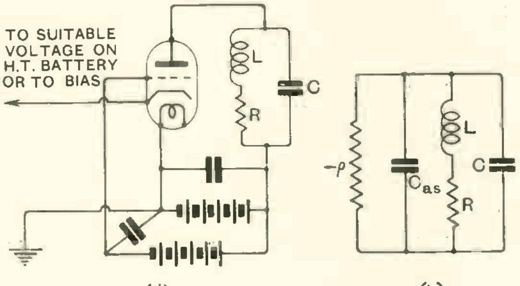
$$\omega^2 = (1/LC - 1/C^2\rho^2) \quad .. \quad .. \quad (6)$$

and also from (1)

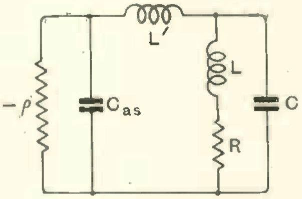
$$\omega^2 = (1/LC)(1 - R/\rho) \quad .. \quad .. \quad (7)$$

expressions very much dependent on the valve. In other words, (5) covers a critical condition which can be expressed in three ways, one of which masks a physical reality.

Coming now to Prof. Mallett's frequency stabiliser, applied to the s.g. valve, we have the circuit‡ shown in Fig. 1c. It will be seen that the anode to s.g. capacity is not now directly across the tuned circuit, and its effective value is reduced by L'.



(a) (b)



(c)

Fig. 1 (*a, b*).—*Diagrammatic representation of screen-grid valve and oscillating circuit.* C_{as} = *anode to screen-grid capacity.*

Fig. 1 (*c*).—*As at* (*a*) *and* (*b*) *but with auxiliary inductance* L' *between anode and oscillating circuit.*

There is a collection of impedances, all of which influence the frequency of the combination. On the basis of an ideal characteristic I fail to see how the inductance L', or any *reactive* impedance for that matter, can possibly prevent a variation in frequency if the *resistance* ρ alters. If ρ increases arithmetically the oscillation stops, whilst decrease is accompanied by growth at a different frequency. In practice, where the amplitude is limited by curvature of the characteristic, the equations of a linear system are inapplicable. Consequently, as with the triode, frequency stabilisation cannot be proved by the $a + jb$ method. Also in all probability the inductance with

---

* Specification 310,915, Feb. 3rd, 1928. *Wireless World*, p. 107, Jan. 23rd, 1929, and *Journal Scientific Instruments*, Vol. 6, p. 327, Oct., 1929. The application of the s.g. valve to reduce damping in an auxiliary circuit is described in 304,631, Oct. 20th, 1927, and as a variable frequency oscillator of constant output in 304,369 of even date.

† When substituting in the formulae, ρ is to be expressed as a positive quantity. Increase in ρ is to be taken in a numerical sense.

‡ This is identical with Fig. 5 in my specification 304,369 of Oct. 20th, 1927, but no mention is made of frequency stabilisation.

its self-capacity would oscillate at a frequency higher than that of the main circuit, as in my modulated C.W. wavemeter.

Data relating to a screened-grid valve low-frequency oscillator will illustrate the limitation of expressions (4) and (6) and indicate the influence of valve and circuital resistance on the frequency.

Example 1.

Inductance of air-core coil $(L) = 1.05$ henry.

A.C. resistance of air-core coil at 1000 ~

$$(R) = 50 \text{ ohms.}$$

Total capacity $(C) = 2.22 \times 10^{-8}$ farad.

Dynamic resistance $(L/CR) = 8.9 \times 10^5$ ohms.

Valve resistance on straight portion of characteristic $(\rho) = 1.75 \times 10^4$ ohms.

Oscillator frequency checked by tuning fork $(f) = 1000$ ~.

Frequency calculated from (4)

$$(f_1) = 1020 \sim$$

The frequency calculated from (4) is 20 cycles too high, this being due to working on the curved portion of the valve characteristic. One cannot make deductions from expression (4), since it only applies when the characteristic is straight and ρ is constant. The additional 20 cycles is not due to alteration in the anode to screen-grid capacity of the valve. From (4) the capacity to make $f = 1000$ cycles is 2.31×10^{-8} farad, *i.e.*, the valve capacity would have to increase to 900 $\mu\mu$F or about 60 times its normal value !

Example 2.

Influence of increase in ρ.

As in Example 1, but

$$C = 2.391 \times 10^{-8} \text{ farad.}$$

$$\rho = 1.44 \times 10^5 \text{ ohms.}$$

Actual $f = 1000$ ~

from (4) $f_1 = 1003$ ~ which is more accurate than the value in Example 1.

Example 3.

Near critical value of ρ.

As in Example 1, but

$$C = 2.41 \times 10^{-8} \text{ farad.}$$

$$\rho > 8 \times 10^5 \text{ ohms.}$$

from (4) $f = 1000$ ~ which is correct and very nearly equal to $1/2\pi(1/LC)^{\frac{1}{2}}$.

As ρ is increased (4) becomes more accurate, until very near the critical condition it is accurate. The wave form is purest here, since the characteristic is linear.

Example 4.

Influence of ρ on the natural frequency of a coil.

Inductance of air-core coil $(L) = 1$ henry.

Self-capacity of air-core coil $(C_s) = 82 \times 10^{-12}$ farad.

Additional capacity of valve and leads $= 18 \times 10^{-12}$ farad.

Natural frequency of coil with valve filament unlighted. $f_0 = 1.59 \times 10^4$ cycles.

Frequency during oscillation $f_1 = 8.45 \times 10^3$ cycles.

This shows quite clearly that the valve resistance reduces the frequency.

Example 5.

Influence of adding resistance to the coil.

As in Example 1, but

Added resistance = 2000 ohms, which caused a *decrease* in frequency of about 15 cycles.

When a resistance R is added to the condenser arm, and that in the coil arm is *negligible in comparison*, the frequency is given by*

$$\omega^2 = (1 - R/\rho)^{-2}\{1/LC - 1/4(R/L + 1/C\rho)^2\} \quad .. \quad (8),$$

and the condition for bare maintenance is

$$R/L = 1/C\rho \text{ or } \rho = L/CR \text{ as before.}$$

Example 6.

Influence of resistance in series with condenser. With $C = 2.22 \times 10^{-8}$ farad, $f = 1000$ cycles, as in Example 1. When 1000 ohms was added to condenser arm, *f increased* and the value of C for 1000 ~ was 2.39×10^{-8} farad. From (8) $f = 1025$ ~ which shows the error in the formula due to non-linearity of the characteristic. The effect of resistance in the condenser arm is opposite to that in the coil arm. It is much easier to conduct a resistance test in the condenser than in the coil arm, since in the former case no variation in the steady anode

---

* A corresponding alteration in expression (1) is required for a triode.

voltage occurs due to ohmic drop in the resistance.

Example 7.

Critical resistance in series with condenser. $C = 2.22 \times 10^{-8}$ farad, $f = 1000 \sim$ with no resistance. With a critical resistance of 2200 ohms $C = 2.73 \times 10^{-8}$ farad, $f = 1000 \sim$.

The actual frequency and that calculated from (8) is 1000 cycles. The critical resistance in the *coil* arm exceeds 2200 ohms, since for $1000 \sim$ the value of C is less than 2.73×10^{-8} farad. This will be clear from (4) and (8). Since $CR = L/\rho$ in this example, the product CR is constant for the coil and condenser cases. In finding the critical coil resistance it is preferable that the anode voltage should be maintained constant for purposes of comparison.

Example 8.

The value of ρ.

ρ can be found in two ways: (1) the slope of the static curve, (2) from the expression $\rho = L/CR$ at the critical condition. (1) gives $\rho = 1.73 \times 10^4$ ohms, whilst from Example (7) $\rho = 1.75 \times 10^4$ ohms, which shows a reasonable agreement.

Example 9.

Curvature of characteristic.

Fig. 2 shows: (1) the static characteristic. (2) the characteristic when the valve is oscillating vigorously. The mean value of i_a varies due to rectification arising from curvature of the characteristic, excepting at $v_a = 50$, when the effect balances out over the swing. The above tests were conducted with v_a near this point. It is probably the best working position on the curve, *i.e.*, when i_a does not alter due to oscillation. For purity of wave form the oscillation should be confined to the substantially linear portion of the characteristic. This means that L/CR must not be too large compared with ρ.

3. Summary of Experimental Results.

(*a*) Oscillation over large part of characteristic, *i.e.*, $L/CR >> \rho$.

(1) Valve resistance reduces natural frequency of circuit.

(2) Resistance in coil arm lowers frequency. f calculated from (4) is greater than actual value.

(3) Resistance in condenser arm raises frequency. f calculated from (8) is greater than actual value.

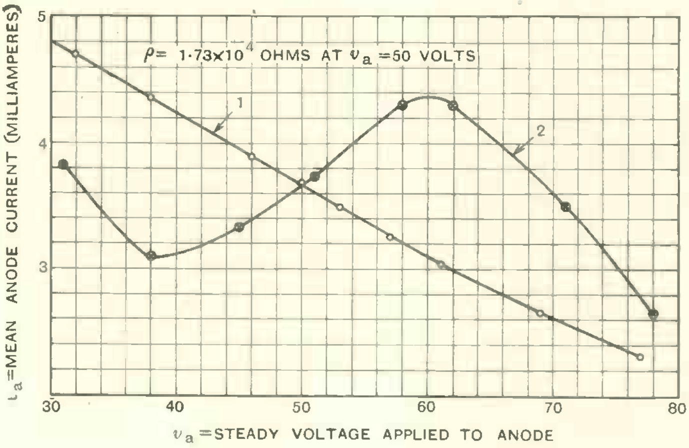


Fig. 2.—*Characteristic curves of screen-grid valve.*

(*b*) Oscillation over small portion of characteristic: near the critical condition, *i.e.*, $L/CR \doteq \rho$.

(4) As at 1, 2, and 3 above, but actual and calculated frequencies from (4) and (8) in agreement. This holds whether the critical condition is obtained by increase in R or in ρ.

(5) The value of ρ calculated from L/CR at the critical condition is substantially equal to that obtained from the static characteristic.

Doubtless a similar series of results would be obtained with a triode.

We have shown that the mathematical expressions are only valid when the valve operates near the critical condition. To preserve constant frequency a "prevention" course should be adopted. The coefficients of the LC circuit should not be affected by temperature variations, etc., the valve should oscillate feebly, small energy being supplied to an external circuit, and the filament and anode voltages should be kept constant. By making ρ and C large the correction term $1/C^2\rho^2$ can be made very small compared with $1/LC$ so that small variations in ρ are immaterial. These conditions conduce to purity of wave form. Possible variations in the anode to screen-grid capacity, due to change in geometrical form with time or electrostatic force, should be reduced to a minimum by using a valve with C_{as} about 2.5 $\mu\mu$F instead of the usual 15 $\mu\mu$F. For this purpose the Osram Lamp Co. kindly made special valves to my specification some years ago.*

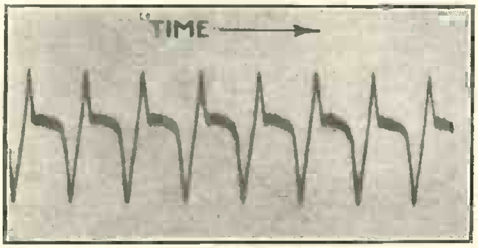


Fig. 3.—*Wave form of relaxation oscillation from s.g. valve and iron-cored choke.*

4. Extension of Frequency Range.

In a variable frequency oscillator it may be desirable to extend the range below that where capacity causes extinction, *i.e.*, $C > L/\rho R$; or above that where either the coil or valve resistance acts likewise, *i.e.*, $\rho > L/CR$ or $R > L/C\rho$. The desired result can be obtained with a given valve using a circuit design having a greater value of L/CR by reducing C and R or increasing L. When this is not feasible it is imperative to reduce ρ, and the reduction can be accomplished either statically or dynamically in a variety of ways, some of which will now be described.

Reduction in ρ Statically.

This can be achieved by (*a*) increasing the voltage of the control grid relative to the filament; (*b*) increasing the screen and anode volts; (*c*) putting a resistance in series with the anode and augmenting the battery voltage to maintain the anode voltage at its original value.† Fine adjustment can be obtained by altering the filament current. By a judicious combination of these methods ρ can be reduced to a low value. Several valves in parallel serve the same purpose, but the additional anode to screen-grid capacity is not always desirable especially at very short wavelengths.

If ρ_e is reduced, say by method *c*, so that $1/4(R/L + 1/C\rho_e)^2 > 1/LC$ but $L/CR > \rho_e$, the frequency is imaginary and the damping negative. Consequently the current grows but is forced to relax at the extremity of the characteristic where the above conditions are violated. Moreover, a relaxation oscillation or pulsation occurs. A typical case obtained four years ago with the secondary of an Ideal intervalve transformer, and taken from my specification 310,915, is shown in Fig. 3.

The frequency and the wave form can be varied considerably by altering the filament current. Using a coil and condenser, as ρ_e is decreased by adding resistance and increasing the battery voltage a point is reached when the pulsation is rendered visible by the milliammeter needle.

Reduction in ρ Dynamically.

In the method illustrated in Fig. 4a, the alternating voltage across r is superposed on the steady potential applied to the grid.‡ In Fig. 4b a resistance XYZ is connected in series with the oscillatory circuit, the battery voltage being identical for the anode and screen circuits. XYZ or the filament current is adjusted to obtain the correct working anode voltage. The condenser C_1 is of low impedance to the oscillations and by-passes YZ and the battery. Consequently the effective dynamic resistance is $\rho - XY$.

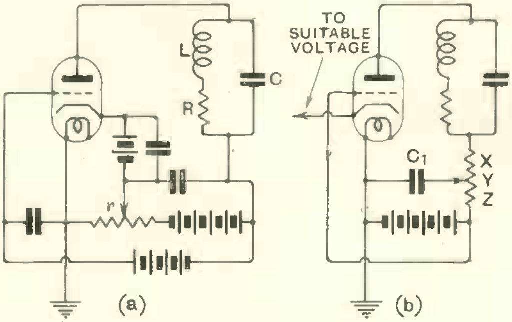


Fig. 4.—*Illustrating methods of reducing negative resistance of valve.*

---

* *Wireless World* and *J.S.I.*, *loc. cit.*

† Effective resistance is then $(\rho - r) . = \rho_e$.

‡ Owing to the resistance r, ρ_e is reduced so that this method also involves method (*b*).

Consider the family of characteristics shown in Fig. 5. The negative resistance decreases with increase in grid voltage, a property we have utilised above. If the grid voltage is increased when $v_a = 20$ and decreased when it is 70, the dynamic characteristic will take the form shown dotted, and its slope dv_a/di_a will be reduced appreciably. This really amounts to the grid and anode voltages being in opposition, and we get back to the triode case. Consequently any of the usual triode reaction methods can be used to reduce ρ. The only difference is that in the triode the static resistance is positive, whilst that of the s.g. valve is negative and therefore needs less reaction to give the necessary reduction in ρ.

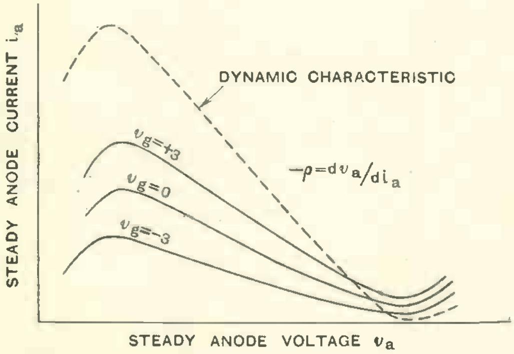


Fig. 5.—*Characteristics of screen-grid valve, showing influence of bias v_g on the control grid.*

From (1) the frequency is given by

$$\omega^2 = 1/LC(1 - R/\rho)$$

and the bare maintenance by

$$CR - (\mu M + L)/\rho = 0,$$

or $$\rho = (\mu M + L)/CR$$

or $$(\rho - \mu M/CR) = L/CR$$

Thus the influence of reaction is equivalent to increasing the inductance by μM or decreasing the valve resistance by

$$\mu M/CR = \rho\mu M/(\mu M + L)$$

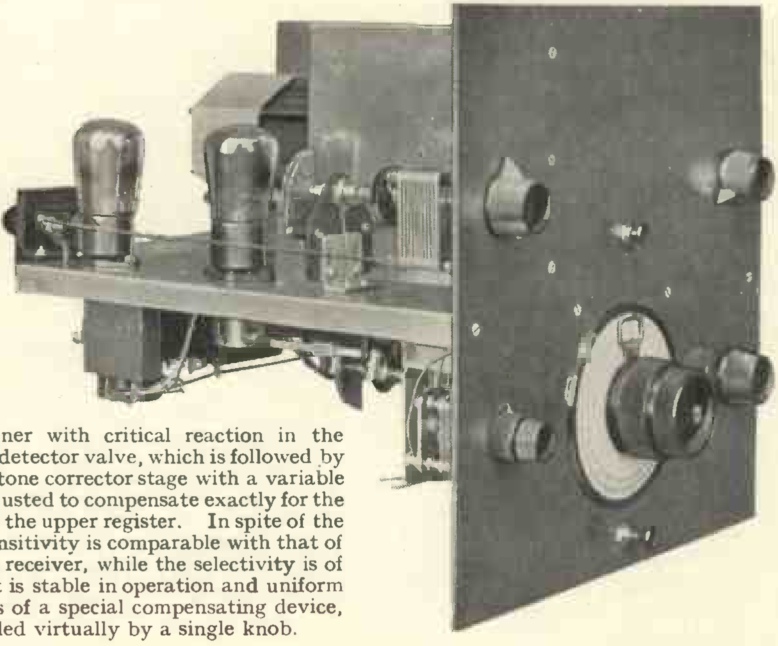
In general an appreciable reduction in ρ causes an alteration in frequency. This must be taken into consideration when employing any method whereby the desired reduction is effected. It is assumed throughout this paper that battery and other non-essential impedances are shunted by suitable condensers.

The Wireless World "Autotone"

High Circuit Selectivity with Tone Correction.

To meet the ever increasing congestion of the ether various methods of obtaining improved selectivity have been introduced. So far the superheterodyne and band pass filter have proved the most successful, but an alternative is provided by the principle of ultra selective tuning in conjunction with reaction followed by the tone correction in the L.F. amplifier to compensate for the inevitable attenuation of the higher audio frequencies.

This is the basic principle of the "Autotone" receiver recently described in our sister journal, "The Wireless World." A loose coupled tuner with critical reaction in the secondary circuit precedes the detector valve, which is followed by two L.F. stages and a special tone corrector stage with a variable characteristic which can be adjusted to compensate exactly for the loss of apparent modulation in the upper register. In spite of the absence of a H.F. stage the sensitivity is comparable with that of the average H.F.-det-pentode receiver, while the selectivity is of a much higher order. The set is stable in operation and uniform reaction is obtained by means of a special compensating device, so that the receiver is controlled virtually by a single knob.



The Mutual Interference of Wireless Signals in Simultaneous Detection.*

By E. V. Appleton, F.R.S., and D. Boohariwalla, M.Sc.

(Wheatstone Laboratory, King's College, London.)

(1) Introduction.

THE experimental work described here was prompted by the theoretical discussions of Beatty† and Butterworth‡ on the subject of the apparent demodulation of a weak signal by a strong one in wireless reception. Both of these authors considered the case of a perfect rectifier, but their conclusions concerning the mutual interference of signals in the process of rectification differed very considerably. Beatty's treatment led to the result that the weaker of the two interfering signals should be completely demodulated, a deduction (as the author himself remarked) not borne out in practice. Butterworth, on the other hand, found out that while the process of demodulation was undoubtedly present, its magnitude depended in a somewhat complicated manner on the ratio of the carrier wave intensities of the two signals. The conclusions to be drawn from the present investigation is that Butterworth's results are the correct ones so far as a perfect rectifier is concerned.

(2) The Theory of Mutual Interference.

Before proceeding to consider the experimental work we give a theoretical treatment of the subject, alternative to that of Butterworth, the results of which are easy to apply and to remember, and, moreover, possess the advantage of being applicable to any type of rectifier, perfect or otherwise.

It is clear that the problem of the apparent demodulation of a weak signal by a strong one is essentially a non-linear one, since for one signal to interfere with another indicates that the principle of superposition does not hold.

Let us consider the simultaneous detection of a strong signal $S \cos \omega_1 t$ and a weak signal $W \cos \omega_2 t$. (We assume that these expressions represent the voltages applied to the detector terminals, the ordinary circuit demodulation consequent on the use of tuned circuits having been taken into account.) The total signal input to the detector is, therefore, given by,

$$V = S \cos \omega_1 t + W \cos \omega_2 t \quad .. \quad (1),$$

or

$$V = S \cos \omega_1 t + W \cos (\omega_1 + \rho) t \quad (2),$$

where $\rho = (\omega_2 - \omega_1)$. We assume that ρ is a supersonic angular frequency.

The equation (2) may be written

$$V = \sqrt{S^2 + W^2 + 2SW \cos \rho t} \quad \cos (\omega_1 t + \phi) \quad .. \quad (3),$$

where

$$\phi = \tan^{-1} \frac{W \sin \rho t}{S + W \cos \rho t} \quad .. \quad (4).$$

Now we can express the properties of any form of rectifier in terms of a characteristic expressing the relation between mean signal current $\bar{i}$ and the amplitude A of a simple periodic electromotive force applied to it. If this characteristic relation has no discontinuities we may express it as

$$\bar{i} = \alpha A + \beta A^2 + \gamma A^3 + \delta A^4 \text{ etc.} \quad .. \quad (5)$$

Case (1) *Perfect Rectifier.*

In the case of a perfect rectifier, which we consider first, we write simply,

$$\bar{i} = \alpha A \quad .. \quad .. \quad .. \quad (6)$$

In our substitution for A we note that the expression (3) for V represents a high-frequency oscillation with amplitude equal to $(S^2 + W^2 + 2SW \cos \rho t)^{\frac{1}{2}}$, which is a varying quantity. Since, however, the telephone receiver does not respond to such supersonic variations, it is clear that it is the mean value of this quantity which gives us the appropriate value for A for insertion

---

* MS. received by the Editor January, 1932.

† *Experimental Wireless*, 5, No. 57, p. 300 (1928).

‡ *Experimental Wireless*, 6, No. 74, p. 619 (1929). (A non-mathematical exposition of Butterworth's work has been given by F. M. Colebrook, *Wireless World*, p. 560, May 27th, 1931.)

in (6). This mean value may be found as follows :—

$$\text{Let } X = \sqrt{S^2 + W^2 + 2SW \cos pt}$$

$$= \sqrt{S^2 + W^2}\left(1 + \frac{2SW \cos pt}{S^2 + W^2}\right)^{\frac{1}{2}}$$

$$= \sqrt{S^2 + W^2}\left(1 + \frac{SW \cos pt}{S^2 + W^2} - \tfrac{1}{2}\frac{S^2W^2 \cos^2 pt}{(S^2 + W^2)^2} + \text{etc.} \ldots\right)$$

Now the mean value of this expression is given by

$$\bar{X} = \sqrt{S^2 + W^2}\left(1 - \tfrac{1}{4}\frac{S^2W^2}{(S^2 + W^2)^2} + \text{etc.} \ldots\right) \quad .. \quad (7)$$

so that, since $\bar{X} = A$, (6) becomes

$$\bar{i} = a\left\{\sqrt{S^2 + W^2} - \tfrac{1}{4}\frac{S^2W^2}{(S^2 + W^2)^{\frac{3}{2}}} + \text{etc.} \ldots\right\} \quad .. \quad (8)$$

Let us now suppose that the weak signal is modulated; that is to say it is changed periodically in amplitude from W to $W \pm \triangle W$ We know that, if the strong signal were not present, we should have this change of amplitude registered as a change in the mean signal current of magnitude $\pm a \triangle W$.

To find the change of signal current in the presence of a strong signal we must find $\dfrac{\triangle \bar{i}}{\triangle W}$ from (8). This is given by

$$\frac{\triangle \bar{i}}{\triangle W} = a\left\{\frac{W}{S\left(1 + \frac{W^2}{S^2}\right)^{\frac{1}{2}}} - \tfrac{1}{2}\frac{W}{S\left(1 + \frac{W^2}{S^2}\right)^{\frac{3}{2}}} + \tfrac{3}{4}\frac{W^3}{S^3\left(1 + \frac{W^2}{S^2}\right)^{\frac{5}{2}}} - \tfrac{5}{4}\frac{W^3}{S^3\left(1 + \frac{W^2}{S^2}\right)^{\frac{7}{2}}} + \text{etc.}\right\} \quad .. \quad .. \quad (9)$$

We thus find that if we write

$$x = \frac{\text{Weak signal input amplitude}}{\text{Strong signal input amplitude}} \quad (10)$$

and

$$y = \frac{\text{Acoustic weak signal in presence of strong signal}}{\text{Acoustic weak signal in absence of strong signal}} \quad (11)$$

$$y = \frac{x}{(1 + x^2)^{\frac{1}{2}}} - \tfrac{1}{2}\frac{x}{(1 + x^2)^{\frac{3}{2}}} + \tfrac{3}{4}\frac{x^3}{(1 + x^2)^{\frac{5}{2}}} - \tfrac{5}{4}\frac{x^3}{(1 + x^2)^{\frac{7}{2}}} + \text{etc.} \quad .. \quad (12)$$

or, if we assume $x^2 << 1$,

$$y = \frac{x}{2} \quad .. \quad .. \quad (13)$$

The simple result expressed in (10), (11) and (13) applies with sufficient accuracy for ratios of $\dfrac{W}{S}$ up to 0.5 and so clearly deals with the range in which practical interest is centred. We can therefore state the following simple results :

If strong and weak signals of carrier frequency intensities S *and* W *respectively are simultaneously received with a linear detector, the modulation of the weak signal is reduced to a fraction* $\frac{1}{2}\dfrac{\mathrm{W}}{\mathrm{S}}$ *of its original value.**

In quite a similar manner the influence of the weak signal on the strong one may be found. The result only need be stated here. Let

$$y_1 = \frac{\text{Acoustic strong signal in presence of weak signal}}{\text{Acoustic strong signal in absence of weak signal.}}$$

and x retains its previous significance. It is then found that if, as before, $x^2 << 1$

$$y_1 = 1 - \frac{x^2}{4} = 1 - \tfrac{1}{4}\left(\frac{W}{S}\right)^2 \quad .. \quad .. \quad (14)$$

The demodulation influence of the weak signal on the strong signal is therefore small.

Case (2) *General Type of Rectifier.*

It is easy to generalise the above treatment using the relation (5). In doing this it is found that, corresponding to (9), we have

$$\frac{\triangle \bar{i}}{\triangle W} = \tfrac{1}{2}a\frac{W}{S} + 2\beta W + 4.5\gamma WS + 8\delta WS^2 + \ldots \quad .. \quad (15)$$

which may be compared with the expression that would be appropriate if the strong signal were absent, namely

$$\frac{\triangle \bar{i}}{\triangle W} = a + 2\beta W + 3\gamma W^2 + 4\delta W^3 + \ldots \quad (16)$$

---

* This result has been previously announced together with our suggestion that the demodulation effect plays a very important part in the behaviour of the Stenode Radiostat Receiver. (*Wireless World*, p. 661, June 17th, 1931).

A comparison of (15) and (16) shows that, if we take the terms in order, a perfect detector gives a pronounced demodulation effect depending on the relative strengths of the two signals, a "Square law" detector gives no such effect at all, while a "Cube law" detector actually gives increased modulation of the weaker signal, the modulation being increased in the ratio $1.5\frac{S}{W}$ to 1. But in considering practical cases it is well to remember that for most types of detector γ and δ are negative. In fact most detector characteristics may be represented by one of the two equations :—

$$\bar{i} = \alpha A - \gamma A^3 \quad .. \quad .. \ (17)$$

or

$$\bar{i} = \beta A^2 - \delta A^4 \quad .. \quad .. \ (18)$$

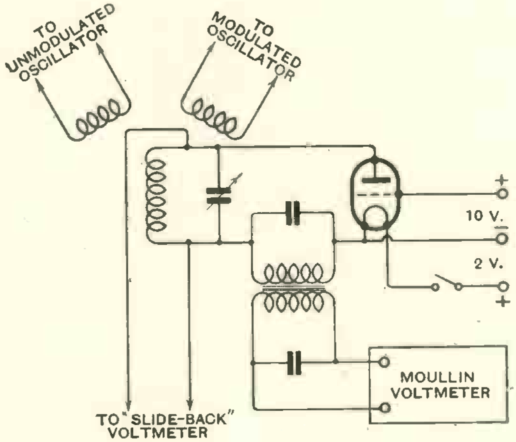
where the coefficients α, β γ and δ are all positive quantities. Equation (17) represents the performance of a rectifier which departs from the straight line relationship at large amplitudes, while (18) represents correspondingly a rectifier which departs from the "Square law" relationship at large amplitudes. Roughly speaking (17) refers to cumulative grid rectification and (18) to anode-bend rectification. From (15) and (16) it is easy to show that the presence of the γ term accounts for the increased demodulation effect at large signal amplitudes. Correspondingly it can be shown that, in anode rectification, the δ term accounts for the demodulation introduced at large amplitudes.

(3) Experimental Investigation.

Experimental tests of the theory given above were carried out using both a "straight line" rectifier of the type advocated by H. L. Kirke* and also a cumulative grid rectifier. The interfering signals were produced by (*a*) an unmodulated high-frequency oscillator and (*b*) an oscillator modulated at an acoustic frequency of 300 cycles per second. The experimental assembly for the case of the "straight line" rectifier is illustrated in the accompanying Figure.

To ensure that the reading on the Moullin Voltmeter referred only to audio-frequency output the unmodulated oscillator was switched on alone and the receiver tuned through resonance. The Moullin Voltmeter was found to give zero reading indicating that no appreciable high-frequency signal was reaching it.

To find the modulation effect of a strong signal on a weak one the modulated oscillator was removed to some distance so that the modulated signal was weaker than the unmodulated one. Each of the oscillators was then switched on in turn and the signal electromotive forces due to each measured by means of the slide-back voltmeter. These readings gave us W and S. In the case of the modulated oscillator the audio-frequency output voltage (p) was also read on the Moullin Voltmeter. Both oscillators were then switched on together and the new reading (q) of the Moullin Voltmeter noted. The results obtained for the two types of rectifier are tabulated below.



Experimental assembly for the "straight line" rectifier.

TABLE I.—TRIODE USED AS DIODE.

Ratio $\frac{W}{S}$ of modulated to unmodulated signal.	Acoustic signal of W in absence of S (p)	Acoustic signal of W in presence of S (q)	$\frac{q}{p}$	$\frac{1}{2}\frac{W}{S}$
	Volts.	Volts.		
0.10	0.90	0.05	0.055	0.05
0.20	0.90	0.10	0.11	0.10
0.24	0.90	0.12	0.13	0.12
0.30	0.90	0.15	0.167	0.15
0.40	0.90	0.20	0.22	0.20
0.46	0.90	0.25	0.275	0.23

---

* *Wireless World*, Vol. 24, Jan., 1929, pp. 32-35.

TABLE II.—CUMULATIVE GRID RECTIFIER.

Ratio $\frac{W}{S}$ of modulated to unmodulated signal.	Acoustic signal of W in absence of S. (p)	Acoustic signal of W in presence of S. (q)	$\frac{q}{p}$	$\frac{1}{2}\frac{W}{S}$
	Volts.	Volts.		
0.21	1.47	0.15	0.10	0.105
0.27	1.47	0.19	0.12	0.135
0.32	1.47	0.21	0.14	0.16
0.40	1.47	0.30	0.20	0.20
0.48	1.47	0.35	0.24	0.24

The approximate agreement of the last two columns in each table we interpret as verifying the theory. Closer agreement could hardly be expected considering that neither of the rectifiers used can be strictly regarded as possessing the type of characteristic contemplated in the theory. We therefore consider the experiments as demonstrating that, in the simultaneous linear detection of a strong signal (S) and a weak one (W), the modulation of the weak signal is effectively reduced to $\frac{1}{2}\frac{W}{S}$ of its original value.

Experiments on the demodulation effect of a weak signal on a strong one were also carried out the results obtained agreeing with theory, but, in view of the relative unimportance of this effect in practice, these results are not described here.

Summary.

The theoretical investigations of Beatty and Butterworth on the mutual interference of signals in simultaneous rectification have been extended and tested experimentally. In cases where the theoretical results obtained by these authors diverged, the experimental results are found to decide in favour of Butterworth's analysis.

A simple result of the work, which is of importance in practice, can be stated as follows :—

If strong and weak signals of carrier wave intensities S and W respectively are simultaneously received with a linear detector, the modulation of the weak signal is reduced to a fraction $\frac{1}{2}\frac{W}{S}$ of its original value. At the same time the modulation of the strong signal is reduced slightly to $\left\{1 - \frac{1}{4}\left(\frac{W}{S}\right)^2\right\}$ of its original value.

Books Received.

THE PRACTICAL ELECTRICIAN'S POCKET BOOK, 1932.

Edited by F. H. Robinson. The 34th annual edition contains, as usual, all kinds of information and data of use to electrical engineers, including a wireless section, in which various types of circuits are described, and articles on Picture Telegraphy, Batteries and Accumulators. The supply voltages of the various towns in the United Kingdom are given in a convenient tabular form. Pp. 569 + lxviii, with numerous illustrations and diagrams. Published by " Electrical Trading and Electricity," London, price 2s. 6d. net.

THERMIONIC VACUUM TUBES AND THEIR APPLICATIONS.

By E. V. Appleton, F.R.S., M.A., D.Sc.

The construction, action and application of Two- Three- Four- and Five-Electrode valves. Pp. 117, with 68 diagrams. Published by Methuen & Co., Ltd., London, price 3s. net.

PITMAN'S ELECTRICAL EDUCATOR (2nd Edtion). Edited by Sir Ambrose Fleming, F.R.S., M.A., D.Sc. ; for Electrical Students, Electricians, Contractors, Power Engineers, and those engaged on the commercial side of the electrical industry, the various subjects being treated by well-known authorities. In three volumes, pp. 1640 (in all), with copious illustrations, plates and diagrams. Published by Sir Isaac Pitman & Sons, Ltd., London. Price (complete), 72s. net.

The Spreading of Electromagnetic Waves from a Hertzian Dipole.

Paper by Messrs. J. A. Ratcliffe, L. G. Vedy and A. F. Wilkins, read before the Wireless Section, I.E.E., on 3rd February, 1932.

ABSTRACT.

Variation of Field with Distance.

AFTER an introductory section the paper proceeds to a brief discussion of previous measurements and of discrepancies shown in previous results. The authors then turn to the variation of field with distance. First they develop expressions for the field from a Hertzian dipole, reducing the electric field-strength (E) and the magnetic field-strength (H) to the final forms.

$$E = -\left\{\frac{chi_0}{pr^3}\sin(pt - mr) + \frac{i_0 h}{r^2}\cos(pt - mr) - \frac{i_0 ph}{cr}\sin(pt - mr)\right\} \quad . \quad (3a)$$

$$H = \frac{i_0 h}{r^2}\cos(pt - mr) - \frac{i_0 ph}{cr}\sin(pt - mr) \quad . \quad (3b)$$

Here $m = 2\pi/\lambda$, c is the velocity of light, while E and M are in electrostatic units and H in electromagnetic units. The ideal procedure for the purposes of the authors' work would be to excite a Hertzian dipole so that a uniform current $i_0 \cos pt$ flowed in it and then to measure the magnitudes of E and H at different positions. Unfortunately, a straight wire aerial cannot conveniently be excited so that a uniform current flows in it. It has been shown that the current distribution along a wire which is excited by a generator at its base is sinusoidal, with a wavelength equal to that of the wave radiated from the wire. If the wire is free at its top, the current there is zero and the current distribution is as shown at *AB* in Fig. 1.* If the aerial height is small compared with the wavelength radiated, then the current distribution along the wire is approximately a straight line. If a small capacitance top is fitted on the aerial, the distribution is as shown at *CD*. If a very large capacitance top is fitted, the distribution is as shown at *EF* and is approximately uniform. This is the current distribution which would be obtained with a dipole. The authors then proceed to show that all these three types of current distribution obtainable in practice with a short aerial give rise to fields which behave like those of a Hertzian dipole. It is only necessary to prove this for the distribution *AB*, since *EF* is already that of a Hertzian dipole, while *CD* is equivalent to one of the type *AB* added to *EF*.

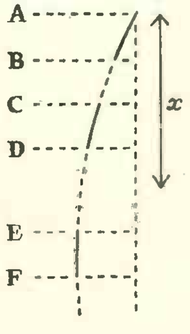


Fig. 1.—*Current distribution in short aerials.*

The variation of electric and magnetic fields with distance for all current distributions of Fig. 1 are thus given by equations (3*a*) and (3*b*). At great distances these reduce to the forms Er = constant and Hr = constant, so that if the product Er or Hr is plotted against r a straight line parallel to the r axis is obtained. For distances of less than one wavelength, however, this is no longer true, and the variations of Er and Hr with distance are shown in Fig. 3. The interesting part of these curves is for values of r less than 0.3λ, a region which has not previously been investigated.

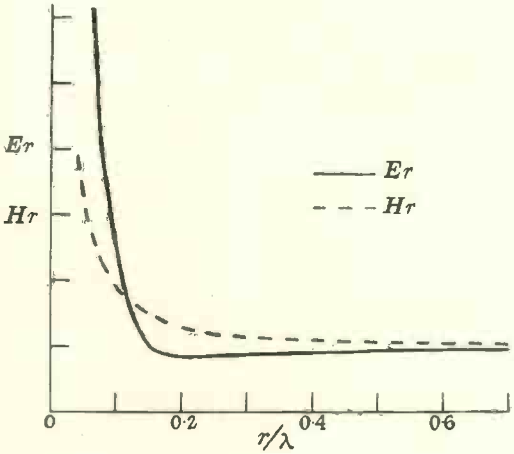


Fig. 3.—*Fields due to a dipole source (theoretical).*

From the analysis given in the paper it is shown that an aerial excited with a sinusoidal distribution of current gives a field of the same nature as a dipole provided the length of the aerial is small compared with a wavelength. It is stated that a like assumption has in some cases been made for a half-wave aerial; and, while this approaches truth at greater distances, it is shown that at short distances (*e.g.*, less than 0.3λ) this is not correct.

The paper then describes experimental verification, using a wavelength of 1000 m., with a vertical aerial of height 4.15 m., excited with a current distribution as at *CD* in Fig. 1. *EF* would have been preferable, but would have necessitated an inconveniently large top on the aerial. The experimental work covered (i) variation of E with distance r over a range of r = 24 m. to 600 m.;

---

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

(ii) variation of H with distance from $r = 50$ m. to 450 m. ; (iii) variation of E with distance over a range of $r = 5$ m. to 40 m. Within this range the finite height of the transmitting dipole (8 m. with "image" in the ground) is not negligible. Details of experimental procedure are given in the paper, and results are shown in Fig. 7, plotting Er against r. The experimental points represent relative values only, and their absolute magnitude has been adjusted so that the point at $r = 0.05\lambda$ falls on the theoretical curve. Similar results for H are shown in Fig. 9, experimental results being made to coincide with the theoretical curve at 0.1λ. The agreement between theory and experiment is sufficiently close to confirm the theory up to a distance of 0.05λ. At shorter distances than 0.05λ the electric intensity should be proportional to $1/r^3$. This is confirmed by the "short distance" measurements also illustrated in the paper.

Re-radiation from an Aerial.

In this connection it is pointed out that many previous observers working on this subject have used short wavelengths which may lead to complications in several directions. In the authors' experiments on 1554 m. the aerial A of Fig. 12 is placed in the path of a train of plane waves incident from a distant transmitter. The resultant field due to the superposition of the oncoming field and the re-radiated field was measured at B, using a measuring apparatus with a very short aerial. In this way the field re-radiated from B to A was negligible compared with that re-radiated from A to B. The re-radiated field E at the point B, distant r from A may thus be deduced from the theoretical expression for the field due to the aerial. It is shown to be

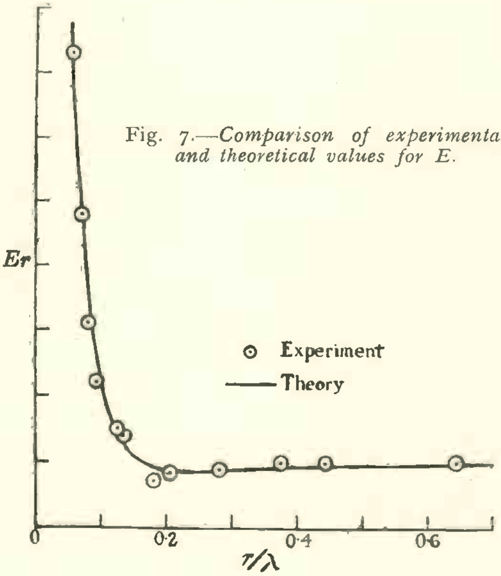


Fig. 7.—*Comparison of experimental and theoretical values for E.*

$$E = -E' \cos (pt - mr - \phi) \quad .. \quad (18)$$

where E' and ϕ are given by the expressions

$$E' = \frac{i_0 hm}{r} \sqrt{\left(1 - \frac{1}{m^2r^2} + \frac{1}{m^4r^4}\right)} \quad .. \quad (18a)$$

and
$$\phi = \text{arc tan}\left(\frac{1}{mr} - mr\right)$$

In the experiment r was never greater than 0.01λ, so that mr was always less than 0.1, and by neglecting mr in comparison with $1/mr$ the error was less than 1 per cent. A small 60 cm. aerial was used with amplifier and calibration apparatus to measure the field at neighbouring points. The receiving galvanometer was noted when aerial A was completely detuned ; the capacity of condenser C was then gradually varied through resonance and simultaneous readings taken of C, voltmeter V (of Fig. 12) and receiving galvanometer.

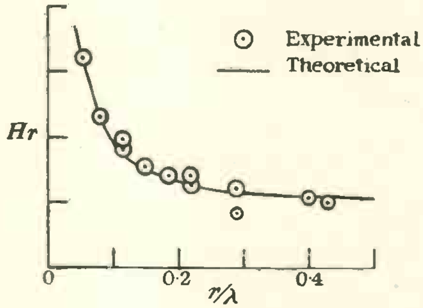


Fig. 9.—*Comparison of experimental and theoretical values for H.*

Results are shown in Fig. 14, while a graphical method of calculating the theoretical values is explained and illustrated in the paper. The agreement between calculated and observed values is probably as close as could be expected. From these results it is concluded that no "absorption of the main wave" takes place. If it did, the observed points would not fit the shape of the theoretical curves, since the "absorption" effect is supposed to vary as the tuning of the aerial is altered.

Absolute Value of Field Intensity.

There has always been some uncertainty as to the actual magnitude of the field radiated from an aerial of known height with its lower end connected to earth. It is seen from equation (3a) that for an aerial in free space carrying a uniform current i_0

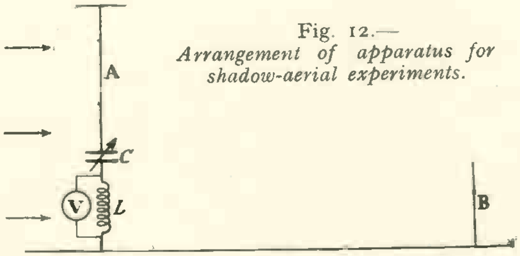


Fig. 12.—*Arrangement of apparatus for shadow-aerial experiments.*

the electric field (E) is given by an expression of the form

$$E = Ai_0 f(r)$$

If the current up the aerial is not uniform a "form factor" k corrects for the effective current, while if the lower end of the aerial is connected to earth a second factor β represents the effect of the "image aerial" in the ground so that the above becomes

$$E = \beta A k i_0 f(r)$$

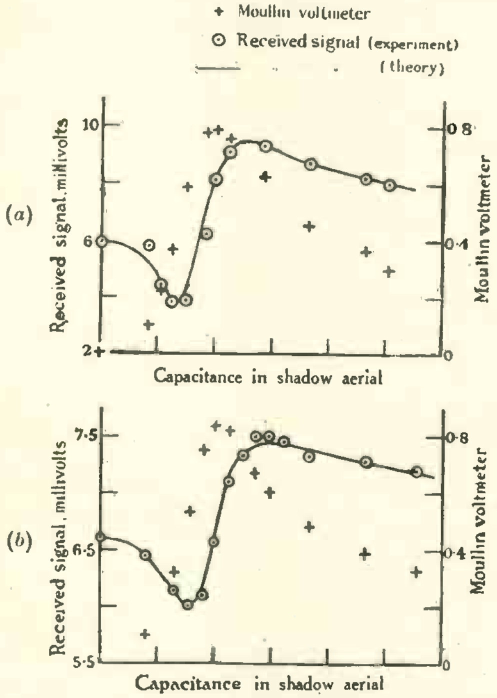


Fig. 14.—*Experimental shadow-aerial results compared with theory.*

The effective height of a transmitting aerial contains both the factors β and k and thus depends jointly on the current distribution and on image.

From the diversity of opinions which exists, there appears to be no sound theory as to the effect of the "image aerial." Experiments on this subject are described in the paper. The result of a series of measurements gave 2.0 as the value of the factor β. Confirmation of this figure is also obtainable from previous experiments. From these results the authors conclude that it now appears incorrect to imagine the waves to be incident tangentially on the ground and to be reflected with the Fresnel reflection coefficient, and it is also incorrect to imagine them incident at the Brewster angle with a zero reflection coefficient.

Discussion.

A long discussion followed the reading of the paper, the first few contributors speaking at considerable length.

Mr. E. B. Moullin said that while he had comments to offer he had no differences to express. He gave an alternative view of one of the authors' equations (not reproduced) and pointed out that, although approximations were used, the authors' formula gave results better than the limits of experimental error. He thought the discrepancies in the "shadow-aerial" results were very small, and agreed with the authors' expressed dislike of reflection processes, referred to in the paper.

Prof. E. Mallet said that the paper removed certain bogys that had stood in the way of applying mathematical theory to practice. He illustrated and explained vector diagrams of the three terms in equation (3*a*) and the two terms in (3*b*), which facilitated following the processes covered by these expressions. Part of the same vector treatment was used to derive the curves of Fig. 14.

Prof. L. S. Palmer did not find the paper a solution of the short-wave problem in which he had been interested. He thought that the authors' results gave no great discrepancies with his own short-wave results at distances beyond 0.2. At less ranges of r/λ a very close approximation to the dipole was essential. As regards Fig. 14, he thought that the peak of the dotted curve should lie nearer to the minimum of the theoretical curve. He expressed interest in the shadow-aerial experiments at greater distances and queried several points in connection with the authors' estimate of effective height of the receiving aerial used in these experiments.

Mr. J. S. McPetrie said that in some experiments near to the earth, the earth itself had not been considered. What would happen in certain cases where the earth's coefficient of reflection was not unity? He also dealt briefly with several cases in which the Fresnel equation would not hold.

Mr. E. White said that one of the authors' expressions (not reproduced) could be used to derive the current in the case of a L aerial, and suggested that with a sinusoidal current the expression could be used to derive the field from any aerial. At a distance from the aerial the field would still be calculable, even over an imperfectly conducting ground.

Mr. R. H. Barfield thought that the authors had got excellent agreement with theory. He suggested that the "shadow" effect put forward by Munro and himself had not been disproved, since conditions of resistance were not the same. Further comment on this point would be reserved for communicated contribution to the discussion.

Dr. Smith-Rose thought that the verification of field at very short distances was of great value, and referred to the fact that in beam and like systems the conditions close to the aerial were of considerable importance.

Mr. L. B. Turner made a query as to the distribution of current with a flat top and said that this might have to be taken into account at very short distances.

Mr. J. A. Ratcliffe briefly replied to the discussion, more detailed reply being reserved for written communication. On the motion of the Chairman, **Lt.-Col. A. S. Angwin**, the authors were cordially thanked for their paper.

On the Equivalent Mass of Driven Loud Speaker Cones.*

By Dr. M. J. O. Strutt.

(Natuurkundig Laboratorium der N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.)

Introduction.

IN a previous paper (5) some measurements on the equivalent mass of loud speaker cones, carried out in this laboratory, were dealt with. The first method there described is an indirect one, as the equivalent mass is derived from the amplitude of oscillation in each point of the cone surface. The aforesaid paper contains some remarks on a second, direct substitution, method for determining this mass, as used in this laboratory. In the present paper a series of measurements by a method resembling the latter one is described.

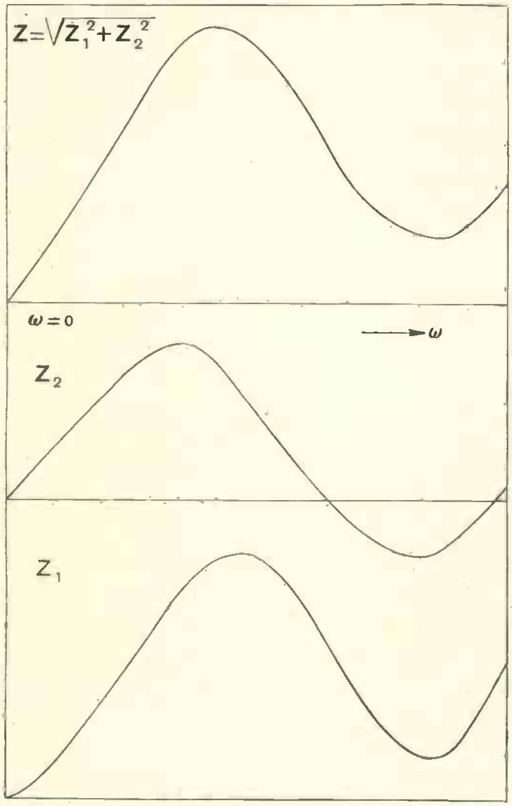


Fig. 1.—*Horizontal axis: frequency* $\omega = 2\pi \times$ *cycles per second. Vertical axis: upper curve, impedance* $Z = \sqrt{Z_1^2 + Z_2^2}$ *of cone; middle curve, imaginary part* Z_2 *of impedance* Z*; lower curve, real part* Z_1 *of impedance* Z.

Before dealing with the experiments it may be worth while to say a few words on the general character of the curve in which mass is plotted against frequency, as derived from theoretical considerations. For details, the reader is referred to a paper: "Ueber die Admittanz linearer Schwingungssysteme," published recently in the *Annalen der Physik* (Vol. 10, p. 244, 1931).

Any linear system, electric or mechanic, when driven at a point by a periodic force, will present to this force a certain impedance Z. From the theory of circuit impedances, it is known that Z is in general a complex quantity:

$$Z = Z_1 + jZ_2 (j = \sqrt{-1})$$

Moreover, with a system resonating at certain frequencies ω_0, ω_1, etc., the curves of Z, Z_1, and Z_2 as a function of the frequency ω are similar to those drawn in Fig. 1. In this figure we have tried to sketch the impedance Z of a loud speaker cone as a function of ω. We shall first make clear that $Z = 0$ for $\omega = 0$. In order to understand this, we have simply to remember that a cone, fastened at a point (*e.g.*, the centre) to a driving system and otherwise free, will reach an infinitely large velocity, if the driving point is moved by a constant force of zero frequency. This is expressed by saying $Z = 0$ for $\omega = 0$.

For simplicity, the reaction of the cone on the driving point may be substituted by the reaction of a mass and resistance. Of course, this choice is arbitrary; a capacity (stiffness) and a resistance would do as well. However, as for $\omega = 0$ the cone represents a mass only, our choice seems reasonable. As the cone is by no means a system without resonances, the aforesaid mass and resistance will depend on the frequency under consideration. The impedance of a system with mass

---

* MS. received by the Editor October, 1931.

m and resistance r is $r + j\omega m$. This quantity must be equivalent to $Z_1 + jZ_2$ (Fig. 1). Hence r amd m depend on ω in a way, sketched in Fig. 2. From this reasoning it is clear that m may be negative in certain intervals of frequency. This is borne out by our measurements.

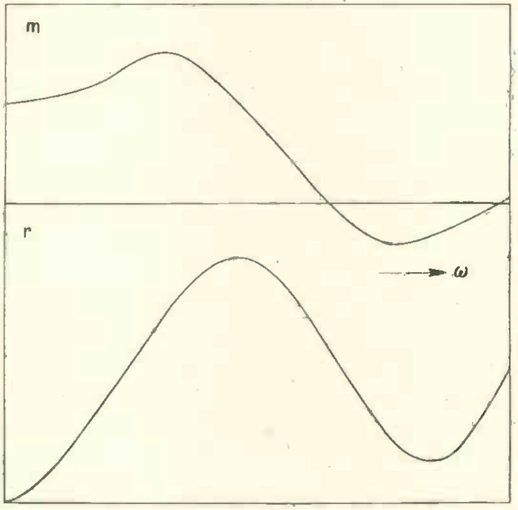


Fig. 2.—*Horizontal axis frequency* ω. *Vertical axis: upper curve, equivalent mass of cone; lower curve, equivalent resistance of cone,*

In conclusion of these considerations a few words will be said on the reaction of the air on a cone driven in this medium by a periodic force. This reaction has two components. The first one is in phase with the velocity of the driving point. This component of the impedance is the radiation resistance r. It is proportional to the sound energy e per second emitted by the cone if driven with a fixed velocity: $e = rv^2$. Here v is, as usual, the root mean square velocity of the driving point. The other component of the reaction on the driving point by the surrounding air lags in phase by one-quarter of a period as compared with the driving point velocity. This component of the impedance is ωm, where m is the mass, added to that of the cone by the air set into vibration by the cone's motion. From theory, for a free cone without baffle, m depends on the frequency, as indicated schematically in Fig. 3. It will be shown hereafter that this frequency dependence of the additional mass is in qualitative agreement with our measurements. Attention should be given to the fact that Fig. 3 holds approximately for a *perfectly stiff cone.* For a cone with nodes, as occur at higher frequencies in our measurements, the equivalent additional mass of the air will in general be smaller than that of Fig. 3. A calculation of this latter case seems a matter of some mathematical difficulty. The influence of nodes on r has recently been published by the author. (*Annalen der Physik*, 11, p. 129, 1931.)

Methods for Measuring the Equivalent Mass of Driven Cones.

In literature, a method for measuring this quantity by electric means has been published by A. E. Kennelly (³). In reality, Kennelly has dealt with telephone membranes, as loud speakers had not come to their present stage in 1915. Kennelly's method consists in measuring the impedance of the electromagnetic driving system as a function of frequency, first with the cone moving with the driving point, and then with

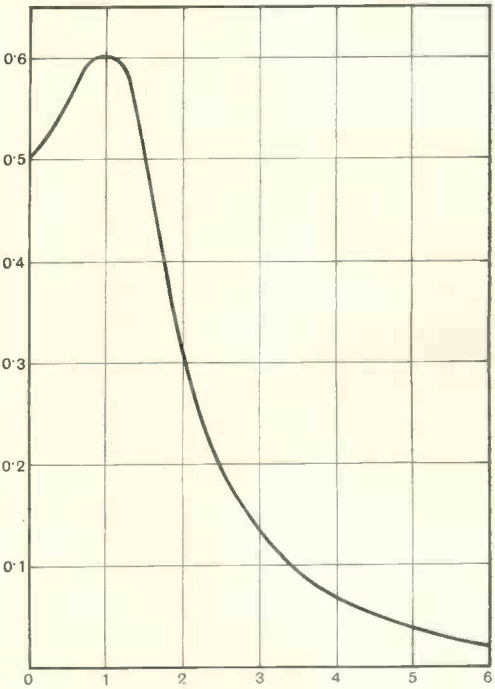


Fig. 3.—*Horizontal axis:* $2d/\lambda$; d = *largest diameter of cone;* λ = *wavelength of sound in air. Vertical axis: factor* f *of formula for additional mass* m *due to air motion:* $m = f \cdot \frac{2}{3} \cdot d^3$.

the cone and the driving point fastened in their equilibrium position. The difference of these two impedances, by analysis, may be shown to be proportional to the admittance which the cone with air and mechanic driving system presents to the driving point.

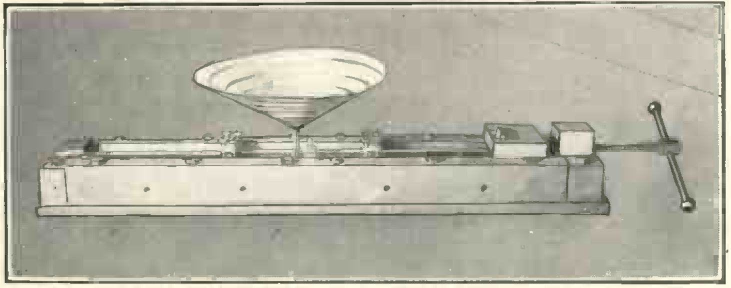


Fig. 4.—*Apparatus for measuring equivalent mass of cones up to 400 cycles. Cone is fastened to a steel band, stretched between supporting metal blocks, to be seen at either side of centre.*

Shortly, Kennelly's method was successfully used by several authors (4, 6), using electrodynamic speakers.

A second method, described in literature by Nukiyama (2) resembles that of Kennelly. It differs therefrom in that the electric impedance of the driving system is compensated. Hence the measured impedance as a function of frequency is directly proportional to the admittance of the mechanical system on the driving point. This enables one to obtain the equivalent mass by one measurement, instead of two if Kennelly's method is used.

In this laboratory, Kennelly's method was tried for several months. It was found, however, that this process was too slow for obtaining many data on m as a function of ω.

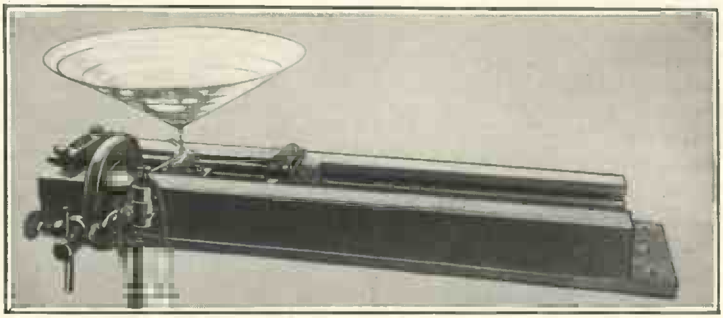


Fig. 5.—*Apparatus for measuring equivalent mass of cones up to 2000 cycles. Cone is fastened to steel rod of rectangular section 3 × 8 mm. and maximum length 20 cm.*

The method worked out in this laboratory starts from the principle of direct substitution. A mechanical system has a sharp resonance at a certain frequency ω_0, if the cone is fastened to it. This resonance frequency is determined. It should be well separated from other resonance frequencies. Now, instead of the cone, an adjustable mass is fastened to the system and varied until the resonance frequency is the same as with the cone. This mass is obviously the equivalent mass of the cone at the resonance frequency. The resonance of the system may be altered from some 20 to 2000 cycles per second by various adjustments, to be described hereafter. Hence we are enabled to measure the mass of cones as a function of frequency between 20 and 2000 cycles. By determining the mass first in air and then in vacuum, the additional mass due to the vibrating air may easily be obtained.

Apparatus for Measuring the Equivalent Mass of Driven Cones.

Our apparatus consists of two principal parts: a mechanical vibrating system and an electric generator of variable frequency. Photographs of our mechanical systems are found in Figs. 4 and 5. Referring to Fig. 4, a heavy steel block with a slider and a screw enables a variable tension to be put on a steel band. This steel band carries an attachment at its centre, to which the cone may be fastened. Directly underneath this centre, not to be seen on the photograph, is an electromagnetic driving system, without mechanical contact to the steel band. By passing a.c. through this electromagnetic system, the steel band is set into vibration. In air its resonance frequency is easily perceivable by the ear. The arrangement with the steel band may be used up to about 500 cycles. The length of the resonating middle part of the steel band may be adjusted by means of two metal blocks as seen on Fig. 4.

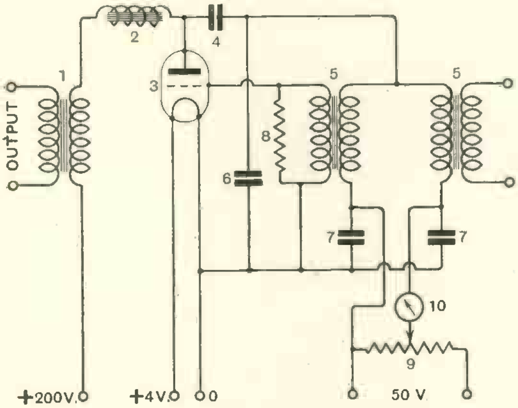


Fig. 6.—*Hartley generator for low frequencies.* 1. *Output transformer.* 2. *Choke, about* 10 *Henrys.* 3. *Philips triode A* 415. 4. *Condenser,* 12μ*F.* 5. *Philips transformer,* 1 : 3, *type* 4003. 6. *Condenser,* 1/3μ*F.* 7. *Condenser,* 4μ*F.* 8. *Resistance,* 10^4 *ohms.* 9. *Potentiometer.* 10. *Milliammeter, max.* 50 *mA. Advantages of scheme : small amount of harmonics and great constancy of frequency.*

Above 500 cycles we have used the arrangement shown in Fig. 5. The heavy metal base block is the same as in Fig. 4. Instead of the steel band we used a steel rod, about 8 × 3 mm. and of 25 cm. length. By clamping this rod at appropriate lengths and fastening a cone to its centre, we could obtain resonance frequencies up to 2500 cycles.

Several details occurring in the use of this apparatus, such as observing the resonance frequency in vacuum, will be described together with the measurements.

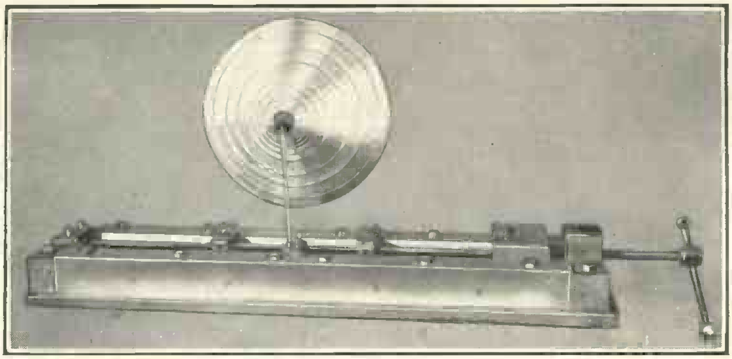


Fig. 7.—*Apparatus of Fig.* 4 *with special support for driving the cone at right angles to its axis.*

The generators used for obtaining the a.c. through the coil of the electromagnetic driving arrangement were of two types. The first one, designed for frequencies from 10 to 600 cycles and essentially due to Mr. Dijksterhuis, of this laboratory, is a modification of the Hartley scheme. It is given in Fig. 6. The frequency is varied by passing a variable d.c. through the two iron-cored transformers, acting as inductances. As may be seen from Fig. 6, the two transformer coils are in series as regards the d.c., but in parallel as to the a.c. This arrangement makes it possible to suppress the higher harmonics, and especially the second one, which would otherwise inevitably be produced in a scheme like this. We checked once for all the d.c. through the coils against frequency. As the d.c. can easily be determined with great precision, our frequency reading and frequency variation may be determined as accurately as is needed.

For the higher frequencies we used a generator of commercial Philips type, due to Mr. Groeneveld (1), of this laboratory, which acts on the principle of beats between two h.f. generators, one of which is varied.

Measurements of the Equivalent Mass of Loud Speaker Cones in Air.

At the start, we used the steel band of Fig. 4 without the two supporting blocks. By putting adequate tension on the band, the frequency could be varied up to 200 cycles.

The actual measurements of effective mass were carried out as follows. With the cone under inspection fastened to the band, the d.c. current through the generator coils needed for obtaining resonance was determined. Hereupon the cone was detached and known weights fastened to the steel band instead of it. These weights were chosen in such a way that two or more values of the d.c. larger than the value with the cone, and two or more values smaller than this value, were obtained. Hence we had a curve of weight against milliamps d.c., *i.e.*, frequency. By interpolation the weight of the cone could be determined to 0.5 gram at least. It was found that the check curve of weight against milliamps d.c. did not always remain the same during an hour or so. For this reason we always checked this curve before and after determining the d.c. value for one or more cones. Only those measurements in which the check-curve was constant within 0.5 gram were used.

We carried out many measurements of this type, on different cones, but unfortunately did not find identical values when measurements at one frequency and one cone were carried out with different steel bands. After some trials, the reason of this was found to be as follows. It was observed that the steel bands did not in general vibrate in the fundamental, but in some higher mode, usually the second or the third. Hence the motion of the driving point on the top of the cone was not always in the same direction, as to the axis of the cone, with one steel band or the other.

It may be seen theoretically that the equivalent mass of a cone, measured at a driving point, which is fastened to its top, will *depend on the direction of the motion.* As a matter of fact, the cone is far more stiff when moved purely axially than at right angles to its axis. This corresponds to the common observation that radial nodes appear at much lower frequencies than circular ones. As soon as nodes begin to appear, the effective mass of a cone will differ appreciably from its static value at zero frequency. From these considerations it is clear that deviations of the effective mass from the static value will occur at lower frequencies when the cone is driven at right angles to its axis than when it is driven purely axially. The two values of effective mass, measured in these two driving directions, will be extreme values, including between them all values of effective mass, measured with intermediate driving directions.

After these considerations had been put forward we tried to check them experimentally. In the first place, we wanted to secure a motion of the driving point in a known direction capable of reproduction with any steel band in use. Such a motion occurs, if the band vibrates in its fundamental mode, with the cone fastened to its centre. If the band itself is stretched horizontally, we may be sure in this case that its centre moves vertically. We reached this state of things experimentally, by using the supporting blocks of Fig. 4. By appropriately tuning the part of the band between them, we could obtain any fundamental oscillation from 60 to 500 cycles. We also checked that with the rod arrangement of

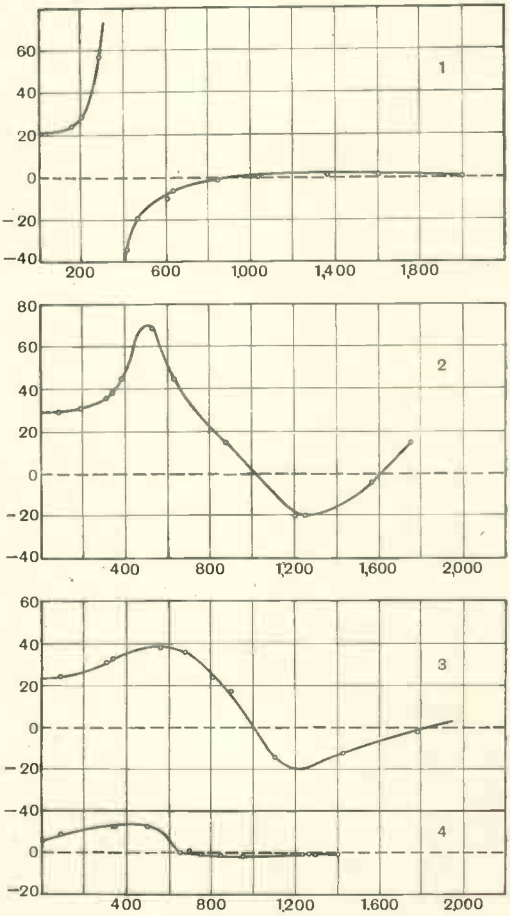


Fig. 8.—*Vertical axis : equivalent mass of cones in grams. Horizontal axis : frequency cycles per second. Cones driven axially* (2834 ; 24–44).

Fig. 5, only the fundamental vibration of the rod occurred if its free length between the clamps was appropriately adjusted. Hereafter, if the top of the cone was fastened to the system as shown in Figs. 4 and 5, we always obtained identical values of the effective mass at one frequency with one cone, using different steel bands and rods.

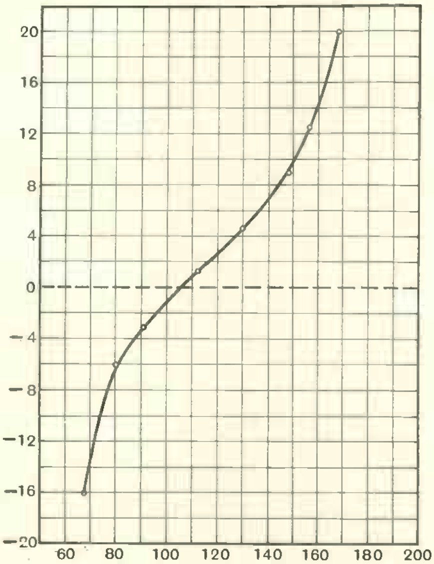


Fig. 9.—*Same as Fig. 8, but cone driven at right angles to its axis* (2905 ; 33–37).

In order to check our theoretical conclusion, that the mass of a cone, when driven at right angles to its axis, must depart from the static value at lower frequencies than for a cone driven axially, a special support was constructed, shown in Fig. 7. This support allowed the top of the cone to be driven at right angles to its axis. The procedure of weighing the cone for any specified frequency was the same as described above, variable masses being put on the support instead of the cone.

TABLE I.

Cone No. and Material.	Top Angle.	Largest Diameter.	Thickness, Millimetres.	Static Weight Grams.	Special Details.
1. Aluminium	118°	25.8 cm.	0.07	12.2	Several circular ribs.
2. Aeroplane cloth	118°	25.8 cm.	0.5	21.6	No ribs
3. Soft paper	118°	25.8 cm.	0.2	15.1	No ribs
4. Soft paper	118°	16.4 cm.	0.21	3.2	No ribs

Most of the cones have no full circular symmetry, owing to some overlapping. It was found that the direction of motion, with respect to this overlapping, did matter when driving the cone with the support just mentioned. This may be easily understood, as the formation of nodes will be dependent on the overlapping and hence also the effective mass. We always put the overlapping at the same position with respect to the driving point when measuring with the support of Fig. 7.

At the higher frequencies, *e.g.*, above 1500 cycles, owing to excessive damping by sound radiation and viscosity, the observation of resonances became a matter of some difficulty. We successfully used the following arrangement. A small spring, provided with a mass and a point at its end, as described in a previous paper (^{5}), was adjusted, by the aid of a micrometer, so as to let the point just make contact with the driving point of the steel band or rod when at rest. As soon as resonance occurs, the point of the spring dances and hereby the resonance frequency can be observed easily and accurately. We also used this device for observing resonance in vacuum. A d.c. was passed from the spring point to the steel band or rod. At the resonance frequency this d.c. decreases by the dancing of the spring point. (See Fig. 5).

Results on the Equivalent Mass of Cones in Air as a Function of Frequency Between 60 and 2000 Cycles.

We have measured the mass-frequency curve in this interval for some 30 cones, of different materials, dimensions and thickness. Here we shall only mention some characteristic results for four cones, numbered 1 to 4. Table I contains some data on the material, thickness, etc. These cones were first weighed with a motion of the driving point in the direction of the axis of the cone (as in Figs. 4 and 5). The results are shown graphically in Fig. 8.

As is seen from Fig. 8, the equivalent mass of these cones, measured axially, increases to a maximum which is several times the static weight, then falls to a negative minimum, increases again, etc. This is in full agreement with the theoretical prediction of Fig. 2. In literature, as far as I know, only cones without any air or other damping have been considered theoretically hitherto, whereas full experimental curves on the equivalent mass have not yet been published.

TABLE II.

Cone No.	Equivalent Mass at 77 Cycles.	At 190 Cycles.
1	6	3
2	13	3
3	9.4	1.0
4	2.9	−9.0

The cones mentioned in Table I were also weighed at several frequencies with the driving point moving *at right angles to the axis of the cones.* Table II contains some results.

As was mentioned in the foregoing section, this mass is much smaller than observed in the axial direction. For one cone, in a small interval of frequency, full curves of equivalent mass were determined (Fig. 9). The variation of mass with frequency is much more abrupt than in the axial direction. This was checked by several measurements, some of which are given in Table III.

TABLE III.

Cone No.	Mass at 90 Cycles.	At 200 Cycles.
1	10	8
2	28	8.7
3	23	8.3
4	5.5	1.8

This is in agreement with the fact that there are always at a given frequency, with appropriately driven cones, much more radial nodes than circular ones.

The mass of a cone, driven neither purely axially nor purely radially, but in some intermediate direction, as with most loud speakers, must lie between the values found for these two fundamental directions.

Measurements of Equivalent Mass in Vacuum and Determination of the Additional Mass Due to Air-motion.

It is interesting to see from Fig. 8 that the axial mass at low frequencies is considerably larger than the static weight. This must be due to the added mass by air-motion. We used a large vacuum drum (Fig. 10), in which the whole vibration apparatus was enclosed. Resonance was observed, as described above, by means of an electric contact. Table IV contains some results obtained in vacuum and in air.

TABLE IV.

Cone No.	Mass at 105 Cycles.		At 320 Cycles.	
	In Air.	In Vac.	In Air.	In Vac.
1	20	12	24	13
4	4.7	2.8	6.5	3.5

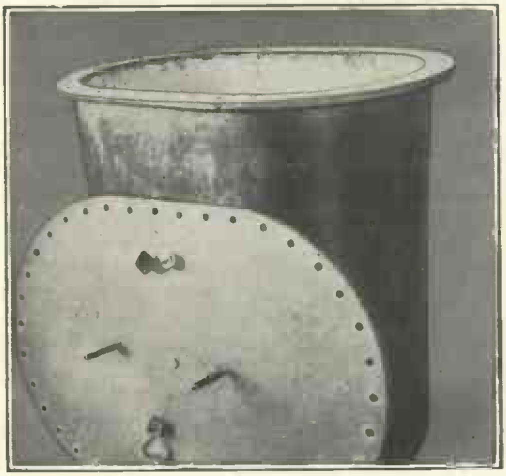


Fig. 10.—*Vacuum drum in which the whole vibration apparatus of Figs. 4 and 5 may be enclosed.*

The additional mass of the moving air, found experimentally, is in fair agreement with approximate theory, as given in Fig. 3. It is interesting to see that with cones of 15 cm. radius and 120 degrees top angle, the additional mass at low frequencies amounts to something like 10 grams. Of course, at 1000 cycles it is practically nil.

It may be expected that with cones driven at right angles to their axes, the additional mass, due to the motion of the air, is much smaller than with cones driven axially. This is borne out by experiment (Table V).

TABLE V.

Cone No.	Mass at 75 Cycles.	
	In Air.	In Vac.
1	11	9

It is clear that in loud speakers where the driving direction of the cone is in general neither purely axial nor at right angles to the axis, an intermediate value of equivalent mass between Table II and Fig. 8 will occur. This was actually checked by us during the preliminary experiments mentioned previously, wherein the cone was fastened to a steel band, oscillating in some higher mode. The mass, measured in this way, was always intermediate between Fig. 8 and Table II, at a fixed frequency.

In conclusion, the author takes pleasure in thanking Mr. N. S. Markus and Mr. C. P. Fritzius for their assistance on these measurements.

BIBLIOGRAPHY.

(1) Y. B. F. J. Groeneveld, *Physica*. 7, 157, 1928.

(2) H. Nukiyama and H. Matsudeira, Selected Papers, *Institute El. Eng. of Japan*, No. 13, May, 1927. See also Katuitiro Koboyashi, *Annales Postes Télégraphes et Téléphones* 19, Nr. 12, Dec., 1930, p. 1105.

(3) A. E. Kennelly, *Electrical Vibration Instruments*, MacMillan, New York, 1923.

(4) N. W. McLachlan, *Phil. Mag.*, 11, pp. 1–54, Jan., 1931.

(5) M. J. O. Strutt, *Experimental Wireless*, May, 1931.

(6) P. K. Turner, *Journ. Inst. El. Eng.*, 69, May, 1931, 591–622.

(7) A. G. Warren, *Phil. Mag.* 9, 881, 1930.

Correspondence.

Letters of technical interest are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

The Stenode Radiostat.

To the Editor, The Wireless Engineer.

SIR,—Dr. Robinson's rather astonishing letter in your February issue contains a more definite statement of his claims for the Stenode than I have hitherto seen published, and I take the opportunity of presenting the case against him in a manner different from usual and which leaves less doubt as to the conclusions.

Suppose our receiver is tuned to the carrier we wish to receive, and that another wave of 5,500 ~ higher frequency impinges on our aerial. This second wave is modulated at 2,000 ~, but it is supposed that the generally accepted conditions for "demodulation" are satisfied, *i.e.*, linear detection and large ratio of wanted carrier to interference. It is quite immaterial, of course, whether this second condition is achieved by small relative field strength of the interfering wave or by selective circuits.

By analogy with the conditions existing immediately after the first detector in a superheterodyne, we must have in the detector anode lead of our receiver a current wave of the beat frequency of 5,500 ~, but by the same analogy, this wave is also modulated at 2,000 cycles, *and therefore it must consist of three components, i.e.*, 7,500 ~, 5,500 ~, and 3,500 ~, and because of the discriminate treatment these components subsequently receive, it does not matter in the least how much they have been attenuated.

This mixture now arrives at our A.F. correcting and filtering device, which operates on all currents of frequency below 5,000 in such manner as to develop from them appropriately amplified voltages which are passed on to the next valve, all frequencies over 5,000 are destroyed.

It is evident, then, that we are inevitably left with the note of 3,500 ~ which receives the same subsequent amplification as any similar note properly belonging to the *wanted* transmission.

It is to be noted that demodulation of the interfering transmission has, in a sense, taken place, for only one of the necessary three components of the modulation frequency has survived.

I suggest that the error Dr. Robinson makes lies in the idea that the whole process of demodulation is effected by the detector.

The important conception I wish to present is that the function of the detector is only to transfer the unwanted modulation to a new frequency band, thus producing a wave having as many components as the original interfering transmission. (This is more generally true than at first sight appears, for it may be said that in straightforward detection the modulation is transferred to a frequency band in which the "carrier" frequency is zero.)

It is the function of the A.F. filter to dispose of these unwanted components, which, therefore, must all lie within the range of operation of that filter, *i.e.*, above 5,000 ~, otherwise they are not disposed of, but restored to their original values.

Evidently, then, if we want to get faithful reproduction up to 5,000 ~ from either of two stations transmitting simultaneously, and without interference, these stations must transmit on frequencies at least 10,000 ~ apart. It is not sufficient merely to render inaudible the heterodyne note due to the interfering carrier, for although we thus can claim to effect demodulation, this does not involve the automatic disappearance of the interfering side bands, and these still produce interference.

In view of this I fervently hope that Dr. Robinson does not succeed in persuading the broadcasting authorities to adopt his suggestion of 5,500 ~ spacing.

I do not wish to convey the impression that I am an opponent of the Stenode principle, but I am an opponent of unjustifiable claims.

Dr. Robinson definitely states that his claims have been proved, I have never seen any theoretical proof published, and I offer the foregoing as disproof.

If the claims have been proved by a sufficiently rigid experimental demonstration, then what is wrong with the theory?

Stratford-on-Avon. P. G. DAVIDSON.

The Loud Speaker Coil of Optimum Mass.

To the Editor, The Wireless Engineer.

SIR,—Mr. F. R. W. Strafford's letter on this topic comes at an opportune moment. I have been studying this problem analytically and experimentally and what follows may be of interest.

Mr. Strafford's assumption of inertia control limits his analysis to a narrow field. In what follows this limitation is removed.

Let H = flux density in gap.
l = length of wire on coil.
$W = i^2(R_c + R) =$ power dissipated = const.
$R_c + R$ = copper + motional res. + iron loss.
$\rho_1 \rho$ = density and spec. res. of wire respectively.
a = section of wire.
M_c = mass of wire (neglecting insulation).
M_0 = effective mass of diap. + coil former + acc. to inertia.
M_e = Total effective mass of diaphragm $= (M_0 + M_c)$
B_1 = force on coil due to sound radiation.
B_2 = force on coil due to diaphragm loss.
Z = mechl. impedance of diaphragm.
v = axial velocity of coil.

Then

$$F = Hli = Hl\sqrt{\left(\frac{W}{R_c + R}\right)} = Hl\sqrt{\frac{W}{R_c'k}} \quad .. \quad (1)$$

where $k = (1 + R/R_c)$ assumed approx. constant.

But $R_c = \rho\frac{l}{a}$ and $M_c = \rho_1 la$. Substituting in (1) we get $F = A\sqrt{M_c}$ .. (2), where $A = H\sqrt{\frac{W}{\rho\rho_1}}$.

Now sound radiated $W_1 = B_1 v^2 = B_1\left(\frac{F}{Z'}\right)^2$.

Subs. for F from (2)

$$W_1 = \frac{B_1 A^2 M_c}{[B^2 + \omega^2(M_0 + M_c)^2]} \quad .. \quad (3)$$

where $B = (B_1 + B_2)$.

For $W_1 = \text{max.}$, $\frac{dW_1}{dM_c} = 0$, which gives the optimum coil mass

$$M_c = \frac{1}{\omega}(B^2 + \omega^2 M_0^2)^{\frac{1}{2}} \quad .. \quad .. \quad (4)$$

or

$$\omega M_c = (B^2 + \omega^2 M_0^2)^{\frac{1}{2}} \quad .. \quad .. \quad (5)$$

i.e., the coil reactance is equal to the diaphragm impedance. In practice the diaphragm cannot be treated as a rigid structure, so that B and M_e vary throughout the frequency range, M_e being negative at times. Measurement of B and M_e was described by the writer in *Proc. Phys. Soc.*, 44, 88 (1932) and the *W.W.* August 12th, 1931, Fig 11, curves for various diaphragms being given. The table refers to curve 6 of this paper and to *W.W.*, Fig. 11. Owing to variation in mechanical impedance an optimum coil cannot be selected to cover the frequency range. It so happens, however, that the optimum coil in the neighbourhood of 2800~ gives a fair overall response. A 2 gm. coil gives a strong paper and comb effect. The influence of coil mass on performance is shown in *Phil. Mag.* 12,771 (1931), section 6. Large mass narrows the upper register whereas very small mass broadens it but makes it too powerful. There is therefore an optimum coil for good tonal balance. This subject is treated in a forthcoming paper.

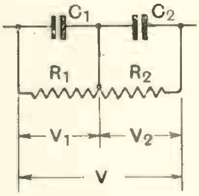
Frequency ~	Effective Mass of Diaphragm and Coil Former M_0 (gm).	Mechl. resistance B (mech. ohms).	Optimum Coil Mass M_c (gm).
50	0.22	3×10^2	22
1800	− 7	$9{\cdot}8 \times 10^4$	11
3000	− 1·5	$3{\cdot}2 \times 10^4$	2.26

London. N. W. McLACHLAN.
February 1st, 1932.

The Variation of the Resistances and Inter-electrode Capacities of Thermionic Valves with Frequency.

To the Editor, The Wireless Engineer.

SIR,—In his letter in your February number, Mr. Benham so seriously misrepresents what I have written on valve capacities that I must ask your indulgence to the extent of a final letter on the subject. Mr. Benham suggests that the difference between us is that I prefer the expression $C\dfrac{dV}{dt}$ for displacement current, and that he prefers $\dfrac{dQ}{dt}$. I must protest that in the whole of my treatment of the problem I have not once used the expression attributed to me, and that its use would be inconsistent with everything I have said. The difference between us is much more fundamental. I have been at some pains to point out that in all systems, including thermionic valves, in which the potential distribution is determined partly by the motion of free electrons or ions (conductance), and partly by dielectric properties (susceptance), the definition and calculation of capacity requires very careful consideration. I have shown that ordinary circuit analysis requires that the capacity of the system shall be regarded as a measure of the energy of its electric field, and that it can only be obtained by an integration over the whole field. Mr. Benham regards capacity as a measure of the displacement current at one particular cross-section of the field (the anode, in the case of a valve). In my last letter I tried to indicate, as briefly as possible, the fallacy in this procedure. The displacement current varies from point to point, and the arbitrary selection of any particular point cannot be justified. In order to make this point quite clear, let us consider the arrangement shown in the diagram, which is the simplest possible system of the kind under discussion, and therefore has the merit that the correctness of the calculations will not be open to dispute.



The equivalent conductance and capacity of this system may be calculated by a simple application of the ordinary network laws, and we find that the capacity at the frequency $\omega/2\pi$ is given by

$$\frac{C_1G_2{}^2 + C_2G_1{}^2 + C_1C_2\,(C_1 + C_2)\,\omega^2}{(G_1 + G_2)^2 + (C_1 + C_2)^2\omega^2}$$

where $G_1 = 1/R_1$ and $G_2 = 1/R_2$

Let us now compare this result with the results of calculations by my method and by Mr. Benham's, and to simplify the calculations, consider the capacity at very low frequencies, for which we may substitute $\omega = 0$ in the above expression and obtain the value.

$$\frac{C_1G_2{}^2 + C_2\,G_1{}^2}{(G_1 + G_2)^2} = \frac{C_1R_1{}^2 + C_2R_2{}^2}{(R_1 + R_2)^2}$$

Now it will be obvious that at very low frequencies V_1 and V_2 will be in phase and proportional to R_1 and R_2 respectively, since the current carried by the capacities will be very small compared with that carried by the resistances. Thus in this case

$$V_1/V = R_1/(R_1 + R_2) \text{ and } V_2/V = R_2/(R_1 + R_2)$$

My capacity value is determined by the ratio of the total energy of the electric fields of the two condensers to the square of the total voltage. It therefore becomes

$$\frac{C_1V_1{}^2 + C_2V_2{}^2}{V^2} = \frac{C_1R_1{}^2 + C_2R_2{}^2}{(R_1 + R_2)^2}$$

a value identical with that given above. Mr. Benham's calculation requires a knowledge of the displacement currents, and we are faced with the difficulty of finding out which one to take, since they are admittedly different. That in condenser C_1 is $\dfrac{dQ_1}{dt} = C_1\dfrac{dV_1}{dt}$ (since C_1 is a pure capacity), and that in C_2 is similarly $C_2\dfrac{dV_2}{dt}$. Suppose we try both. From the first we obtain the capacity value

$$C_1\frac{dV_1}{dt}\Big/\frac{dV}{dt} = C_1\frac{R_1}{R_1 + R_2}$$

and from the second $C_2\dfrac{dV_2}{dt}\Big/\dfrac{dV}{dt} = C_2\dfrac{R_2}{R_1 + R_2}$

and both are inconsistent with the value obtained from Kirchhof's laws. This also holds for other frequencies. Thus Mr. Benham's method is inconsistent with the ordinary laws of networks: it cannot therefore be used for the calculation of equivalent networks, from which it follows that it is of no use to the experimental worker.

In his last letter Mr. Benham saw fit to indulge in personal remarks. Such remarks add nothing to the value or to the dignity of a scientific discussion.

L. Hartshorn.

N.P.L., Teddington.

The Dynatron Oscillator.

To the Editor, The Wireless Engineer.

Sir,—May I make some belated comments on Mr. Colebrook's paper on the use of tetrodes to produce dynatron oscillations (*W.E.*, 8, 581, November, 1931)?

Surely the mechanism of the new circuit, with a variable condenser between control grid and anode, is not so obscure as Mr. Colebrook suggests. Fig. 1 of his paper shows that the negative slope of the anode volts/anode current curves increases as the grid potential increases. It is evident from Fig. 4 (the new circuit) that there is an alternating component of control grid potential whose phase (relative to the anode potential alternation) and magnitude depend on the sizes of the grid-anode condenser and the grid leak. In reality, the circuit is more complicated than Fig. 4 at frequencies high enough to make the inter-electrode capacities important, but, generally speaking, it is evident that as the grid-anode capacity is increased the phase of the grid voltage alternation will vary from (approximately) −90° to zero and its magnitude from zero to unity, both relative to the anode voltage alternation.

It will be seen from Fig. 1 in the paper that for a small alternating component of grid potential the average negative slope of the *operating* characteristic is greater when the grid alternation is in phase with the anode alternation than when it is in phase opposition. It is probably true to say that, in general, the negative resistance is a maximum when the phase difference is zero except at very high frequencies.

When the grid swing is large, pulses of (negative) anode current will flow during the positive half cycle of anode voltage and practically no current during the negative half cycle. Thus the L.C. circuit receives a pulse of energy each positive half cycle as in the reaction oscillator, where, however, the negative sign is associated with the anode voltage (instead of the anode current) variation.

If the amplitudes of grid and anode voltages were measured (*e.g.*, by a valve voltmeter) and their phase difference estimated from the circuit constants and the frequency it would be a simple matter to determine the anode current waveform graphically from a more complete family of characteristics of the type shown in Mr. Colebrook's Fig. 1. The output and efficiency can be similarly determined by the well-known methods introduced by Prof. Fortescue many years ago for triode calculations. Admittedly it is difficult to get at all complete curves for an ordinary S.G. valve without damaging it, but there are other types of tetrode available with which it should be possible—or one can use oscillographic methods.

The principle of Van Ryn's "Numans" oscillator is just the same as Mr. Colebrook's, only in the former case the dynatron (*i.e.*, secondary emission) region of the outer grid characteristic is used (see *E.W.*, 2, 134, December, 1924).

I used an oscillator with a strong "family likeness" to both these—in that it used the "Numans" circuit with Mr. Colebrook's feature of variable grid excitation—at the City and Guilds (Engineering) College two or three years ago with results that confirm Mr. Colebrook's conclusion that such circuits compare favourably with reaction oscillators for frequency stability at short waves *when the grid excitation is not excessive*. The reason for this proviso is evidently the fact that the rate of change of anode negative resistance with voltage increases with grid swing and R_a appears in the expression for frequency.

E. C. S. MEGAW.

Research Laboratories of the
General Electric Co., Ltd.
Wembley.

Amplifier Tone Control Circuits.

To the Editor, The Wireless Engineer.

SIR,—Mr. Scroggie's article in your January number deals with a subject of great practical use to designers, and these will no doubt be grateful to him for providing them with such a complete treatment and such useful data. There is little doubt that this work will find its way into the text-books.

For the benefit of future students of text-books, however, I should like to point out an artifice by which the mathematical treatment given by Mr. Scroggie can be greatly simplified. The method is one which arose quite naturally out of a special way of considering one of the problems that Mr. Scroggie had set himself, and the resulting mathematical simplicity suggests that this method may be usefully employed in other problems.

In Fig. 2 of Mr. Scroggie's article, ignore the intermediate circuit 2 (b), and express at once the condition that the admittance of R_1 in parallel with the combination of R_2 and X in series is equal to the admittance of the combination of R_s and X_s in series in the equivalent circuit 2 (c). The condition is

$$\frac{1}{R_1} + \frac{1}{R_2 + jX} = \frac{1}{R_s + jX_s}$$

Mr. Scroggie set himself the problem of finding the locus of the representative point (R_s, X_s) of the vector, $R_s + jX_s$ with variation of frequency, *i.e.*, with variation of X. We require, therefore, to deduce a relation between R_s and X_s from which X has been eliminated.

The method indicated is to solve the equation obtained above for $R_2 + jX$ and then take the real part of the result. This will eliminate X.

We get $$\frac{R_1}{R_2 + jX} = \frac{(R_1 - R_s) - jX_s}{R_s + jX_s}$$

Invert and add unity to each side to simplify the right-hand side.

$$\frac{(R_1 + R_2) + jX}{R_1} = \frac{R_1}{(R_1 - R_s) - jX_s} = \frac{R_1}{R - jX_s} \quad (1)$$

putting R for $R_1 - R_s$.

Equating real parts.

$$\frac{R_1 + R_2}{R_1} = \frac{RR_1}{R^2 + X_s^2}$$

$$\therefore \quad X_s^2 + R^2 - R.\frac{R_1^2}{R_1 + R_2} = 0 \quad .. \quad .. (2)$$

$$\therefore X_s^2 + \left[R - \frac{R_1^2}{2(R_1 + R_2)}\right]^2 = \left[\frac{R_1^2}{2(R_1 + R_2)}\right]^2$$

$$\therefore X_s^2 + \left[R_s - \frac{R_1(R_1 + 2R_2)}{2(R_1 + R_2)}\right]^2 = \left[\frac{R_1^2}{2(R_1 + R_2)}\right]^2$$

The locus of (R_s, X_s) is therefore a circle with radius $\frac{R_1^2}{2(R_1 + R_2)}$ and with centre at

$$\left\{\frac{R_1(R_1 + 2R_2)}{2(R_1 + R_2)}, 0\right\}$$

In addition to finding the locus of $(R_s X_s)$, Mr. Scroggie derived a relation exhibiting the effects of X, the quantity to be eliminated, on the results of the elimination, and showing in particular which point of the locus corresponded to which value of X. The method of elimination used above is very well adapted for the easy derivation of additional relations of this kind. This is shown in the next paragraph in the particular case of the circuits we are treating, and it is easily seen that there are quite general reasons why results of the same order of simplicity should be obtained in other problems.

Returning to equation (1), the form of this equation suggests that the influence of X can best be considered in terms of its ratio to $R_1 + R_2$. This ratio is the tangent of the angle made with the x axis by the vector quantities on both sides of the equation. Calling this angle θ, we get the result Mr. Scroggie found so useful :—

$$\tan \theta = \frac{X}{R_1 + R_2} = \frac{X_s}{R_1 - R_s} = \frac{X_s}{R} \quad .. (3)$$

It is safe to say that whenever one quantity has to be eliminated from a vector equation, the method illustrated here, if it can be applied at all, will be found to give similar simplicity in treatment.

Boston Manor, R. H. NISBET.
Middlesex.

Abstracts and References.

Compiled by the Radio Research Board and reproduced by arrangement with the Department of Scientific and Industrial Research.

PROPAGATION OF WAVES.

AUSTRALIAN RADIO RESEARCH BOARD WORK ON THE PROPAGATION OF WAVES.—Australian Radio Research Board. (*See* under "Miscellaneous.")

Field strength work :—*see* 1931 abstracts, pp. 614–615—Baker and Huxley, and 629—Baker and Pulley.

Work on fading and the Heaviside layer :—(a). Martyn's height-measuring method (*ibid.*, pp. 29–30, 55) : practical details : results—" in general the beat note is detectable only after sunset. It can be heard to fade quite quickly, and to vary gradually in pitch from moment to moment, thus indicating the undulatory nature of the Heaviside layer . . . . steps are at present being taken to obtain a stronger signal, with a view to the recording of the notes."

(b). Analysis and interpretation of fading records taken in Victoria on 3LO and 3AR, by simultaneous reception on a loop or frame and a vertical aerial, at distances from 35 to 120 miles : there is usually a large slow fading cycle of, say, 3 minutes period, with a smaller quick fading of, say, 20 seconds period superposed. " The first type of fading is attributed to an ionised layer at a height of about 100 km. and of relative stability, while the second type is to be associated with a considerably higher layer. It is possible theoretically to deduce the heights of the reflecting layer or layers from a consideration of the relative magnitude of the fading experienced on the two types of aerial system. When this method is applied to the slow fading, a layer of about 100 km. height is found, but very erratic results are obtained if the method be applied to the fading of quick period. Possible explanations of this anomaly have been considered and experiments devised to test their validity.

" While both types of fading are generally found in any fading record obtained during the evening hours, it sometimes happens that either the quick or the slow fading may be almost entirely absent. This is interpreted as indicating in the first event exceptional density, and in the other event exceptional transparency, of the lower layer. For example, quick fading only is found to be present in some of the early morning records, before dawn. As sunrise approaches, this gives place to slower period fading which finally ceases altogether soon after sunrise. The rates of movement of the layers as deduced from the fading curves agree well with those measured directly by A. L. Green in Sydney, using the wavelength change method" (1931 Abstracts, p. 55, and below).

(c). Green's layer-height and polarisation researches on a 351-m. wave :—evening tests over part of winter, spring and summer gave a height never very far from 110 km., with limits of 95 and 150 km. Subsidiary effects were noticed which are ascribed to the F (" Appleton ") layer, usually at about twice the height of the lower layer. " The inference to be drawn from the Jervis Bay work is that the upper layer is likely to be more important in Australia in its effects on the fading of broadcast signals than it is in England ; in fact, some statistics compiled from the results of the above evening tests indicated that the F region was important as a cause of fading on about 54 evenings out of a total of 90 on which tests were made, while it was the sole cause of fading on a further 23 evenings. Evidence was also obtained . . . in support of the view that waves can be received after having been twice reflected at the one layer, the third point of reflection being at the surface of the earth midway between the sending and the receiving stations."

Polarisation measurements, taken round sunrise for the sake of steadier layer conditions, show a *clockwise* rotation due to the earth's magnetic field, thus confirming Appleton and Ratcliffe's prediction based on the dip of the magnetic field being south in Australia and north in England (1928 Abstracts, p. 221). These measurements are also important in connection with methods, now being investigated by the Board, for the partial elimination of fading in certain cases.

POLARISATION OF DOWN-COMING WIRELESS WAVES IN THE SOUTHERN HEMISPHERE.—E. V. Appleton. (*Nature*, 19th Dec., 1931, Vol. 128, p. 1037.)

Appleton and Ratcliffe predicted (see preceding abstract) that the most direct test of the magneto-ionic theory of the propagation of wireless waves through the upper atmosphere would be to carry out at corresponding points in the Southern Hemisphere experiments similar to those performed by them and described in the paper referred to, the result of which was that " the down-coming [400 m.] waves were very approximately circularly polarised with a left-handed sense of rotation." Theory predicts that under similar conditions in the Southern Hemispheres the down-coming waves should be approximately circularly polarised with a right-handed sense of rotation, and this letter announces that this has now been verified by A. L. Green in a lengthy series of observations in New South Wales.

The bearing of such experiments on the polarisation of down-coming waves on the explanation of the cause of night errors in direction finding is shortly explained. " We can say that ' night errors ' in wireless direction finding are due to the arrival at the receiver of waves which leave the emitter as plane polarised waves in a direction inclined to the horizontal and reach the highly ionised regions in the upper atmosphere. There, under the influence of the earth's magnetic field, they are separated into their two component circularly or elliptically polarised waves, which undergo differential absorption and changes in polarisation and are bent round until they leave the ionised regions with a direction of propagation towards the earth. On reaching the receiver they cause fading and errors in the observed direction of the emitting station."

It is also noted that Smith-Rose and Barfield, following suggestions made by Adcock, have developed " a practical direction finder which is substantially free from errors even under conditions when down-coming waves of abnormal polarisation are being received."

PROPAGATION OF WIRELESS WAVES.—H. Nagaoka. (*Rep. of Rad. Res. and Works in Japan*, No. 1, Vol. 1, 1931, pp. 1–19.)

The full paper, a very abbreviated version of which (differently entitled) was dealt with in 1931 Abstracts, p. 606. Section 5(a) deals with the *effects* of the established diurnal variation of *N*. It is shown that the surface on which *N* has the same value during the night is not a sphere concentric with the earth, but has its E side decidedly higher than the W, so that transmission from E to W over a long distance is concentrated ; the signal intensity for certain angles of incidence is therefore stronger for E to W transmission than for that in the opposite direction, especially for short waves. For long waves the effect of the inclination may be contrary to that for short waves. The probable " corrugated " shape of the layer near the magnetic poles, and the consequent distortions and possibility of " mirage " effects, are discussed.

Section 7 gives a tentative explanation of the existence of the multiple layers. " Suppose the electrons coming from the sun reach the atmosphere at the height of about 100 km. with velocity just sufficient to ionise oxygen, nitrogen and hydrogen, which are still abundant, to be ionised to saturation. The position of the first ionised layer can be considered as marking the energy level of incoming electrons. Helium at this height is no longer ionised on account of its higher ionisation potential. If we next suppose that the energy level at the second layer corresponds to that of helium, there must exist a layer in which the ionisation state changes almost abruptly. Below this layer helium, though abundant, is not ionised. As all the gases of the atmosphere except helium are ionised, the conductivity of the medium imparted to it by numerous ions decreases the strength of the electric field. The field is directed downwards to the earth, and the motion of the electrons retarded. The existence of two layers can thus be explained from the ionisation potentials and the constituent gases of the upper atmosphere. It may perhaps be remarked that the second ionised layer is the lower limit of short light waves just capable of ionising helium. Calculating from the ionisation potential, it corresponds to λ 505 A.U. It is extremely doubtful if such radiation can come out of the solar atmosphere." In addition, the ionisation of the uppermost atmosphere is caused by protons and alpha particles. The positively charged protons are probably to be found above the second ionised layer : as the velocity of projection is not constant, the position of the proton layer is not so definite as those of the ionised layers. A third ionised layer (mostly hydrogen), whose position may perhaps be located by ultra-short waves, may be produced by streams of alpha particles from the sun.

In addition to the effects of ultra-violet radiation, electrons, protons and alpha particles, another possible phenomenon is mentioned as needing consideration, namely the variation of viscosity, in regions where the mean free path is long, in direct proportion to the pressure and inversely with the square root of the absolute temperature. " In the upper part of the atmosphere where the ionisation is great, the viscosity is swayed by the latter, while in the lower region the former is applicable. Consequently, if the upper atmosphere be much disturbed, there is the possibility of the disturbed layer gliding over the undisturbed ; the state of ionisation is affected, and the effect is felt in the route of transmission."

JAPANESE PAPERS IN THESE AND RECENT ABSTRACTS.

Many of these papers appear also in publications other than those specified in the various abstracts. Thus a paper quoted from *Proc. Imp. Acad. Tokyo* may also be found in *Japanese Radio Research Committee*, Reports presented to U.R.S.I. Assembly, 1931 ; or in *Reports of Rad. Res. and Works*, No. 1, Vol. 1, 1931 ; or in both of these.

OSSERVAZIONI SULLA STRATIFICAZIONE DELLA REGIONE DI HEAVISIDE. NUOVO DISPOSITIVO SPERIMENTALE (Observations on the Stratification of the Heaviside Region. New Experimental Equipment).—I. Ranzi. (*Nuovo Cimento*, No. 7, Vol. 8, 1931, pp. 258–263.)

The apparatus described has already been dealt with in 1931 Abstracts, p. 549. The c.-r. oscillograph employed was of the von Ardenne type : the wavelength 100 metres. Specimen oscillograms and layer-height curves are given. The numerous tests " confirm the existence of two ionised layers (Appleton's regions E and F). In addition, it is shown that the sudden alterations of the apparent height of reflection in region F, during the night, are due to rapid upward movements of the layer and not to a further stratification of the ionised region F." This latter point is deduced from the fact that all the sudden jumps in apparent height are accompanied by sudden phase changes in the reflected wave.

WIRELESS ECHOES OF SHORT DELAY.—E. V. Appleton and G. Builder. (*Proc. Physical Soc.*, 1 Jan., 1932, Vol. 44, Part 1, No. 241, pp. 76–87.)

Authors' abstract :—" An account of a simple method of producing short pulses of radio-frequency energy is given [1931 Abstracts, p. 492], together with notes on its application in the investigation of wireless echoes of short delay. Details of simultaneous visual and photographic methods of delineating such echoes are also described. The discussion of sample records and results serves as a basis for drawing conclusions concerning the relative advantages of the frequency-change and group-retardation methods of investigating the ionised regions of the upper atmosphere."

In an appendix, the writers describe a new linear time-base oscillator circuit (neon tube and triode), which was found very satisfactory, easy to adjust, and little affected in frequency by adjustment of the operating conditions of the oscillograph—*e.g.*, doubling the anode potential to change from visual observation to photography.

AUTOMATIC RECORDER FOR HEIGHT OF KENNELLY-HEAVISIDE LAYER.—Note from U.S. Bureau of Standards. (*Journ. Franklin Inst.*, Dec., 1931, Vol. 212, No. 6, pp. 798–799.)

A short notice of the report dealt with in Feb. Abstracts, p. 87.

INVESTIGATIONS AT THE PERKINS OBSERVATORY OF CHANGES IN THE KENNELLY-HEAVISIDE LAYERS AS A FUNCTION OF LUNAR ALTITUDES. —H. T. Stetson [and G. W. Pickard]. (*Nat. Res. Council*, 1931, p. 124.) *See* 1931 Abstracts, p. 375—two.

NOTES ON CORRELATION INVESTIGATIONS BETWEEN KENNELLY-HEAVISIDE LAYER AND LUNAR ALTITUDES.—G. W. Pickard. (*Ibid.*, pp. 125–126.)

Beginning with a recantation of the writer's earlier disbelief in the influence of the moon on radio reception (*cf.* his criticism of C. E. Paulson's suggestions, 1928 Abstracts, p. 637). Curves from 1926–1930 are given to confirm his present views—see preceding abstract.

EFFECT OF METEORS ON THE HEAVISIDE LAYER.—A. M. Skellett. (*Science*, 27th Nov., 1931, Vol. 74, p. 14 of Supplement.)

Meteors approaching the earth tend to lose most of their speed about 70 miles away from the surface, in the Heaviside layer region. The cloud of electrified particles accompanying the meteor disturbs the condition of balance so that the effective height of the layer is temporarily lowered. A recent Leonid shower of metors is stated to have caused such disturbances, resulting in a "fogging" of radio signals. *Cf.* 1931 Abstracts, p. 549.

UNTERSUCHUNGEN ÜBER POLARISATIONSFADINGS (Investigations into Polarisation Fading).—K. Krüger and H. Plendl. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 673–678.)

Investigations connected with the writers' system of fading-free transmitting aerials (1931 Abstracts, pp. 40 and 93). To examine the rotation of polarisation, a pair of horizontal aerials at right angles to each other was employed for transmitting and receiving, in the one case the transmitter, and in the other case the receiver, being connected alternately to each dipole of the pair by a commutator. In the preliminary tests the reflection was at almost vertical incidence, the receiver being only 10 km. from the transmitter. On a 53-metre wave, 1 to 20 revolutions per minute of the plane of polarisation were observed.

The next tests, also at a short distance, were with the object of neutralising the fading. Two methods were compared: (a) the aerials at the transmitter were alternated at a frequency of 1 000 p.s. by means of a 500 c.p.s. anode-voltage transformer, and (b) at the receiving end the neutralisation was obtained by combining the rectified signals from two receivers, one for each aerial. These tests were then repeated over a long distance (420 km.), on wavelengths 52.6 and 40 m. Each method gave generally a good anti-fading effect, but under conditions existing in about 10 % of the tests the transmitting method was superior to the receiving method.

TWENTY-FOUR-HOUR RECEIVING MEASUREMENTS OF LOW-FREQUENCY RADIO STATIONS NAUEN AND WARSAW.—E. Yokoyama and I. Tanimura. (*Res. Electrot. Lab. Tokyo*, No. 311, 1931, 35 pp.)

PROPAGATION OF THE BROADCASTING WAVES [345–441 METRES] IN JAPAN.—Y. Takata and Y. Itow. (*Reports of Rad. Res. and Works in Japan*, No. 1, Vol. 1, 1931, pp. 101–111.)

"The daytime variation [of intensity] is generally very small in magnitude, but at a distance of a few hundred kilometres a considerable variation appears sometimes as a prominent fading, and it accompanies commonly a very marked distortion of sounds. The night-time intensity (considered in the mean value) varies very irregularly. At one point, intensity is sometimes below that at a further distance, or the intensity of a nearer station is lower than that of a distant one. These phenomena, like the skip distance in short waves, are special ones on land, and these being never experienced by wireless operators on board ocean-going steamers in the open sea, may be considered to be the effect of hilly and mountainous land features of Japan.

"As to the skip distance phenomenon, the following daytime example which we met with at city Kanawa was the most conspicuous one of this kind." Reasonable strengths (round 25 μV/m) were obtained from stations 165—292 km. away, but JOHK Sendai (390 metres, and no more powerful) at 423 km. gave 200 μV/m. "Not only that, but also, to our astonishment, at any other places which are situated only several kilometres apart around the city, we could get no measurable strength for JOHK."

The night-time intensity was generally greater than that in daytime, but not always: thus at 200 or 300 km. the former was several times stronger than the latter, but at a short distance the strengths were nearly equal and at about 100 km. the latter was often the stronger by 20%.

Investigations on the effect of the city zone were made in Sendai, Tokyo, and Fukuoka. The last city gave more marked effects than the other two: its station is at the centre of the city, whereas the other stations lie in the suburban areas. But even in Fukuoka the wooden houses produced no very marked effect in the intensity. There was, however, about 10% difference between results indoors and out of doors; the lighting circuits appear to have been the principal cause of this. On certain occasions the intensity at the side of a house facing the station was 10% less than that on the opposite side, owing presumably to re-radiation from the lighting circuits. "It is a noticeable fact that during the test we saw always the re-radiation from conducting wires near-by, but not even a single case of screening from the same."

EFFECT OF SHORE STATION LOCATION UPON SIGNALS. —R. A. Heising. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 77–86.)

Author's summary:—Experiments are described for ascertaining the attenuation suffered by the unreflected wave in traversing relatively small amounts of land between the seashore and hypothetical inland sites. The results show 8 to 12 db attenuation for 1 mile inland with greater attenuation thereafter for unfavourable terrain. Swampy ground produces small attenuation. The classical theory of wave transmission past a straight edge used in optics is applied to explain the reduction. Coexisting phenomena are mentioned.

RECENT DEVELOPMENTS IN RADIO-TRANSMISSION MEASUREMENTS.—G. W. Kenrick and G. W. Pickard. (*Nat. Res. Council*, 1931, pp. 101–108.)

LES GAZ IONISÉS DANS LE CHAMP MAGNÉTIQUE : PREUVE DE L'EXISTENCE DE L'ÉLECTRON TOURNANT (Ionised Gases in a Magnetic Field : Proof of the Existence of the Rotating Electron).—Th. V. Jonescu and C. Mihul. (*Comptes Rendus*, 4th Jan., 1932, Vol. 194, pp. 70–72.)

"We have shown (1931 Abstracts, pp. 144 and 204 : also 315) that ionised air has a natural period of vibration corresponding to a wavelength of 9.50 m. and independent of the intensity of the ionisation current. This fact is explained by the hypothesis that the molecules have the power of attaching electrons to themselves. In a new series of measurements, on wavelengths between 2 and 40 m., we have found the same results ; in addition, we have found that at pressures below 10^{-5} mm. Hg the number of free electrons increases, while the number of electrons attached to the molecules decreases.

"We have then made tests to see the effect of a magnetic field, parallel to the plates of an ionised gas condenser, on the capacity variation Δc and the conductivity σ, for wavelengths between 2.34 and 19 m." Curves are given showing, for six wavelengths from 2.34 to 8.64 m., the variation with H of the conductivity σ due to both types of electron, the free and the attached, and also the variation due only to the two types separately. It is found that the free electrons have a natural frequency $\nu = \frac{eH}{2\pi m}$, as Benner has already shown (1929 Abstracts, p. 440 : *see* also 1930, p. 152, and 1931, p. 490).

The attached electrons enter into resonance with the external frequency for field values H' less than H. For wavelengths greater than 4 m. the difference $H - H' = H_0$ is constant and approximately equal to 10.5 gauss. For shorter wavelengths H_0 increases. "These results can be interpreted by supposing that the attached electrons find themselves in a molecular magnetic field of 10.5 gauss. In this field the electrons possess movements of precession with the angular velocity [expression given] which corresponds perfectly with the natural frequency of the ionised gas without any external magnetic field. When an external field H' is applied, the molecules direct themselves in the sense of the field and the precession takes place in the resultant field $H = H_0 + H'$; the gas resonance is then obtained for a wavelength smaller than 9.50 m." Calculated curves for σ agree well with those obtained experimentally.

THE KENNELLY-HEAVISIDE LAYER [THE ORIGINAL PUBLICATIONS].—(*E.N.T.*, December, 1931, Vol. 8, pp. 515–516.)

In an article by Wagner to Kennelly on his birthday, the latter's contribution to the *Electrical World* of 13.3.1902 and the extract from Heaviside's *Encyclopædia Britannica* paper are quoted.

THE PICCARD-KIPFER ASCENT.—A. Piccard. (*Journ. de Phys. et le Rad.*, Dec., 1931, Vol. 2, Series 7, pp. 148 s – 149 s.)

A brief summary of the programme and results. Intensity of ionisation and number of secondary beta rays were measured at 15 500 and 16 000 metres. Provisional results of a final calibration now in progress give an ionisation of the order of 200 ions/cm³ sec. for air at atmospheric pressure. *See* also Feb. Abstracts, p. 88, and below.

PROFESSOR PICCARDS FORSCHUNGSFLUG IN DIE STRATOSPHÄRE (Prof. Piccard's Exploration Ascent into the Stratosphere).—A. Piccard, P. Kipfer and others. (*Physik. Ber.*, 15th November, 1931, Vol. 12, p. 2529.)

Notice of a pamphlet of 128 pages with 50 pictures, published in Augsburg.

OZONE CONTENT OF THE ATMOSPHERE.—R. Mecke. (*Zeitschr. f. phys. Chem.*, Bodenstein Commemoration Volume, 1931, pp. 392–404.)

From the spectroscopic data of the photochemical equilibrium O_3/O_2 an equation has been developed giving the concentration of ozone as a function of the air pressure. At a height of 50 km. the concentration is calculated at about 2×10^{-4}, compared with about 10^{-8} at the earth's surface.

THE MECHANISM OF THE FORMATION OF OZONE FROM OXYGEN UNDER THE INFLUENCE OF ELECTRON DISCHARGE : OF NITROGEN OXIDES FROM A NITROGEN-OXYGEN MIXTURE.—L. A. M. Henry. (*Bull. Soc. chim. Belg.*, Vol. 40, 1931, pp. 339–360 ; 371–383 ; long summaries in *Physik. Ber.*, 15th Nov., 1931, Vol. 12, pp. 2607–2608.)

THE SHORTEST WAVELENGTH IN SUNLIGHT [AND THE MEASUREMENT BY IT OF THE AMOUNT OF OZONE].—F. W. P. Götz. (*Strahlentherapie*, No. 4, Vol. 40, 1931, pp. 690–695.)

July measurements show several sudden steps in the intensity values, finishing with a wavelength of 2 863 A.U., and agreeing well with the structure of the ozone band.

ÜBER PRÄZISIONSMESSUNGEN VON ELEKTRISCHEN BRECHUNGSEXPONENTEN NACH DER ZWEITEN DRUDESCHEN METHODE (Precision Measurements of Refraction Coefficients [of Water] by Drude's Second Method).—G. Mie and E. Frankenberger. (Summary in *Physik. Ber.* 15th Nov., 1931, Vol. 12, pp. 2589–2590.)

See also 1929 Abstracts, pp. 386–387. The precautions to avoid all possible sources of error are described, particularly those connected with the Lecher wire system.

EEN OPMERKING OVER ZWEVINGEN (An Observation on Interference Phenomena).—J. M. Faber. (*Physica*, No. 6, Vol. 11, 1931, pp. 197–202.)

An investigation of the interference lines resulting from the interaction of two spherical wave systems.

The Development of the Wave Conception: Part VI.—K. Uller. (*Gerlands Beitr.*, No. 1/3, Vol. 31, 1931, pp. 40–82.)

Continuation of the mathematical investigation referred to in 1931 Abstracts, p. 432.

A Delay Recording Equipment using a Steel Band Telegraphone.—Decker. (*E.N.T.*, December, 1931, Vol. 8, pp. 516–527.)

The Possibility of a Periodic Electrical Disturbance, possessing an Axial Symmetry, passing along a Cylinder without Dissipating Itself Laterally.—R. Ferrier. (*Comptes Rendus*, 4th Jan., 1932, Vol. 194, pp. 65–67.)

Formation of Standing Waves on Lecher Wires.—Mohammed and Kantebet. (*See* under "Measurements and Standards.")

The Optics of Radio Transmission.—E. Merritt. (*Proc. Inst. Rad. Eng.*, January, 1932, Vol. 20, pp. 29–39.) *See* 1931 Abstracts, p. 203.

The Propagation of Longitudinal and Transverse Waves in Isotropic Elastic Non-homogeneous Media [Mathematical Study].—G. Lampariello. (*Atti Accad. dei Lincei*, 5th June, 1931, Vol. 13, pp. 856–860.)

Formation of Love Waves in a Two-Layer Crust.—H. Jeffreys. (Summary in *Sci. Abstracts, Sec. A.*, Nov., 1931, Vol. 34, p. 950.)

Preliminary Study of the Acceleration of Earthquake Shocks.—M. Ishimoto. (*Bull. Earthqu. Res. Inst.*, No. 2, Vol. 9, 1931, pp. 159–167; long summary in *Physik. Ber.*, 15th Nov., 1931, Vol. 12, p. 2701.)

Velocity of Explosion-generated Longitudinal Waves in a Nepheline System.—L. D. Leet and M. Ewing. (*Nat. Res. Council*, 1931, pp. 61–65: summary in *Physik. Ber.*, 15th Nov., 1931, Vol. 12, p. 2735.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

On the Results of the Continuous Record of Atmospherics [at Tokyo, since 1927]. J. Asakura. (*Japanese Radio Research Committee*, Reports presented to U.R.S.I. Assembly, 1931, 14 pp.)

Reception was on a T aerial 200 feet high, nat. $\lambda = 870$ m. The receiver (one triode only is shown) was tuned to 13 000 m. and worked a relay in the secondary circuit of a 3/1 step-down transformer in the anode circuit. The recorder was an anemocinemograph of the Richard pattern showing the *number* of contacts per unit time. The mean monthly *intensity* of atmospherics, on a 4 000 m. wavelength, was also obtained by the shunted telephone method.

Both of these curves, over the three years September 1927 to August 1930, show a similarity to that of the thunderstorm frequency curve in Japan. The air temperature curve also agrees, while the barometric curve shows a reverse variation (except that in summer high pressure is often associated with thunderstorms). *This latter negative correlation appears in the diurnal, annual, and also the secular variations.* But on occasions much disturbance is found when the sky is clear, and little disturbance in stormy weather: for instance, atmospherics increase on fine but cold windy days in February and March. Generally, however, the existence of a low pressure centre or a line of discontinuity in the neighbourhood is the cause of increasing atmospherics. But the fact that even severe depressions do not always cause atmospherics shows that the generation of a thunderstorm associated with a depression *does not depend solely upon the depth of barometric pressure of the low centre.* Much increase of atmospherics after the passing of a low is due to the marked deepening of the low or the development of lines of discontinuity on the rear side.

As regards solar activity and the amount of atmospherics, the observations show that the yearly decrease in the number of atmospherics per minute agrees with the yearly decrease of the Wolfer-Brunner sunspot number, the former figures for the three years being 23.2, 19.2 and 16.2, while the latter figures are 76.4, 64.4 and 48.2. "This fact is not in accordance with the results obtained by L. W. Austin during four years from 1920 to 1924."

Among various other results may be mentioned:—The maximum in Tokyo appears in July, the minimum in February: the hours of daily maxima and minima vary with the season but average 16^h and 21^h for the former and 7.5^h and 19^h for the latter. The sunrise and sunset minima are liable to be disturbed by thunderstorms, but the modes of diurnal variation are nearly the same every day. These minima are probably due to great scattering of the waves, caused by disordered reflection and refraction in the Heaviside layer.

Correlation of Atmospherics [in Japan] with Thunderstorms.—A. Kimpara. (*Japanese Rad. Res. Committee*, Reports presented to U.R.S.I. Assembly, 1931, 24 pp.)

Relation between atmospherics and (i) *observed* thunderstorms, (ii) typhoons, and (iii) discontinuous surfaces. (iv) Comparison of atmospherics coming from the direction of thunderstorms, typhoons, and discontinuous surfaces. (v) Relation between atmospherics and *distant* thunderstorms.

Australian R.R.B. Work on Atmospherics.—Australian Radio Research Board. (*See* under "Miscellaneous.")

Forecast of a report by Munro, Huxley and Pawsey, now under preparation, on the continuation of the investigations referred to in 1931 Abstracts, p. 55. The work is demonstrating the value to Australia of the cathode-ray direction finders, developed and supplied by the British Radio Research Board, for long-range weather forecasting and for the following of thunderstorms with a view to warning aircraft. The system has been particularly effective in tracing cyclonic disturbances and low-pressure areas across the Tasman Sea. Another point brought out by the work is that atmospherics arising in Australia do not vary much in size at their origin, and it is thus possible for even one investigator, unaided, to find their approximate source from their direction and size alone. This applies in particular to observations on 3 000 metres; on 30 000 metres (the second of the two wavelengths on which most of the observations were made) the atmospherics may come from the other side of the world. The work is now being extended to the shorter waves of the broadcasting band.

Synthesis of the Polar Aurora.—A. Dauvillier. (*Comptes Rendus*, 16th Nov., 1931, Vol. 193, pp. 946–948.)

Electron beam experiments with a sphere of aluminium covered with a luminescent coat, on which are traced the principal meridians and parallels; it encloses a thin iron shell, which carries a winding in an equatorial groove and is arranged so that its magnetic axis is inclined at 15° to the axis of rotation of the whole sphere. This axis of diurnal rotation is set at 23° to the normal to the direction of the incident cathode ray, and can itself turn so as to reproduce the annual variation. The scale is 0.5×10^{-8}, and the electrons are therefore given an energy of $(3 \times 10^{10}) \times (0.5 \times 10^{-8})$, *i.e.*, 150 volts. The problem consists in reproducing auroral coronas presenting, on the scale indicated, the same radius of curvature as those of Nordenskjöld. Using a wide beam and a suitable pressure (so that the tracks of primary and secondary electrons can be observed) it is easy to reproduce the corona and auroral rays. The electrons approaching the poles are successively deviated in opposite directions, carrying the auroral pole to the north east of the magnetic pole. Under favourable conditions it is possible to distinguish up to three geodesic spirals corresponding to the multiple coronas of Nordenskjöld. The area of the corona, whose ellipticity is very variable, is greater in summer than in winter—it increases with the speed of the electrons. This explains the opposed variations, at high and low latitudes, of the 11-year frequency, the energy of the solar electrons increasing with the activity of the sun.

The experiment shows also that the primary electrons do not reach the sphere and that their deviation into a spiral path may occur at a distance from the globe equal to its diameter. But above all it shows that the auroral pole of Nordenskjöld (coinciding with that of Fritz' chart), far from being fixed, undergoes a diurnal and an annual displacement so that it really describes a trajectory of variable speed round the geographical poles. This rotation of the electronic spirals round the globe represents precisely the demagnetising field of Faraday and of Schuster, accounting for the diurnal and annual variations of terrestrial magnetism. At Paris, for example, the curve of declination is explained thus:—the opposed maxima at 8^h and 13^h are due to the passage of the N. corona, while those at 22^h and 3^h are due to the S. corona, the sense of displacement and the areas of the two coronas being opposed. Certain other phenomena are mentioned which also seem to be explained by these movements.

"But the spiralling of the solar electrons at a distance of the order of the diameter of the globe shows that the luminous phenomena (representing the aurora to us) can by no means localise either the altitude of the demagnetising current or the source of the cosmic rays. Our atmosphere reaches theoretically to 6.6 earth radii; if we suppose that the spiralling only takes place at the height of one radius, we see that a whole hemisphere is, at each instant, irradiated by the corona. If we also notice that its brilliance is hardly double that of the night sky (ray 5577) and that the cosmic rays are strongly degraded and diffused before reaching the ground, we see that we cannot expect any sensible variation in the intensity of these rays as a function of latitude. On the contrary, their well-known sudden fluctuations must be connected with those of magnetism, earth currents and terrestrial electric field." In a footnote the writer attributes the variations of the last-named quantity to the arrival, at the bottom of the stratosphere, of clouds of negative ions (which also produce cirrus) arising from clouds of secondary auroral electrons which have expended their ionising powers at a height of about 100 km. "This layer of negative ions, to which Idrac has also called attention (Abstracts, 1929, p. 147; 1930, p. 270), tends to reverse the normal electric field and the vertical current, without the negative ions having time to traverse the troposphere owing to their feeble mobility. It is thanks to this phenomenon of induction that the variations of magnetism and of earth current are simultaneous."

Work of the Bell System relating to Terrestrial Magnetism and Electricity.—O. B. Blackwell. (*Nat. Res. Council*, 1931, pp. 112–113.)

Use of Magnetic Data for Investigating Radiation from the Sun.—J. Bartels. (*Nat. Res. Council*, 1931, pp. 126–131.)

The Ultra-Violet Light Theory of Comet-Activity.—H. B. Maris. (*Ibid.*, pp. 131–132.)

Pulsations of Terrestrial Magnetism [Eschenhagen's Waves] as the Result of the Action of Clouds of Electric Corpuscles.—C. Störmer. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, pp. 1086–1087.)

Dependence of the Normal Earth Current on Latitude.—D. Stenquist. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, p. 1084.)

"It is conceivable that diurnal inequalities of the low-latitude type for earth currents and for the magnetic elements are connected with the ultraviolet radiation of the sun, that the high-latitude type is connected with ordinary auroral rays having diurnal variation, and that the magnetic storms are connected with the cosmic rays, which have diurnal variation."

Periodic Variations in Natural Phenomena [Correlation of Sunspot Periods with Climatic Elements, Submarine Upheavals, Mortality, etc.].—W. B. Schostakowitsch. (*Gerlands Beitr.*, No. 3/4, Vol. 30, 1931, pp. 281–335.)

Significance of Geoelectric Data from the Polar Regions.—O. H. Gish. (*Nat. Res. Council*, 1931, pp. 140–142.)

Atmospheric Electricity: Field and Ionic Distribution in a Gas Traversed by a Current and Containing Electricity Carriers of Little Mobility.—J. Scholz. (Summary in *Sci. Abstracts, Sec. A.*, November, 1931, Vol. 34, p. 989.)

The Ageing of Ions in Air and Nitrogen.—J. Zeleny. (*Phys. Review.*, 1st September, 1931, Series 2, Vol. 38, No. 5, pp. 969–976.)

For previous papers see 1930 Abstracts, pp. 175 and 585.

Theory and Method of Determination of Size of Ions in the Atmosphere.—H. Israel. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, p. 1091.)

The Ionisation of the Atmosphere Measured from Flying Aircraft.—D. C. Rose. (*Canadian Journ. of Res.*, Dec., 1931, Vol. 5, No. 6, pp. 625–635.)

Author's abstract:—The Gerdien type of atmospheric ionisation measuring apparatus was attached to a cabin aeroplane so that the state of ionisation of the atmosphere could be studied . . . Measurements were taken from ground level to heights of 15 000 feet. The results indicate that at the cloud level there is an abnormal excess of small positive ions, and a minimum in the excess of positive ions over negative ions from 4 000–6 000 feet higher. This does not include large ions such as charged water drops or dust particles. The observations were taken in regions free from clouds, the cloud level being determined by observations on clouds in the sky, and by relative humidity measurements taken at the same time.

Ionisation Measurements on the Piccard-Kipfer Ascent. (*See* under "Propagation of Waves.")

Electrical Conditions in Stratified Clouds.—M. Grabham. (*Nature*, 5th Dec., 1931, Vol. 128, p. 969.)

A short description of experiments made in 1908 which suggest that the stratified appearance of certain clouds is due to the repulsion between the positive charges which the component masses of vapour were found to carry.

Observations magnétiques et électriques au Sahara (Magnetic and Electric Observations in the Sahara).—C. Le Camus and F. de Saint-Just. (*Comptes Rendus*, 12th Oct., 1931, Vol. 193, pp. 600–601.)

Study of the Infra-Red Radiation emitted by the Earth's Atmosphere.—J. Devaux. (*Comptes Rendus*, 7th Dec., 1931, Vol. 193 pp. 1207–1209.)

Polarisation of Light from the Sky, and Its Connection with Other Meteorological Elements.—W. Smosarski. (Summary in *Sci. Abstracts, Sec. A.*, Nov., 1931, pp. 947–948.)

Cyclic Variations in the Heat and Light given out by the Sun.—C. G. Abbot. (*Science*, 18th Dec., 1931, Vol. 74, p. 14.)

"Many years of research have led him to the belief that these fluctuations are indirectly reflected in weather changes, and that eventually a reliable method for long-range forecasting may be based on them." The paragraph deals with a mechanical device which will "automatically untangle a curve representing one period of activity from a compound curve in which more than one such period may be indicated."

Beitrag zur Kenntnis der Solarkomponente der kosmischen Ultrastrahlung (Contribution to the Knowledge of the Solar Component of Cosmic Radiation).—A. Corlin and V. F. Hess. (*Gerlands Beitr.*, No. 1/3, Vol. 31, 1931, pp. 169–172.)

Arriving at the conclusion that the solar component is very much more penetrating than the hard ra-c γ-component. *See* also Hess and Pforte, 1931 Abstracts, p. 609.

Measurements of Cosmic Radiation between 57° and 67°N.—K. Wölcken. (*Zeitschr. f. Geophys.*, No. 5/6, Vol. 7, 1931, pp. 267–271.)

Observations on a voyage between Denmark and Greenland. Within the 10% limits of error, no relation between intensity and geographical or geomagnetic latitude was found.

Absorption and Diffusion of Cosmic Rays in Lead and Iron.—B. Rossi: Steinke. (*Atti Accad. dei Lincei*, 26th April, 1931, Vol. 13, pp. 600–606.)

Tests which do not show the difference in behaviour of the two metals observed by Steinke (1931 Abstracts, p. 147). An explanation of the discrepancy is suggested.

Il Problema della Radiazione penetrante (The Problem of the Penetrating Radiation).—B. Rossi. (*La Ricerca Scientifica*, Nov., 1931, Vol. 2, pp. 307–320.)

Disintegration of the Atomic Nucleus by Cosmic Rays.—C. D. Anderson and R. A. Millikan. (*Sci. News Letter*, 12th December, 1931, Vol. 20, p. 373.)

Cosmic Ray Fluctuations Connected with Those of Magnetism, Earth Currents and Electric Field.—Dauvillier. (*See* "Synthesis of Polar Aurora.")

Angular Distribution of the Cosmic Rays.—D. Skohelzyn. (*Comptes Rendus*, 4th Jan., 1932, Vol. 194, pp. 118–121.)

Sur les Éclairs en Chapelet avec Traits ("Bead Necklace" Lightning composed of Short Lines).—E. Mathias. (*Comptes Rendus*, 28th Dec., 1931, Vol. 193, pp. 1375–1377.)

Properties of Aerosols.—S. C. Blacktin. (*Nature*, 5th Dec., 1931, Vol. 128, p. 968.)

A letter commenting on the observations of W. Cawood and H. S. Patterson (1931 Abstracts, p.

610); the author would expect "the phenomenon they observed to show itself as producible merely through controlled spontaneous electrification without the necessity for introducing an independent source of electrification."

SPHERICAL LIGHTNING WITH MULTIPLE EXPLOSIONS.—J. Imbrecq. (*Comptes Rendus*, 16th Nov., 1931, Vol. 193, p. 949.)

PROPERTIES OF CIRCUITS.

THE TRANSIENT RESPONSE OF THE TRIODE VALVE EQUIVALENT NETWORK.—W. Jackson. (*Phil. Mag.*, Jan., 1932, Series 7, Vol. 13, No. 82, pp. 143–153.)

Using Colebrook's generalised analysis of the triode valve equivalent network (1929 Abstracts, p. 149), an operational equation is found for the output voltage $v(t)$, steady and transient, developed across the load circuit Z on the sudden application of a voltage of form $e(t)$ to the input circuit of the valve. This equation is solved by means of the Expansion and Superposition Theorems for Heaviside Operators to give the nature of the transient response in typical amplifier networks and the effect of the self-capacities. The cases considered are (1) resistance-capacity coupling, where it is found that the effect of the stray capacities can be neglected in deriving the transient response; (2) transformer coupling, where the same applies to the effect of stray capacities but the local disturbing transient is much more prolonged than in (1); (3) choke coupling and (4) parallel-fed choke coupling, where, in audio-frequency amplifiers, "the transient response is likely to be periodic and dies away exponentially at a comparatively slow rate."

The mode of solution of the operational equation by means of the Expansion Theorem is explained in an appendix.

ÜBER AUSGLEICHSVORGÄNGE IN EINIGEN ZUSAMMENGESETZTEN KREISEN (Equilibrating [Transient] Processes in Some Composite Circuits).—L. Mirlas. (Summary in *Physik. Ber.*, 1st Nov., 1931, Vol. 12, p. 2432.)

DÄMPFUNG UND ENTDÄMPFUNG IN GEKOPPELTEN KREISEN (Damping and Its Reduction in Coupled Circuits).—H. J. Eilers. (*Dissert. Tech. Hochsch. Dresden*, 1931, 28 pp.; summary in *Physik. Ber.*, 1st Dec., 1931, Vol. 12, p. 2804.)

In relation to the formation of highly selective but distortion-free receivers for broadcast reception.

APPARATUS FOR EXHIBITING SOME PROPERTIES OF COUPLED CIRCUITS.—R. C. Clinker and T. H. Kinman. (*Wireless Engineer*, Jan., 1932, Vol. 9, pp. 11–13.)

AN OUTLINE OF THE THEORY FOR THE OPERATION OF TRIODE POWER AMPLIFIERS [AND OSCILLATORS].—Y. Fukuta. (*Res. Electrot. Lab. Tokyo*, No. 309, 1931, 21 pp.)

In Japanese. A simple theory is given for the mode of operation of triode power amplifier and transmitting valves, and a simple method described by which the output power, efficiency, etc., can be determined approximately. In the case of constant amplification and known saturation voltage and current, an approximate value for distorted and undistorted maximum output can quickly be found for a given voltage supply—leading to a determination of the optimum working conditions.

AN UNTUNED RADIO-FREQUENCY AMPLIFIER [USING AN INTERVALVE TRANSFORMER WITH ASSOCIATED TIGHTLY-COUPLED CIRCUIT TUNED TO A HIGH FREQUENCY].—F. W. Schor. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 87–94.)

Author's summary:—"This paper outlines in brief a number of untuned radio-frequency transformers which have been used in the past. It discusses their characteristics and reasons for their limitations. It is pointed out that if the plate-load impedance of a tube can be increased at the high frequencies, the amplification will be increased. A method of doing this by closely coupling a circuit tuned to a high frequency is analysed, and the equation for amplification is derived. The construction of a transformer embodying this principle is next described and amplification curves throughout the broadcast band are given for several varieties." A slit cylindrical soft iron core, with a small bakelite washer over the centre and a large one at each end, is used. The primary is wound in the one half, and the secondary in the other, till the small dividing washer is covered: the two wires are then held together and wound in parallel throughout the space remaining in the bobbin. Primary and secondary are identical.

QUALITY DETECTORS: A SURVEY OF RECTIFICATION.—W. Greenwood and S. J. Preston. (*Wireless Engineer*, Dec., 1931, Vol. 8, pp. 648–658.)

From the B.B.C. Research Department. "Now that all modern transmitters have provision for 100% modulation, it has become important that detectors should be capable of handling signals modulated to this extent without introducing any appreciable distortion." The various practical methods are discussed, and the paper ends with a table of practical data giving a comparison of the various types of detector, the final column giving for each type a figure of merit which takes into account the effective damping due to the detector: it represents the rectified volts output per unit power input, assuming a carrier 100% modulated. The various types considered are the grid current and anode bend detectors (single and in push-pull), the "Kirkifier" (triode used as diode detector, with grid positive with regard to filament, to neutralise space charge), and the crystal detector.

AN APPLICATION OF THE CIRCLE DIAGRAM TO THE DESIGN OF ATTENUATION AND PHASE EQUALISERS. PART I.—N. M. Rust. (*Marconi Review*, November–December, 1931, No. 33, pp. 19–28.)

Author's summary:—It is well known that it is possible in a case of circuits arranged as for either parallel or series resonance to adjust the values of the resistances of the capacity and inductance in such a manner that the total impedance measured across the circuit is real and constant for all frequencies. This condition is applied in what follows to the design of attenuation and phase correcting networks.

A Simple Procedure for the Investigation of the Magnetic Field of a System of Current-Carrying Conductors of Any Shape of Cross Section.—W. Krämer. (*E.T.Z.*, 7th Jan., 1932, Vol. 53, pp. 9–10.)

TRANSMISSION.

On Asymmetric Telegraphic Spectra [and the Possibilities of Single Side Band Morse Transmission].—C. R. Burch. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2191–2218.)

Author's summary :—It is shown that single side band Morse transmission, if practicable, would relieve the present long-wave spectral congestion. Methods are developed whereby the wave shape of the single side band signals can be visualised when the original message envelope is given, and it is shown that the prolonged transmission of true single side band signals would in general necessitate the radiation of infinite amplitudes. Wave forms of approximations to single side band signals which evade this difficulty are determined : the wave form of the original message can be recovered without distortion from these "asymmetric side band" waves, the use of which, however, requires more power and also greater crest amplitudes than normal double side band transmission. The production and reception of asymmetric side band waves is discussed.

The subject is treated *de novo*, and the paper therefore overlaps considerably that of H. B. Nyquist in which many of the present conclusions were obtained by slightly different analytical methods.

Phase Displacement between Current and Voltage as a Possible Carrier of Communication.—Lubberger and Schleicher. (*See* abstract under "Miscellaneous.")

Amplitude, Phase, and Frequency Modulation. —H. Roder. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2145–2176.)

Author's summary :—This paper presents a comparative theoretical study of amplitude, phase, and frequency modulation.

In the first part, the fundamental mathematical expressions for the three types of modulation are derived. They are expressed in three different forms : as amplitude equations, side band equations and modulation vector equations. The amplitude equations indicate the envelope of the radio-frequency directly. The side band equations refer to the number, amplitude, and phase of the side bands produced by modulation. In the modulation vector equations, corresponding side bands are combined in pairs to form a "modulation vector." This is a r-f magnitude, rotating with the angular velocity of the carrier, and its amplitude is simultaneously being changed at an audio rate. The main results derived from a discussion of these equations are :

In phase and frequency modulation an infinite number of side bands is produced. Amplitude modulation produces but one pair of side bands.

In amplitude modulation the modulation vector, representing the first pair of side bands, is in phase with the carrier. In phase and frequency modulation it is 90 degrees out of phase with respect to the carrier.

Frequency modulation is equivalent to a phase modulation in which the phase shift is inversely proportional to the audio frequency.

By means of the modulation vector, a new vector diagram of the phase modulation is given.

In the second part, amplitude modulation is considered in which undesired phase or frequency modulation or a combination of the two takes place simultaneously. Regarding distortion and interference with a signal in an adjacent frequency channel, it is found that additional frequency modulation has little effect, while phase modulation may give rise to either distortion or interference or both. The magnitudes of corresponding upper and lower side bands, which are equal in the case of pure amplitude modulation and in the case of amplitude modulation and additional phase modulation, are found to be different when additional frequency modulation is present. This provides a method of measuring additional phase or frequency modulation.

In the third part, a few cases of so-called "false phase modulation" are treated. These are obtained when in a normal amplitude modulation signal the amplitude or the phase of one or both side bands are changed. The results are applied to find the performance of two special sending systems, in which carrier and side bands are radiated from separated antennas.

The Modulation System of the Russian High-Power Station at Schtschelkowo.—H. Wigge. (*Zeitschr. f. Hochf: tech.*, Dec., 1931, Vol. 38, p. 231.)

The output stage of the audio-frequency amplifier consists of two valves controlled in push-pull but supplied with no d.c. potential to the anodes. The anode supply is at radio-frequency and is taken directly from the oscillator coil of the first generating stage. The l.f. currents flow to earth *f*, by way of the centre tap *e* of a choking coil across the two anodes, through a resistance *R*. The potential drop between *e* and *f* gives l.f. modulation to the second oscillator stage.

An Experimental Study of the Tetrode as a Modulated Radio-Frequency Amplifier [particularly for Radiotelephone Transmission on Frequencies of and above 500 kc.].—Robinson. (*See* under "Valves and Thermionics.")

A Direct Reading Modulation Meter.—A. H. Cooper and G. P. Smith. (*Wireless Engineer*, Dec., 1931, Vol. 8, p. 647.)

A single-triode circuit with d.c. milliammeter and a valve voltmeter, which requires no calibration from an oscillograph or other apparatus, and which is useful for measurements not only on transmitters and standard signal generators but also (by the use of a good r.f. amplifier) on distant transmissions. For a letter on priority of use, *see* January issue, 1932, p. 25.

Versuche mit sehr langsamen durch die Elektronenröhre erzeugten elektrischen Schwingungen (Experiments with Very Slow Oscillations [1 c.p.s. and under] produced by Thermionic Valves).—F. Moeller. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 669–673.)

Frequencies down to 0.5 c.p.s. were generated with a pair of ordinary receiving valves, and the conditions investigated under which they could be passed through an amplifier so as to give an a.c. output of the same frequency and of the order of 10 watts. The phase laws at the generator and amplifier are examined. *See* also Ito, 1930 Abstracts, p. 332.

A New Treatment of Electron Tube Oscillators with Feed-Back Coupling.—C. K. Jen. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2109–2144.)

Author's summary :—In an electron tube oscillator with feed-back coupling, the ratio E_g/E_p may be expressed as $\epsilon\,|\,\Phi$ in which ϵ and Φ are respectively called "excitation" and "phase difference." For the maintenance of self-oscillation it is absolutely necessary to have a correct Φ, and for the optimum intensity of self-oscillation there is usually a most favourable ϵ for a given oscillator. The complex ratio E_g/E_p is a function entirely of the constants outside of the tube (*i.e.*, independent of the tube characteristics), provided the grid current and the effect of resistances on the oscillation frequency are assumed negligible.

Expressions for E_g/E_p are given for several types of oscillators, which are derived from a general oscillator network containing three parallel resonant circuits connecting the plate, grid, and filament. All ordinary oscillators are subderivatives of these types and their expressions for E_g/E_p are easily obtained by applying special conditions. Numerical computations have been made for practically all special oscillators and the resulting values for ϵ and Φ are illustrated by curves from which considerable information concerning the operating behaviours of oscillators can be obtained.

In a two-mesh oscillator there are two frequencies, at either of which the oscillation may take place. It is shown that only the wave which gives the correct Φ can be excited.

Experimental check of the theory has been found quite satisfactory in most cases.

La Mesure du Rendement des Générateurs à Lampes à l'Aide du Photo-Élément (The Measurement of the Efficiency of Valve Oscillators with the help of a [Copper Oxide] Photoelectric Cell).—J. Groszkowski. (*L'Onde Élec.*, December, 1931, Vol. 10, pp. 541–545.)

Thermometric methods of measuring oscillator efficiencies, such as the writer's 1925 method and Crossley and Page's surface pyrometer procedure (1929 Abstracts, pp. 48–49) have the inconvenience that the stabilisation of temperature at each measuring point requires a delay of 10 to 15 minutes, so that a complete efficiency measurement takes at least one hour. The thermal inertia of the anode itself, however, is comparatively small, and its temperature stabilisation requires a delay of only about one minute. The use, therefore, of the Lange-Schottky copper–copper oxide cell, type C ("Tungsram"), which is sensitive to infra-red radiation, is particularly convenient. The photoelectric cell is enclosed and provided with an optical system in quartz, which gives a clear image of the anode while dispersing that of the walls of the valve.

Historical Review of Ultra-Short-Wave Progress [chiefly in the Generation of Oscillations].—W. H. Wenstrom. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 95–112.)

Author's summary :—"This paper is a historical review up to the year 1931 of the more significant experiments with radio ultra-high frequencies and ultra-short waves. Developments are classified, in accordance with the type of oscillation generator employed, under four main heads : spark oscillators, regenerative oscillators of conventional type, electronic oscillators of Barkhausen-Kurz and Gill-Morrell type, electronic oscillators of the magnetron type. Within these four divisions arrangement is chronological." A selected bibliography of 54 items ends the paper.

An Experimental Study of Regenerative Ultra-Short-Wave [3-Metre] Oscillators.—W. H. Wenstrom. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 113–130.)

Author's summary :—This paper gives a quantitative account of operating performance for two representative oscillator circuits, one of single tube type and the other of two-tube balanced type. Wavelength (approximately 3 metres) was measured by two independent methods. Efficiency and stability were measured under various plate, grid and filament voltage conditions. Normal efficiency values ranged from 20 per cent. to 40 per cent. Under certain conditions the single tube circuit was more efficient, while under certain other conditions the balanced circuit was more efficient ; under most conditions the efficiencies were about equal. In stability the two circuits were about equal ; frequency variations were less than 1 per cent., while output variations rarely exceeded 2 per cent.

Radio Telephony by Ultra-Short [50-Centimetre] Waves.—Uda. (*See* under "Reception.")

Constant Frequency Oscillators.—F. B. Llewellyn. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2063–2094.)

Author's summary :—The manner in which the frequency of vacuum tube oscillators depends upon the operating voltages is discussed. The theory of the dependence is derived and is shown to indicate methods of causing the frequency to be independent of the operating voltages. These methods are applied in detail to the more commonly used oscillator circuits.

Experimental data are cited which show the degree of frequency stability which may be expected as a result of application of the methods outlined in the theory, and also show that the best adjustment is in substantial agreement with that predicted by theory. With a carefully built and adjusted oscillator the effects of normal variations in the operating voltages are negligible in comparison with the effects of temperature variations resulting from the changed operating currents. Methods of preventing these latter effects are not discussed in the present paper.

The appendix contains an analysis of the conditions under which the performance of an oscillator may be represented by the use of linear circuit equations.

A Recent Development in Vacuum Tube Oscillator Circuits: Correction.—Dow. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, p. 182.)

A correction to an equation in the paper dealt with in February Abstracts, p. 93.

The Dynatron Oscillator: Ease of Modulation and Use as Beat-Frequency Oscillator: The Frequency Formula and the Influence of the Varying Negative Resistance.—Wm. D. Oliphant: F. P. Basto: Colebrook. (*Wireless Engineer*, Dec., 1931, Vol. 8, pp. 661–662.)

Letters prompted by Colebrook's article dealt with in January Abstracts, p. 34.

RECEPTION.

Über die Wirkung des Pendelrückkopplers (The Action of the Super-regenerative Receiver).—G. Gorelik and G. Hintz. (*Zeitschr. f. Hochf:tech.*, Dec., 1931, Vol. 38, pp. 222–228.)

From the Moscow ultra-short-wave laboratory. In the absence of signals, three different zones are distinguished, depending on the part of the valve characteristic over which the action takes place, and the relation of this part to the superimposed Rukop "reiss" diagram defining the starting and breaking-off of the receiver oscillations. These zones are: i.—the region of "modulation," where the radio frequency ω suffers amplitude variation by the low frequency Ω; ii.—the region of "mush," caused by irregular impulses which resuscitate the r.f. oscillations after they have been quenched by the l.f.; and iii.—the region "without self-excitation," where ΩV_{eff} is so great that the r.f. oscillations have no time to build up (V_{eff} being the effective value of the l.f. auxiliary potential on the grid). Of these three zones, the "modulation" zone corresponds to what David calls "super-regeneration *B* (stroboscopic)"—*see* 1928 Abstracts, p. 519: the relations between the other two zones and David's conditions *A* and *C* "are not clear to us." The explanation of the "mush" is on lines similar to those of Ostroumow (*T.i.T.b.P.*, 1927), but the irregular impulses arise not only from atmospherics but also from battery voltage fluctuations, mechanical vibrations, "shot" and thermal effects, etc. The effect of incoming signals is different in the three zones: this is discussed in Sec. 4 (pp. 224–225).

Theoretical and experimental proof is given of the existence of a "multiple resonance" corresponding to resonance points $p \pm n\,\Omega = \omega$, where p is the signal frequency and $n = 0, 1, 2. . . .$ In cases i and ii, in the neighbourhood of each of these points a phenomenon occurs which is very similar to the "mitnahme" (pull-in) effect in an ordinary reaction circuit: in case i ("modulation") the combination notes disappear; in case ii ("mush") the mush vanishes. If signals are strong enough, the separate silence zones blend into one another. The dependence of this phenomenon of multiple resonance on the oscillating conditions and the amplitude of the signals is examined; it explains the existence of a reception threshold. The smaller Ω is, the closer together are the multiple resonance points, and the smaller the threshold value E_0 of the signals, for which the central silence zone can form itself. Thus in practical ultra-short-wave reception Ω is so small that the multiple resonance points are not usually noticed, since they merge into one. Small values of Ω and the consequent partial superposition of the resonance curves produce blunt tuning and an enhanced amplification: an increase of Ω sharpens the tuning and decreases the sensitivity.

Throughout the investigation, the frequency modulation caused by the periodic grid-potential fluctuations has been neglected: this frequency modulation, which is fairly important in ultra-short-wave reception, requires examination. The researches were carried out with push-pull circuits, and the l.f. oscillations were applied to the grid. Single wave circuits, and the application of the l.f. to the anode, would produce similar results with some quantitative differences.

Radio Telephony by Ultra-Short [50-Centimetre] Waves.—S. Uda. (*Japanese Rad. Res. Committee*, Reports presented to U.R.S.I. Assembly, 1931, 3 pp.)

In the writer's previous tests (1930 Abstracts, p. 568) the transmitter and receiver were entirely different in construction, so that two-way communication required a separate transmitter and receiver at each station. In the arrangement now described, advantage is taken of the fact that an oscillator of Barkhausen type behaves excellently as a regenerative detector: actually, super-regeneration is employed, a locally generated oscillation of several hundred metres being applied to the plate of the electronic detector valve. As a result, a simple two-way ("change-over") system of telephony or I.C.W. telegraphy has been developed with a range of 30 km. (between Sendai and the peak of Otakamori).

Historical Review of Ultra-Short-Wave Progress.—Wenstrom. (*See* under "Transmission.")

Quantitative Untersuchungen an Rundfunkempfängern (Quantitative Investigations on Broadcast Receivers. Part II.—Measurements on Receivers).—A. Harnisch. (*Zeitschr. f. Hochf:tech.*, Dec., 1931, Vol. 38, pp. 209–222.)

The first part of this paper was dealt with in February Abstracts, p. 94. This second and final part deals with actual measurements on a number of German and American 3- to 7- valve (1- to 4-circuit) receivers, which are not named. Section A deals with the r.f. stages: as regards aerial coupling, this has been dealt with so thoroughly that the writer merely refers to Zepler's paper in the 1926 *Telefunken-Zeit.*, No. 44, and to Rechnitzer's work in the same journal (1929 Abstracts, pp. 510 and 511). He then considers the r.f. amplifying stages and their various methods of coupling, particular attention being paid to the screen-grid valve with transformer coupling. Stability, selectivity and side-band cutting are investigated, and sub-section 6 (pp. 218-219) examines in detail the advantages and disadvantages of damping-reduction by retroaction. The writer emphasises that experience has shown the advantage of starting with good circuits and treating retroaction only as a " reserve," applying it only to one circuit. Latest practice is to choose the grid circuit of the detector as this one circuit: next to the input circuit (which is put out of court by the danger of re-radiation) it is the most highly damped circuit, whether grid or anode detection is employed. The end of the sub-section deals with de-tuning by retroaction adjustment, and its avoidance (Fig. 25 shows complete success in this, by the use of a screen-grid valve and a retroaction coil capacitively decoupled with respect to the grid circuit).

Section B deals with the detector and the l.f. stages. " Measurements on a number of receivers show that the great majority, when supplied with the r.f. potentials necessary to give loud-speaker strength in a room from a 70% modulated transmitter, function according to the square law; *i.e.*, they give non-linear distortion corresponding to a ' klirr '-factor of $m/4$, where m is the degree of modulation. Modern transmitters are already modulated 70% and more, and it is therefore high time that German receiver design should be converted to linear detection" [detection at high potentials, either grid or anode bend; references to Ballantine and Schäfer]. *Cf.* Greenwood and Preston, below.

To-day's receivers are also far from ideal with regard to linear distortion, and this is dealt with on pp. 220 and 221. The l.f. stages are practically free from distortion. Finally, Fig. 31 shows the sensitivity curves of a number of receivers measured according to the I.R.E. standard tests. " Reception of the big European stations on an indoor aerial, with receivers commonly used in Germany, is only possible by the use of strong retroaction." But this involves a serious cutting of side-bands, and consequent distortion (Figs. 24 and 25).

Quality Detectors: a Survey of Rectification.—Greenwood and Preston. (*See* under " Properties of Circuits.")

Physical Reality of Side-Bands [and the Relative Height of the Three Peaks].—F. M. Colebrook. (*Wireless Engineer*, Dec., 1931, Vol. 8, p. 660.)

In his paper dealt with in 1931 Abstracts, p. 153, the writer showed as a fact of experiment that with large amplitude or linear rectification of a modulated wave received on a very selective circuit, the resonance curve of modulation frequency output voltage gave side peaks *taller than the centre peak*. This result is now found to be in accord with theory: the height of the centre peak, in volts, will be approximately equal to the height of the side peaks multiplied by the modulation percentage. This implies that between certain limits of relative intensities in heterodyne reception, a larger output will be obtained with linear rectification *when the set is tuned to the weaker of the two e.m.f.s.* Moreover, Moullin's result, that tuning to a side wave introduces a second harmonic component into the modulation wave form, appears to be a particular case of a more general proposition that any process of reception which impairs the original phase and amplitude symmetry of the three components of a pure tone-modulated wave will introduce, with linear rectification, not merely the second harmonic but the full range of harmonics.

Selectivity and Tone Correction.—F. M. Colebrook. (*Wireless World*, 30th December, 1931, and 6th January, 1932, Vols. 29 and 30, pp. 734–736 and 14–16.)

This article is virtually a continuation of a previous article by the same author (1931 Abstracts, p. 614). It is mainly a refutation of the argument that tone correction, in restoring the audio-frequencies lost in highly selective tuning arrangements, also brings back the unwanted interference. Immunity in respect of *heterodyne* interference involving the carrier of the wanted transmission, however, " cannot be obtained by any normal arrangement of tuned circuits without some sacrifice of quality . . ."

Background Noises.—W. T. Cocking. (*Wireless World*, 30th December, 1931, Vol. 29, pp. 728–729.)

The causes and alleviation of background noises in modern radio receivers.

The Receiver of the Future.—(*Wireless World*, 27th January, 1932, Vol. 30, pp. 90–91.)

Some preliminary technical notes on the development of a receiver based on the principle of achieving distortionless selectivity by critical retroaction and subsequent tone correction in the a.f. amplifier. The broad principles of the arrangement have been dealt with previously (1931 Abstracts, p. 614).

The Stenode Radiostat.—F. G. Philpott: G.W.O.H. (*Wireless Engineer*, Dec., 1931, Vol. 8, pp. 662 and 637–638.)

A letter from the London Secretary of the Corporation with the object of correcting two suggestions about the S.R. receivers at Olympia (*ibid.*, Nov., 1931, pp. 587–588): i.—that the crystal gate was absent owing to its leading to difficulty in handling the receiver, and to its being unreliable for the reception of stations not crystal-controlled; and ii.—that it is possible to obtain " equivalent performance in a superheterodyne receiver using band-pass couplings." In an editorial, G.W.O.H. discusses this letter.

A NEW LIGHT-WEIGHT RECEIVER FOR SMALL AEROPLANES.—Standard Telephones and Cables, Ltd. (*Wireless World*, 27th Jan., 1932, Vol. 30, p. 95: *Electrician*, 22nd January, 1932, Vol. 108, pp. 91–92.)

A 4-valve equipment weighing 19½ lb. complete (receiver only, 4 lb. 10 oz.). The ordinary speaking-tube equipment is modified by replacing the usual by-pass unit (enabling pilot and passenger to hear their own speech) by a special unit containing a small loud speaker unit connected to the receiver. Thus the wireless signals are heard by both pilot and passenger without special earpieces in the helmets. Two screen-grid r.f. stages are included: single knob control covers a wave-range of 600 to 1 000 metres.

NEW BAND PASS CIRCUIT.—N. R. Bligh. (*Wireless World*, 6th January, 1932, Vol. 30, pp. 2–4.)

It is shown that by the employment of a suitable capacity coupling at both the high and low potential ends of a band pass filter circuit, it is possible to obtain the same constancy of peak separation as is obtained with a mixed capacity and inductance coupling.

ÜBER ART UND URSACHE DER VON HOCHSPANNUNGSFREILEITUNGEN AUSGEHENDEN STÖRUNGEN DES RUNDFUNKEMPFANGS (On the Nature and Causes of the Interference with Broadcast Reception proceeding from H.T. Overhead Lines).—J. Herweg and G. Ulbricht. (*Zeitschr. f. Hochf: tech.*, Dec., 1931, Vol. 38, pp. 228–230.)

i.—Interference produced by the line frequency and its harmonics: this can be almost eliminated by careful screening of the receiver, particularly the amplifier and its valves; but complete elimination is only possible if aerial or frame lies at right angles to the line. ii.—Radio-frequency interference: (*a*) from brush discharges, (*b*) from switching, commutator, and make-and-break processes on the low-tension side, the disturbances passing across the transformers to the h.t. lines.

As regards (*a*), the brush discharges are attributed to the binding wires, twisted by pliers, which fasten the lines to their insulators. *They occur, therefore, practically only on lines using bracket insulators*, since suspension insulators are not bound in this manner. A footnote mentions that so far as the writer knows, all new h.t. lines are using the latter type. Secondary sources of brush discharges are binding wires at joints, but these give little trouble compared with the far more numerous points of attachment. These brush discharge interferences occur when the service voltage is as low as 6 kv., are very bad for voltages 15 to 25 kv., and still worse for 40 kv.

The section on (*b*) is short. The final section gives results of measurements, Fig. 3 being a curve showing the decrease of interference strength with increasing distance at right angles to the line, and Fig. 4 showing the strength distribution of the r.f. interference over the frequency spectrum: pronounced maxima are seen at 400 and 1 100 metres.

OVERLOAD LIMIT EXTENSION OF THE TETRODE DETECTOR [AUTOMATIC GRID BIAS REGULATION EXTENDED TO FILAMENT-TYPE DETECTORS].—P. O. Farnham. (*Electronics*, Dec., 1931, p. 228.)

The usual procedure for indirectly heated detectors, by which the cathode current is made to flow through a resistance and the resulting d.c. bias is applied to the input circuit control grid, cannot be applied unchanged to apparatus using filament-type valves unless a separate filament or plate battery is employed for the detector. The solution here described depends on the insertion of a resistance in series with the screen-grid battery so that an increasing carrier input increases the d.c. screen-grid current and thereby reduces the steady s.g. voltage below that of the battery.

AN UNTUNED RADIO-FREQUENCY AMPLIFIER [USING AN INTERVALVE TRANSFORMER WITH ASSOCIATED TIGHTLY-COUPLED CIRCUIT TUNED TO A HIGH FREQUENCY].—Schor. (*See* under "Properties of Circuits.")

DAMPING AND ITS REDUCTION IN COUPLED CIRCUITS [IN CONNECTION WITH SELECTIVE AND DISTORTION-FREE BROADCASTING RECEIVERS].—Eilers. (*See* under "Properties of Circuits.")

CAN RADIO SETS BE SOLD TO EUROPE? [WITH STATISTICS].—S. E. Laszlo. (*Electronics*, Dec., 1931, pp. 299–230.)

AERIALS AND AERIAL SYSTEMS.

VORLÄUFIGER BERICHT ÜBER VERSUCHE ZUR BEKÄMPFUNG DER SCHWUNDERSCHEINUNGEN IM RUNDFUNK MIT ANTENNENGEBILDEN ÜBLICHER HÖHE (λ/4) UND GRÖSSERER HORIZONTALAUSDEHNUNG (Preliminary Communication on Experiments on the Prevention of [Short Range] Fading in Broadcast Transmissions with Aerial Systems of Ordinary Height—Quarter Wavelength—and Great Horizontal Spread [Suppression of Space Wave]).—H. Harbich and W. Hahnemann. (*E.T.Z.*, 17th Dec., 1931, Vol. 52, pp. 1545–1549.) *See* 1931 Abstracts, p. 499.

A description of tests undertaken jointly by the German P.O. and the Lorenz Company, with a view to the reduction of the space radiation by the use of a system of short vertical aerials, each suitably fed as regards amplitude and phase, arranged either as a ring surrounding one of them as a centre, or as two or more concentric rings without a central element. The present paper deals chiefly with the simple, fundamental arrangement of three such aerials in a row, the important influence of the spacing of the elements, and of the relative amplitudes and phases of the middle and end elements, being thus conveniently studied. But preliminary tests on the ring-shaped systems showed that the results obtained with the simple 3-aerial row could be applied to the practical ring systems.

The choice of the best design, to give the greatest possible suppression of space wave together with sufficiently good ground-wave efficiency, in each practical case and for a given wavelength, must be a compromise involving element-spacing, mast-height, and the ratio of current amplitudes.

RADIATION RESISTANCE OF COMPLEX ANTENNAS.—K. Tani. (*Japanese Rad. Res. Committee*, Reports presented to U.R.S.I. Assembly, 1931, 13 pp.)

Pistolkor's work is restricted to the case where all elements oscillate in the same phase or anti-phase. The more general case where the elements oscillate in any phase is here considered, an expression being found for R_{AB}, the increase of radiation resistance of a doublet B due to the presence of a parallel doublet A, the distance between the axes being d and the axial displacement h, while the oscillation current in B lags by ϕ from that of A. R_{AB} can be evaluated for any value of ϕ provided two values R'_{AB} and R''_{AB}, the resistances for $\phi = 0$ and $\phi = \frac{\pi}{2}$, are known. These can be calculated from equations 8 and 9, p. 3, but for practical purposes they are tabulated for several values of d and h in Tables I to VI.

Various applications are described : the radiation resistance of a system of doublets can be calculated by the summation of the increase of radiation resistance due to each of them : the e.m.f. induced in B by a current in A can be found, etc.

A GRAPHICAL SYNTHESIS OF AERIAL ARRAYS.—A. W. Ladner. (*Marconi Review*, November–December, 1931, No. 33, pp. 11–18 and plate.)

Author's summary :—The following article describes a simple method of calculating graphically the polar diagrams, both in a vertical and horizontal plane, of any array of spaced aerials. The basis of the method is the combination of two diagrams [the "spacing diagram" given by two spaced point sources, depending for its shape on their distance apart in terms of wavelength and on their phases, and the "unit diagram" which is dependent on the diagrams of the sources themselves], both of which are easily constructed from a knowledge of the array constants.

STRAHLUNGSMESSUNGEN AN EINER MODERNEN TELEFUNKEN - RICHTANTENNEN - ANLAGE DER GROSSFUNKSTELLE NAUEN (Radiation Measurements on a Modern Telefunken Beam Aerial System at the Nauen High-power Station).—K. Krüger and H. Plendl. (*Zeitschr. f. Hochf: tech.*, Dec., 1931, Vol. 38, pp. 205–209.)

Theoretical and experimental (aeroplane) determination of the vertical polar diagram of the Nauen N. American service aerial (DFA, $\lambda = 15.59$ m. ; 192 horizontal dipoles), and experimental determination also of the horizontal radiation measured at 3 different levels (2°, 7° and 13°). Diagrams for the calculated vertical radiation are given for the two cases where the effect of the earth is neglected and where the earth is assumed to be a perfect reflector. Comparison between the calculated and measured diagrams shows that only the "perfect reflector" case can be considered, as was found in previous tests ; this diagram agrees well with the experimental diagram (up to about 30°) except that the second subsidiary maximum, at about 27°, is from 2.1 to 2.5 times as large in the experimental diagram as in the calculated. This second subsidiary maximum looks, in the diagrams, as if it were the first : this is due to the first subsidiary maximum, calculated at 18°, being too small to be visible ; it is, however, shown in Fig. 6c, which gives the calculated vertical characteristic in rectangular co-ordinates.

Possible causes of the discrepancy in the magnitudes of the second subsidiary maximum are discussed (pp. 207–208) but no satisfactory explanation is found. As regards the main ray, which is broader and blunter in Fig. 4 than in Fig. 3 (measured diagrams for March, 1931, and June, 1930, respectively), it is mentioned that the ground was much wetter in the former case. The sharper ray for the dry earth is more like the calculated ray in this respect, but on the other hand its angle of elevation is 6°, whereas the broader ray for the wet earth has an angle of 7°, which agrees exactly with the calculated diagram.

The horizontal radiation is dealt with on p. 208, Fig. 5, showing the results measured at heights of 225, 725 and 1 280 metres. The proportion of the subsidiary maxima to the main ray is shown to decrease continually as the height increases. The field strengths of the main ray at these heights are about 55, 100 (this height corresponds to 7°) and 27, in relative values.

For previous work of a similar nature on other Nauen aerials, *see* Abstracts, 1930, p. 631, and 1931, p. 385—two.

A HALF-WAVE MAST ANTENNA.—(*Radio Craft*, Nov., 1931, p. 269.)

Description of a steel mast mounted on a porcelain base and used as a half-wave aerial.

FEEDER ADJUSTMENTS FOR SHORT WAVE VERTICAL AERIALS.—N. Wells. (*Marconi Review*, November–December, 1931, No. 33, pp. 1–10.)

Notes on "matching the impedance at the base of an aerial to the natural or surge impedance of a particular form of feeder, the Marconi Concentric type."

VALVES AND THERMIONICS.

UNTERSUCHUNGEN ÜBER DEN DURCHGRIFF VON EMPFÄNGERRÖHREN (Researches on the Penetration Coefficient or Mutual Controllance of Receiving Valves).—F. Greve. (*Zeitschr. f. Hochf: tech.*, Dec., 1931, Vol. 38, pp. 234–237.)

Jena Dissertation, 1930. An investigation to determine under what conditions the quantity D ($= 1/\mu$) varies, and the extent of the variations for various types of receiving valve. The "Hausser" method used by van der Pol, wherein a variation of D is evident as a deviation from the straight line in the E_g/E_a curve for constant emission current, was applied, and the results simultaneously controlled and compared by a bridge arrangement (Marten, Schottky) specially modified to extend to values of D both negative and greatly exceeding 100%. Numerous curves are given. Among the results are the following :—no connection was found between the appearance of negative " durchgriff " and Barkhausen oscillations. Variation of D with variation of heating only occurred when D would also be changed by a change of anode potential : and in such a case (*e.g.*, with an RE 86) a change in heating produced the same effect as a 10-times greater change of anode potential. A clear connection between variation of D and size of grid mesh could not be found.

An Experimental Study of the Tetrode as a Modulated Radio-Frequency Amplifier [particularly for Radiotelephone Transmission on Frequencies of and above 500 kc.].—H. A. Robinson. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 131–160.)

Author's summary :—" The advantages and limitations of the tetrode employed as a modulated radio-frequency amplifier tube are considered and the results of an experimental study made upon one type of screen-grid tube are given. Oscillograms and characteristics are presented from which the operation of the type UX-865 tetrode can be predicted under varied operating conditions and for several methods of modulation.

" The method of graphical analysis is employed to determine the relative effects of the circuit parameters and electrode voltages upon the performance of the tetrode as a modulated amplifier.

" A method of modulation is described in which the modulating signal voltage is introduced in both the screen-grid and plate circuits, eliminating the detrimental effects of secondary emission and permitting the complete modulation of the radio-frequency carrier with a negligible degree of distortion, the tetrode performing in a manner similar to that of a neutralised triode."

The author concludes that the advantages of the tetrode, particularly the elimination of all neutralising devices and their critical adjustments, are especially useful for aircraft and other portable transmitters requiring rapid changes of the operating frequency over wide ranges, and for signal generators. The several methods of modulating the tetrode each have their advantages and their limitations.

A German 150 kw. Niobium-Cathode Valve.—(*See* abstract under " Miscellaneous "—Harnisch.)

The Characteristic Surfaces of the Russian Valve Type J_{-1}.—W. Patruschew. (*Zeitschr. f. Hochf : tech.*, Dec., 1931, Vol. 38, pp. 231–232.)

An Electromagnetically Controlled Three-Electrode Vacuum Tube.—F. B. Haynes. (*Physics*, Sept., 1931, Vol. 1, No. 3, pp. 192–193.)

Filamentless [Cold Cathode] Radio Tubes [on Glow-Discharge Principle].—M. Güntherschulze and F. Keller. (Summary in *Electronics*, Dec., 1931, p. 242.)

Discharges are produced in a rare gas at a few tenths of a millimetre pressure, between a magnesium disc and a nickel gauze (56% empty surface). An iron disc a short distance behind the nickel cathode acts as a third electrode. Kossel's 1921 article is discussed. *See* also 1930 Abstracts, pp. 571 and 632.

A Self-Stopping D.C. Thyratron Circuit [using a Glow-Discharge Tube].—H. J. Reich. (*Electronics*, Dec., 1931, p. 240.) *See* also Feb. Abstracts, p. 98 (Weiller).

Distortion in Valve Characteristics.—G. S. C. Lucas. (*Wireless Engineer*, Nov., 1931, Vol. 8, pp. 595–598.)

From the British Thomson-Houston laboratories. With valves where the characteristic curvature introduces harmonics other than the second (*e.g.*, pentode and screen-grid valves), the percentage distortion must be obtained from the ratio of the amplitude of the *largest* harmonic to that of the fundamental. The writer gives a simple arithmetical method for determining the amplitudes of the second, third and fourth harmonics with fair accuracy from the characteristic curves of the valves. P. K. Turner (*ibid.*, December, 1931, pp. 660–661) criticises this method as failing if there are harmonics above the fourth, and recommends the use of a complete 12-ordinate scheme, or for economy of labour a 6-ordinate scheme which he has developed in a special manner.

The Variation of the Resistances and Inter-electrode Capacities of Thermionic Valves with Frequency.—W. E. Benham : Hartshorn. (*Wireless Engineer*, November, 1931, Vol. 8, pp. 600–602.)

Continuation of the discussion on Hartshorn's paper (1931 Abstracts, p. 618) and particularly on the ratio of " hot " and " cold " capacities. Hartshorn's experimental result that the electrons *increase* the capacity " is adequately explained " by the fact that, in the triode case with grid negative, the input impedance is so high that the term involving the inertial effect of the electrons loses its importance ; whereas with Benham's diodes (1931 Abstracts, p. 212) such is not the case, and values of the " hot "/" cold " capacities as low as 3/5 are obtainable experimentally.

Cobalt Alloy Filaments [with Tensile Strength Four Times that of Nickel].—De Forest Company. (*Electronics*, Dec., 1931, p. 232.)

Über den Ausbrennvorgang der im Vakuum geglühten Drähte.—I. (On the Burning-Out Process of Wires Heated in Vacuo.—I.)—L. Prásnik. (*Zeitschr. f. Phys.*, 1931, Vol. 72, No. 1/2, pp. 86–94.)

This paper contains a theoretical investigation of the decrease with time of the mean filament diameter and temperature of a glowing wire heated *in vacuo* by a direct current at constant voltage. Assuming that the weakest spot of the wire (that of smallest diameter) is known, the total decrease in wire diameter up to the point when it burns out is calculated by expressing the mode of dependence of the evaporation on temperature by an exponential function or by the Nernst formula.

The Emission of Positive Ions from Cu and Ag.—H. B. Wahlin. (*Phys. Review*, 1st September, 1931, Series 2, Vol. 38, No. 5, p. 1074.)

" By using an electrometer with a sensitivity of 3×10^{-16} amp./mm. for measuring the current, it has been possible to detect Cu^+ ions from Cu and Ag^+ at temperatures just below the melting point and above."

DIRECTIONAL WIRELESS.

Variation of Bearings observed in Short-Wave Direction-Finding [on a Small Rotating Frame].—M. Asukai and T. Hayasi. (*Japanese Radio Research Committee*, Reports presented to U.R.S.I. Assembly, 1931, 2 pp. and plates.)

At 177 km., direction finding on 30 to 150 m. waves was practically impossible, zeros being very broad and signals often showing no direction at all, or sometimes giving a fairly clear but quite wrong bearing, which varied with the time of day. Occasionally the bearing seemed to oscillate from time to time about a definite direction—roughly the true bearing. The shorter the wavelength and the nearer to night, the more difficult was it to find the direction.

At 18 km., direction finding was possible within a few degrees, but the error was liable to increase with decrease of wavelength, as at the greater distance. " Unexpectedly we found that this amount of divergence varies with the time." The curves for both long and short distances seem to be nearly symmetrical about the local noon at the mid-point between the stations. " These figures suggest that there may exist a certain agency to cause variation of bearings of a short-wave transmitter " *even at short distances*. If this agency is a deflecting or reflecting layer, it would appear likely that this must be at a distance comparable with such short distances.

Australian R.R.B. Results with the Cathode-Ray Direction Finder. (*See* under " Atmospherics.")

Night Errors and the Polarisation of Down-Coming Waves.—Appleton. (*See* abstract under " Propagation of Waves.")

Direction Finding for Aviation, especially for the Luft-Hansa Line.—E. Schwandt. (*Funk*, 16th Oct., 1931.)

Theory of Design and Calibration of Vibrating Reed Indicators for Radio Range Beacons.—G. L. Davies. (*Proc. Inst. Rad. Eng.*, Jan., 1932, Vol. 20, pp. 161–181.)

See 1931 Abstracts, p. 559.

Airplanes See Through Fog with New Photocell Device.—Langmuir and Westendorp. (*Sci. News Letter*, 12th December, 1931, Vol. 20, p. 372.)

Cf. 1931 Abstracts, p. 560. It is suggested that special beacons should be fed with 1 000-cycle current, to distinguish their light from other lights.

ACOUSTICS AND AUDIO-FREQUENCIES.

The Effective Mass of Flexible Discs and Conical Diaphragms Used for Sound-Reproduction.—N. W. McLachlan. (*Proc. Physical Soc.*, 1 Jan., 1932, Vol. 44, Part 1, No. 241, pp. 88–97 : Discussion, pp. 98–100.)

Author's abstract :—An experimental method of measuring mechanical impedance, which is used to ascertain the effective mass of vibrating discs and conical diaphragms, is described. It is shown that the effective mass of a circular aluminium disc vibrating in air is zero at the centre-stationary and centre-moving modes. At a centre-stationary mode the effective mass attains a positive maximum before the zero value and a negative maximum thereafter. From the shape of the curves for a disc it is possible to interpret those obtained for conical diaphragms. In the latter case the curves depend upon the apical angle of the cone. Three types are illustrated : (a) a large cone having ψ equal to 160° ; (b) a loud-speaker cone having ψ equal to 90°, with reinforced edge ; (c) a loud-speaker cone having ψ equal to 90°, mounted on a rubber annulus. In case (a) the disc characteristics are clear, whilst in (b) and (c) the behaviour is modified owing to the greater degree of conicality. The rubber surround acts as an auxiliary resonant diaphragm, introducing an abrupt change in the effective mass. Finally, the effective mass of a rigid disc vibrating in a finite and in an infinite baffle is considered.

Additional Experiments on Moving Coil Reproducers and on Flexible Discs.—N. W. McLachlan. (*Phil. Mag.*, Jan., 1932, Series 7, Vol. 13, No. 82, pp. 115–143.)

This paper discusses various details of moving coil reproducers, including investigations on the modulus of elasticity of paper, the combination modes of a reed-driven paper disc, the case of a coil-driven circular aluminium disc, the influence of the magnetic field upon output and coil impedance of the reproducer, etc. " Lastly, a series of impulse records showing the natural damped oscillations of moving-coil reproducers of the horn and hornless (large diaphragm) variety are given." For other properties of the discs and diaphragms treated herein, *see* January Abstracts, p. 41, and above.

The Law of Similarity for the Natural Frequencies of Elastic Bodies and Particularly Loud Speaker Diaphragms.—E. Spenke. (*Wiss. Veröffent. a.d. Siemens-Konz.*, No. 4, Vol. 10, 1931, pp. 128–136.)

Über die Schallstrahlung einer mit Knotenlinien schwingenden Kreismembran (On the Sound Radiation from a Circular Diaphragm vibrating with Nodal Lines.)—M. J. O. Strutt. (*Ann. der Physik*, No. 2, Vol. 11, 1931, pp. 129-140.)

The diaphragm is assumed to be mounted in a large, plane and rigid wall. Mathematical expressions are derived for determining the radiation when both circular and radial nodes exist on the diaphragm.

A discussion of these formulae leads to the conclusion that the radiation is very small compared with that from a rigid piston of equal size, provided the radius of the membrane is small compared with the wavelength in air; or if these are comparable, provided the lowest natural membrane frequency is deep enough for the corresponding air wavelength to be large compared with the diameter. But if the lowest natural frequency is so high that the corresponding air wavelength *is equal to or smaller than* the membrane diameter, the radiation may become considerable owing to a certain resonance effect—and at all frequencies.

ÜBER DIE THEORIE UND ANWENDUNG DES HORNLAUTSPRECHERS (The Theory and Application of the Horn Loud Speaker [and the Superiority of the Exponential Horn]).—H. Stenzel. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 621–627.)

i.—The difficulty of obtaining uniform radiation at different frequencies by membranes without horns (particularly for large outputs). ii.—The effect of a membrane with an air chamber at the entrance to the horn. iii.—The radiation impedance of various shapes of horn, and the reason for the superiority of the exponential shape. But the dimensions must be large enough, or reflection at the mouth will nullify the advantages.

ÜBER DIE ERZEUGUNG VON SCHALLVORGÄNGEN DURCH DAS ELEKTROSTATISCHE FELD (The Generation of Sound by the Electrostatic Field [and the " Statophone " and " Oscilloplane " Loud Speakers]).—H. Vogt. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 632–639.)

A particularly long section (II) deals with the problems presented by the choice of materials, and describes how certain irregularities in the behaviour of bakelite (hitherto standing in the way of its employment in positions of accuracy) were elucidated and cured by suitable thermal after-treatment. For previous papers on the " Oscilloplane " loud speaker, *see* Abstracts, January, p. 42, and 1931, pp. 45 (Schwandt) and 389.

EIN- UND AUSSCHWINGVORGÄNGE AN ELEKTRODYNAMISCHEN LAUTSPRECHERN MIT STARKEN MAGNETFELDERN (Building-Up and Decay Processes in Electrodynamic Loud Speakers with Strong Magnetic Fields).—H. Neumann. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 627–632.)

From the Siemens laboratories. The use of specially strong magnetic fields (up to 20 000 gauss) not only increases the efficiency of a loud speaker (*see* same writer, Abstracts, 1930, p. 163; 1931, pp. 158 and 389) but also improves the quality of reproduction by greatly increasing the damping of the natural membrane frequencies, so that the building-up and decay processes are considerably shortened. This is illustrated by a number of frequency curves and oscillograms of the building-up and decay processes, for different strengths of field.

BERECHNUNG VON LAUTSPRECHERN MIT STARRER KREISMEMBRAN (The Calculation of Loud Speakers with Rigid Disc Membranes).—W. Hähnle. (*Wiss. Veröffentl. a.d. Siemens-Konz.*, No. 4, Vol. 10, 1931, pp. 73–116; summary in *Physik. Ber.*, 1 Dec., 1931, Vol. 12, pp. 2806–2807.)

THE LOUD SPEAKER EQUIPMENT OF THE STADIUM OF THE DARMSTADT TECHNICAL COLLEGE.—F. Schilgen and C. Starkloff. (*E.T.Z.*, 31 Dec., 1931, Vol. 52, pp. 1589–1591.)

THE RECORDING OF TRANSIENTS BY THE C.-R. OSCILLOGRAPH.—Hollmann. (*See* abstract under " Subsidiary Apparatus and Materials.")

HIGH POWER RADIATORS FOR FREQUENCIES BELOW 100 CYCLES PER SECOND.—E. W. Kellogg. (Summary in *Sci. Abstracts, Sec. B.*, Nov., 1931, Vol. 34, p. 635.)

CARBON MICROPHONES [A DEFENCE OF THEIR TRANSMISSION QUALITY].—S. T. Fisher. (*Electrician*, 8th Jan., 1932, Vol. 108, p. 44: Reply, *ibid.*, 22nd Jan., p. 104.)

MICROPHONE TECHNIQUE IN RADIO BROADCASTING.—O. B. Hanson. (Summary in *Sci. Abstracts, Sec. B.*, Nov., 1931, Vol. 34, p. 626.)

THE RECORDING OF SOUND FILMS IN THE TOBIS AND KERR-KAROLUS (KLANGFILM) SYSTEMS.—(*Génie Civil*, 26th Dec., 1931, Vol. 99, pp. 654–655.)

Including a diagram and description of the Tobis recording lamp.

PHYSICS IN SOUND RECORDING.—A. Whitaker. (*Journ. Scient. Instr.*, Dec., 1931, Vol. 8, pp. 396–398.)

Summary of a recent lecture. One point mentioned is the successful elimination of ground noise in sound-on-film recording by diverting a portion of the a.f. currents in the recording amplifier, rectifying them, and after a certain amount of smoothing (the smoothing circuit having a time factor of the order of 1/50 sec.) causing the rectified current either to operate a separate shutter (variable area recording) or to control the mean slit width (variable density recording) *Cf.* Lewin, Jan. Abstracts, p. 43.

RESEARCHES ON THE FIGURE OF MERIT OF RECORDING IN SOUND-ON-FILM RECORDS [INCLUDING AN OBJECTIVE METHOD OF TESTING IT]: THE MEASUREMENT OF SENSITIVITY IN SOUND-ON-FILM RECORDING.—A. Küster and R. Schmidt. (*Veröffentl. Wiss. Zentral-Lab. Agfa*, Vol. 2, 1931, pp. 83–93: 94–103; long summaries in *Physik. Ber.*, 15th Nov., 1931, Vol. 12, pp. 2633–2634.)

PHYSICAL FACTORS AFFECTING THE ILLUSION IN SOUND MOTION PICTURES.—J. P. Maxfield. (Summary in *Sci. Abstracts, Sec. B.*, Nov., 1931, Vol. 34, p. 636.)

Gegenwärtiger Stand der photographischen Technik bei der Lichttonaufzeichnung (The Present Position of Photographic Technique in Sound-on-Film Recording).—J. Eggert. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 639–644.)

Lichtquellen für Tonfilmaufnahmen (Light Sources for Sound-on-Film Recording [and in particular the "Lichtspritze" Lamp]).—H. Ewest. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 645–647.)

The Triergon "ultra-frequency lamp": the somewhat similar lamp used by Schröter for picture telegraphy: the Osram tungsten arc lamp: the oxide-cathode "light-spray" lamp ("lichtspritze") giving a concentrated point of light for television purposes and following fluctuations up to and beyond 100 000 c.p.s.

Bestimmung des Auflösungsvermögens photographischer Schichten (Determination of the Resolving Power of Photographic Layers).—H. Frieser. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 661–663.)

Physical Properties and Construction of [Alkali] Photoelectric Cells for Sound-Film Purposes.—W. Kluge. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 649–661.)

Die Lichtverteilung im Aufnahmespalt beim Schwarz-Weissverfahren (The Distribution of Light in the Recording Slit in the Black-and-White [Amplitude] Process [including a Description of the Räntsch—Siemens and Halske—Optical System]).—H. J. Eilers. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 647–649.)

Photomicrographs of Gramophone Records [and the Use of a Thin Coating of Immersion Oil].—A. Morris Thomas. (*Journ. Scient. Instr.*, Nov., 1931, Vol. 8, p. 363.)

Wireless World Power Radio-Gram.—A. L. M. Sowerby and H. F. Smith. (*Wireless World*, 27th January and 3rd February, 1932, Vol. 30, pp. 80–84 and 106–109.)

A three-valve instrument deriving all its power from a.c. mains, in which everything has been subordinated to the requirements of realistic reproduction. It is not intended for use outside the normal service area of a Regional broadcasting station.

The Acoustic Resonator Interferometer: I. The Acoustic System and its Equivalent Electric Network.—J. C. Hubbard. (*Phys. Review*, 1st Sept., 1931, Series 2, Vol. 38, No. 5, pp. 1011–1019.)

Author's abstract:—The steady state of motion of a fluid between two infinite plane parallel boundaries is found for the case in which one of the boundaries is given a prescribed periodic motion normal to its surface, the other boundary being infinitely rigid or being assigned a coefficient of reflection. The excess pressure at any point in the fluid is found, being of particular interest at the boundary of the source where it has a term in phase with the velocity of the source and one in phase with its displacement. These terms pass through cyclical values as the distance between the source and reflector is increased, the first passing through sharp maxima, the second changing rapidly from negative to positive values at reflector distances of an integral number of half wavelengths in the fluid. Application is made to the case where the source is the surface of a piezo-electric plate maintained in forced vibration. The equivalent electric network of the plate and coupled fluid column is found to be the same as that for the plate alone, with modified resistance and capacity coefficients, making possible consideration of the theory of the acoustic resonator interferometer in conjunction with driving and measuring circuits.

Ein selbstanzeigendes raumakustisches Messgerät (A Direct-Indicating Acoustic Measuring Equipment [using the Hollmann-Schultes "Room Acoustic" Relaxation Oscillations]).—H. E. Hollmann and Th. Schultes. (*E.N.T.*, Dec., 1931, Vol. 8, pp. 539–543.)

A combination of the arrangement dealt with in February Abstracts, p. 99, with a direct-reading frequency meter.

Bibliography of the Acoustics of Buildings.—F. R. Watson. (*Journ. Acous. Soc. Am.*, Part 1, Vol. 3, 1931, pp. 14–43.)

Acoustics of a Building Improved 25 % by the Audience Standing Up.—S. K. Wolf. (*Sci. News Letter*, 19th December, 1931, Vol. 20, p. 397.)

Soundproof Partitions.—Notes from the U.S. Bureau of Standards. (*Journ. Franklin Inst.*, Jan., 1932, Vol. 213, No. 1, pp. 92–93.)

A note on the results of sound transmission measurements made on a set of wall panels constructed of cinder block and clay tile. The method is described in Bureau of Standards Scientific Paper S 526.

The Precision of Measurement of Absorption Coefficients by Reverberation Methods.—P. E. Sabine. (*Journ. Acous. Soc. Am.*, Part 1, Vol. 3, 1931, pp. 139–154.)

The Study of Sound-Insulating Building Materials by means of Electrical Measuring Apparatus.—Cellerier. (*Génie Civil*, 12th Dec., 1931, Vol. 99, pp. 601–603.)

Continuation of the work referred to in 1931 Abstracts, p. 273.

Measurement of Capacities at Audio-Frequencies by Double-Beat Method.—Colebrook. (*See* abstract under "Measurements and Standards.")

"A pure wave form is used in the measurement circuit, but this is made to control a distorted wave form in a detector circuit so that high harmonics can be used for frequency adjustment."

Measurements of Sound Reflection Coefficients of Materials for Defined Sound-Field Ratios.—L. Casper and G. Sommer. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, p. 1079.)

Interspaced [Audio-frequency] Transformer Windings [and the Production of Flat Response Curves without the use of Special Core Material or Change of Mass of Core or Copper].—W. J. Leidy. (*Electronics*, Dec., 1931, p. 233.)

Die Klangspektren der Musikinstrumente (The Sound Spectra of Musical Instruments).—E. Meyer. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 606–610.)

An analysis, by the Grützmacher automatic recording method, of the spectra of all kinds of commonly used orchestral instruments. The frequency range extended from 30 to 15 000 c.p.s., and the building-up, stationary, and decay zones are all dealt with. The writer concludes by pointing out that the characteristic quality of an instrument depends not merely on its spectrum but also on the course of the intensity of a note. The adjustable quality of the Bechstein-Siemens-Nernst piano (*cf.* Jan. and Feb. Abstracts, p. 44—Miessner—and p. 101—Schultz : Noack) is quoted as a good example of this.

Vowel Characteristics.—A. Stefanini. (*Nuovo Cimento*, No. 6, Vol. 8, 1931, pp. 213–216.)

An investigation of the damped oscillations of the vowels *a* and *e*. The possibility is discussed that the characteristic sound depends not only on the period but also on the extinction processes.

The Natural History of the Vibrato.—C. E. Seashore. (*Proc. Nat. Acad. Sci.*, 15th Dec., 1931, Vol. 17, pp. 623–626.)

Über den Zusammenhang zwischen Schallempfindung und Schallreiz, und seinen Einfluss auf die Hörbarkeit von Verzerrungen (The Connection between Auditory Sensation and the Effective Value of the Exciting Sound Pressure, and Its Influence on the Audibility of Distortions).—W. Janovsky. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 611–621.)

Sterilisation of Milk by High-Pitched Sound Waves.—N. Gaines and L. A. Chambers. (*The Times*, 1st Jan., 1932.)

See 1931 Abstracts, pp. 216 and 458—two. "Waves like those of a high-pitched musical note directed into the large end of an inverted funnel, through which milk was fed, were found to kill 99% of the bacteria . . . . Dr. Gaines said the 'sound steriliser' would sterilise any fluid containing bacteria, and it could be operated continuously. Thus milk might be fed into the steriliser as fast as it came from the dairy, and immediately put into bottles for use."

PHOTOTELEGRAPHY AND TELEVISION.

On the Physiology of Television [and the Cyclical Line-Shift Process].—E. Hudec. (*E.N.T.*, December, 1931, Vol. 8, pp. 544–554.)

Author's summary :—It is shown that the *apparent* reproduction in television, as perceived by the eye, is much better as regards sharpness of definition than the *actual* reproduction. This result is traced to the logarithmic sensitivity characteristic of the eye, and is confirmed by experiments which at the same time indicate the good effect of the line-shift process" (*see* 1931 Abstracts, pp. 506–507).

Multi-Channel Television.—C. O. Browne : Gramophone Company. (*Electrician*, 8th Jan., 1932, Vol. 108, p. 37.)

Summary of a recent paper to the I.E.E., on the five picture-channel system demonstrated by the Gramophone Company at the Physical and Optical Societies' Exhibition, 1931.

Über hochempfindliche Vakuum-Photoelektrishe Zellen (Vacuum Photoelectric Cells of High Sensitivity).—M. C. Teves. (*Zeitschr. f. tech. Phys.*, No. 11, Vol. 12, 1931, pp. 556–558.)

De Boer and the present writer found (1931 Abstracts, p. 103) that a displacement of the red limit and of the whole spectral sensitivity distribution towards longer wavelengths could be obtained by the adsorption of the alkali metals (particularly caesium) at sublimated layers of salts (BaF_2, CaF_2, NaCl, etc.). This was explained by the polarisation of the adsorbed Cs-atoms by the negative F-ions. Adsorption at oxide layers, especially CsO_2, led to still greater displacement and increase of sensitivity, values of 12×10^{-6} A/Lumen being obtained for a limiting wavelength of $1.1–1.2\mu$ with a maximum sensitivity at 6 100 A.U. and a quantum output of 1 : 50 (*i.e.*, 50 quanta liberate 1 electron). *Under practical conditions* (*e.g.*, for sound-film work) a gas-filled cell is limited to some $10 - 20 \times 10^{-6}$ A/Lumen, so that already the vacuum cell could begin to rival it in sensitivity, without possessing its disadvantages.

Now, however, it has been found possible to increase the output still further, without appreciably shifting the long-wave limit but with a displacement of the maximum sensitivity to between 6 800 and 8 000 A.U. The more the maximum is displaced towards the red, the higher becomes the sensitivity, and a value of 65×10^{-6} A/Lumen (about 1 electron per 10 quanta) has actually been obtained, though with production cells this is reduced to some 20 to 30×10^{-6} A/Lumen (1 electron per 20–25 quanta). All these values are taken at 2 680 degrees Kelvin. The new results are obtained by the adsorption of the caesium at very thick (100 to 1 000 molecules) mixed oxide layers. The following restrictions must be observed in working these new cells :—the anode voltage must not go much above the saturation potential, *i.e.*, not higher than 60 v, and the output must not exceed 3 to 5×10^{-6}A, corresponding to an illumination of 0.1 to 0.2 Lumen.

Sensitised Potassium Photocells [and Their Selective Emission].—R. Suhrmann. (Summary in *Electronics*, Nov., 1931, p. 206.)

The sensitising substance must be one which can combine with the potassium, the sensitised cell consisting of three layers—a conducting support, a film of a metal compound, and a film of pure metal. The properties of the cell depend on the thickness of the compound film and on that of the metal film. *Cf.* 1931 Abstracts, p. 333.

A New Selenium Tube: an Application of Modern Vacuum Technique.—G. F. Metcalf and A. J. King. (*Electronics*, Dec., 1931, pp. 234–235.)

Description of the G.E.C. type FJ–31 evacuated tube and its characteristics.

Photoelectric Cells for Sound-Film Work.—Kluge. (*See* abstract under "Acoustics and Audio-frequencies.")

Constancy of Emission of Gas-Filled Photoelectric Cells after a Momentary Glow Discharge.—W. R. G. Atkins. (Summary in *Sci. Abstracts, Sec. A.*, Nov., 1931, Vol. 34, p. 1000.)

Über Leitungs- und Photoelektronen in Isolatoren und Halbleitern (On Conducting and Photo Electrons in Insulators and Semi-Conductors).—B. Gudden. (*Physik. Zeitschr.*, 1st Nov., 1931, Vol. 32, No. 21, pp. 825–833.)

An account of a lecture giving a general summary of the present situation with regard to the two questions: (1) What is known about the mechanism of non-metallic electronic conduction? and (2) What is the origin of the conducting electrons?

Optimum Outputs of Photo-Sensitive Devices.—E. D. Wilson. (*Review Scient. Instr.*, Dec., 1931, Vol. 2, pp. 797–806.)

Author's abstract:—The terms *power sensitivity* and *voltage sensitivity* are defined for photoelectric elements in a circuit, and a mathematical expression is derived to evaluate each of these characteristics for the three classes of light-sensitive devices. Curves are plotted for comparing the outputs with one another for various intensities of light flux.

Photoelectrons and Negative Ions.—E. M. Wellish. (*Proc. Roy. Soc.*, Dec., 1931, Vol. A 134, pp. 427–444.)

Author's summary:—The object of the investigation was to test experimentally the view that during the passage of electrons through a gas a fraction of these become attached to molecules and thus give rise to the negative ions. The electrons were generated by ultra-violet light incident upon a gold-plated electrode distant 2 cm. from a similar electrode; between these electrodes an alternating potential difference of square wave form was established. The gas contained in the measuring vessel was air at various pressures.

The experimental procedure consisted in determining, for a given gas pressure and for various applied potential differences V, the steady current i_0 and the currents i_1 and i_2 corresponding to frequencies of about 30 and 600 cycles per second respectively. The ratios $\frac{i_1}{i_0}$ and $\frac{i_2}{i_0}$ were then plotted against $\frac{1}{V}$ and the curves of characteristic type were obtained, the range of pressures extending from 7 mm. to one atmosphere. These curves were then compared with curves deduced from mathematical considerations of a general character. It was found that the view-point stated above, which has been generally accepted for many years, is untenable.

The experimental curves taken in conjunction with the mathematical theory lead to the conclusion that the great majority of the negative ions are formed in the vicinity of the electrode at which the electrons originate. Those electrons which do not give rise to negative ions near this electrode traverse in general the whole interval between the electrodes in the free state.

Photoelectrons and Negative Ions.—J. L. Hamshere. (*Nature*, 21st November, 1931, Vol. 128, p. 871.)

This letter comments critically on the work of Wellish referred to above and states that re-examination of the writer's published data (*cf.* 1929 Abstracts, p. 567) shows that at least an appreciable fraction of the electron capture must occur in the body of the gas.

Causes of the Selective Photoelectric Effect.—R. Suhrmann. (Long summary in *Physik. Ber.*, 1st November, 1931, Vol. 12, p. 2426.)

Reflection of Electrons by a Special Potential Field.—E. L. Hill. (*Phys. Review*, 1st Sept., 1931, Series 2, Vol. 38, No. 5, p. 1072.)

A letter amplifying the derivation of the formula for the reflection coefficient for a special one-dimensional potential field as given by Frenkel in a recent paper on the photoelectric effect (1931 Abstracts, p. 622).

Angular Distribution of Photoelectrons.—A. Sommerfeld. (*Phys. Review*, 1st Sept., 1931, Series 2, Vol. 38, No. 5, p. 1078.)

A letter correcting a remark by Frenkel in his recent paper on the photoelectric effect (1931 Abstracts, p. 622) about a discrepancy between his formula and that proposed by Sommerfeld and Schur.

Di alcune nuove Ricerche fotoelettriche (Some New Photoelectric Researches).—Q. Majorana. (*Lincei Rendic.*, No. 5, Vol. 13, 1931, pp. 318–323.)

Description of the writer's results on directing an intermittent illumination on to the first triode of an amplifier: the telephones gave out a corresponding note. An explanation will be given in a later paper. *See* also 1929 Abstracts, p. 47.

Nuove Richerche sul Fenomeno fotoelettrico (New Researches on the Photoelectric Phenomenon). — Q. Majorana. (*Nuovo Cimento*, No. 8, Vol. 8, 1931, pp. 273–280.)

Author's summary:—"The paper describes and discusses certain ponderomotive effects produced by electrons set free by ultra-violet light acting on certain metallic conductors. Evidence of the existence of such forces is obtained by the use of a special ring electrometer." (*See* also *Sci. Abstracts, Sec. A*, Nov., 1931, Vol. 34, pp. 999–1000—three ; also 1929 Abstracts, p. 47.)

Influence of the Electrolytes on Photovoltaic Phenomena. — R. Audubert. (*Comptes Rendus*, 4th Jan., 1932, Vol. 194, pp. 82–84.)

On the Law of Equidistance in Photovoltaic Cells.—A. Grumbach and F. Taboury. (*Ibid.*, pp. 84–86.)

Variazione di Suscettività di Ioni paramagnetici sotto l'Azione della Luce (Variation of the Magnetic Susceptibility of Paramagnetic Ions under the Influence of Light). —O. Specchia. (*Nuovo Cimento*, No. 8, Vol. 8, 1931, pp. 291–297.)

The "Lichtspritze" (Light-Spray) Lamp with Oxide-Coated Filament, and other Light Sources.—Ewest. (*See* abstract under "Acoustics and Audio-frequencies.")

A Further Study of Galvanoluminescence [Development of Light at Aluminium and other Anodes at Passage of Current through the Electrolyte].—R. R. Sullivan and R. T. Dufford. (*Journ. Opt. Soc. Am.*, No. 8, Vol. 21, 1931, pp. 513–523.)

MEASUREMENTS AND STANDARDS.

Notes on Generation of Absolute Frequencies. T. Kujirai and S. Fujitaka. (*Japanese Rad. Res. Committee*, Reports presented to U.R.S.I. Assembly, 1931, 3 pp. and plate.)

Standard frequencies with an error less than 1 in 100 000 are usually generated by a multivibrator controlled by a standard tuning fork of frequency about 1 000 c.p.s., which is calibrated in terms of observatory time with an accuracy of 0.001 %. The writers have tried to eliminate this tuning fork stage, and describe an arrangement in which they control a l.f. multivibrator directly from the pendulum, with a photoelectric link. Fractions of potential drops in the multivibrator grid resistances are amplified in a push-pull amplifier, filtered by a high-pass filter (cut-off at about 100 c.p.s.), amplified again and coupled to a regenerative selector circuit. By proper adjustment of this, any harmonics up to the 200th or higher can be selected. The p.d. in the selector circuit is then superposed on the anode voltage of a second multivibrator, whose fundamental is adjusted to be nearly equal to the selector circuit frequency. The system is claimed to be far more simple and reliable than that using an intermediate standard such as a tuning fork.

Frequency Measurement and Control : I.E.E. Wireless Section, Chairman's Address. —A. S. Angwin. (*Wireless Engineer*, Dec., 1931, Vol. 8, p. 659.)

Long summary of the address dealt with in February Abstracts, p. 112.

Visite de quelques Laboratoires étrangers à l'Occasion de Comparaisons internationales de Fréquence (Visit to Foreign Laboratories for the International Comparisons of Frequency).—B. Decaux. (*L'Onde Élec.*, December, 1931, Vol. 10, pp. 521–540.)

The French Laboratoire National de Radioélectricité (L.N.R.) was entrusted by the C.C.I.R. with the task of comparing the national absolute standard frequency meters of various nations. The writer describes his visits on this mission, and their results. Sections deal with the equipments at the L.N.R., the Physikalisch Technische Reichsanstalt, the Heinrich-Hertz Institut, the German P.O., the Italian R. Istituto sperimentale delle Communicazioni and R. Istituto elettrotecnico e delle Communicazioni della Marina, the N.P.L., and the British P.O. Although varying greatly in detail, all these equipments depend on the use of a tuning fork, with the exception of the Italian Naval Institute equipment, where the frequency to be measured is reduced directly to round 100 c.p.s. (1931 Abstracts, p. 49, Vecchiacchi ; p. 393, Ruelle) and then made to feed a phonic wheel.

The Service Available from the Standard-Frequency Transmissions of the Bureau of Standards.—J. H. Dellinger. (*Nat. Res. Council*, 1931, pp. 27–29.)

The Accuracy of the Primary Frequency Standard of the Bureau of Standards. —C. G. McIlwraith. (*Nat. Res. Council*, 1931, pp. 29–32 ; summary in *Physik. Ber.*, 15th November, 1931, Vol. 12, pp. 2588–2589.)

Symposium on Time-Signals : U.S.A. Naval Observatory Time-Service : Time-Signals for Electrical and Physical Measurements : Time-Signal Needs for Geodetic Work : Establishment of World-Time.—Hellweg : Wenner : Brown : Lee. (*Nat. Res. Council*, 1931, pp. 13–27 ; summaries in *Physik. Ber.*, 15th November, 1931, Vol. 12, pp. 2507–2508.)

On the Possibility of Constructing an Arrangement for the Measurement of Time which shall be Independent of the Accelerations of Its Support.—P. Le Rolland. (*Comptes Rendus*, 4th Jan., 1932, Vol. 194, pp. 47–49.)

Constant Frequency Oscillators.—Llewellyn. (*See* under "Transmission.")

Frequency Stabilisation to 5×10^{-6} by Quartz Crystal and Bolometer Combination.—German P.O. (*See* abstract under "Miscellaneous"—Harnisch.)

A Tourmalin Oscillator for Wavelengths down to 1.2 Metre.—Straubel. (*Ibid.*)

A New Method of Investigating the Modes of Vibration of Quartz Crystals.—J. A. Strong. (*Nature*, 9th Jan., 1932, Vol. 129, p. 59.)

This letter gives a short description of a method of examining the modes of vibration of quartz plates which, when combined with a polarised light method, should give useful results. The method has arisen out of Tawil's development of Töpler's *Schlieren* method (1931 Abstracts, p. 100, and these Abstracts, under "Miscellaneous"—Gawthorp). An accurately worked quartz crystal is set up in an incident light beam and oriented so that the light transmitted through it is undeviated. When the crystal is set into oscillation, a pattern of light and dark bands is formed which shows the antinodal and nodal lines of the crystal oscillations.

The Adjustment of the Multivibrator for Frequency Division.—V. J. Andrew. (*Proc. Inst. Rad. Eng.*, Nov., 1931, Vol. 19, pp. 1911–1917.)

Author's summary:—In a multivibrator controlled by a voltage of another frequency bearing a harmonic relationship to the multivibrator frequency, the effect of varying the control voltage is analysed, and a method for determining the best value of this voltage is described. Methods of coupling the control voltage are shown in which frequency division by an odd integer will occur more readily than by an even integer, and *vice versa*.

On the Forced Vibration of an Elastic Rod [taking into account the Internal Friction].—S. Higuchi. (*Sc. Rep. Tôhoku Univ.*, No. 3, Vol. 20, 1931, pp. 399–432.)

See also Muto, *Zeitschr. f. angew. Math. u. Mech.*, No. 4, Vol. 10, pp. 346–353.

Young's Modulus for Two Directions in a Steel Bar.—G. A. Wedgwood. (*Proc. Physical Soc.*, 1st Jan., 1932, Vol. 44, Part 1, No. 241, pp. 25–30.)

The Double Beat Method of Frequency Adjustment: Applications to the Measurement of Capacity and Inductance.—F. M. Colebrook. (*Wireless Engineer*, Dec., 1931, Vol. 8, pp. 639–646.)

The method of resonance indication and the double-beat method of frequency adjustment used by Colebrook and Wilmotte for measuring r.f. resistance and reactance (1931 Abstracts, p. 334) is very conveniently applicable to a variety of other measurements, as is here shown. The actual apparatus has been considerably modified since the earlier paper, and the present article describes the new equipment and gives a number of practical notes: "none of the methods here described is essentially novel, but certain refinements of technique have been introduced which give them a greatly enhanced sensitiveness and adaptability." Certain possible errors are pointed out, together with the means of avoiding them.

Oscillating Glow-Discharge Tube Capacity Meter for Small Capacities [50–11 000 cm. with an Accuracy of 1%].—Geffcken and Richter. (*Zeitschr. f. Hochf: tech.*, Dec., 1931, Vol. 38, p. 239.)

Formation of Standing Waves on Lecher Wires.—A. Mohammed and S. R. Kantebet. (*Proc. Inst. Rad. Eng.*, Nov., 1931, Vol. 19, pp. 1983–1987.)

Authors' summary:—"With a short review of the work on the Lecher wire method of wavelength measurement [including Takagishi's mathematical proof in explanation of the double-hump formation under certain conditions of line and bridge impedances—1930 Abstracts, p. 404], this paper describes in detail the wave form of current distribution along wires under a variety of terminal conditions of length and impedances." The conclusions are that the wave form is liable to be complex *if the lines are exactly a multiple of a half-wavelength and the far ends are bridged*. Under other conditions the distribution is controlled to a large extent by the dimensions of the system compared with the wavelength.

The Use of a Neon Lamp in Determining the Amplitude of a Periodically Varying Voltage.—S. Franck. (*E.T.Z.*, 9th July, 1931, Vol. 52, pp. 901–902.)

Theory and Technique of Valve Potentiometers for the Measurement of E.M.F.—F. Müller. (*Zeitschr. f. phys. Chem., Sec. A.*, No. 5/6, Vol. 155, 1931, pp. 451–465.)

The various precautions in design and operation lead to a current sensitivity of 10^{-14} A. and a potential sensitivity of 10^{-5} to 10^{-6} v.

Conditions of Equilibrium in the Wheatstone Bridge for Measurements of Audio- and Radio-Frequency.—A. Marino: Wagner. (Summary in *Sci. Abstracts, Sec. A.*, December, 1931, Vol. 34, p. 1098.)

A method of eliminating the difficulty caused by the capacity to earth or to case of the arms of the bridge was indicated by Wagner, but has not yet been applied generally. The writer gives a full theoretical discussion relative to the conditions necessary for securing equilibrium in such conditions.

A Method for Measuring Very High Values of Resistance [up to 10^{17} Ohms].—G. M. Rose. (*Review Scient. Instr.*, Dec., 1931, Vol. 2, pp. 810–813.)

From the Vacuum Tube Engineering Department of the G.E.C., New York. In the method depending on measuring, by a high-sensitivity galvanometer, the current forced through the resistance by a given voltage, the galvanometer is replaced by a low grid current pliotron: the value of the resistance is obtained from voltmeter readings.

An Electrostatic Voltmeter for Measuring High Voltages at High Frequency.—E. Wilkinson. (*Journ. Scient. Instr.*, Nov., 1931, Vol. 8, pp. 350–355.)

A Delay Recording Equipment using a Steel-Band Telegraphone, for the Measurement of Transit Time Effects in Communication Systems.—H. Decker. (*E.N.T.*, December, 1931, Vol. 8, pp. 516–527.)

High Insulation Testing and Surface Leakage.—D. C. Gall. (*Journ. Scient. Instr.*, Dec., 1931, Vol. 8, pp. 389–391.)

A New Treatment of Electron Tube Oscillators with Feed-Back Coupling.—Jen. (*See* under "Transmission.")

A Direct Reading Modulation Meter.—Cooper and Smith. (*See* under "Transmission.")

SUBSIDIARY APPARATUS AND MATERIALS.

DIE AUFNAHME NICHTPERIODISCHER VORGÄNGE MIT DEM KATHODENSTRAHLOSZILLOGRAPHEN (Recording Non-Periodic Phenomena with the Cathode Ray Oscillograph).—H. E. Hollmann. (*Archiv f. Elektrot.*, 12th Oct., 1931, Vol. 25, No. 10, pp. 689–694.)

Author's summary :—The paper describes a method of recording non-periodic phenomena with the cathode-ray oscillograph. The principle of the method is that a time base is provided by means of a "trip" oscillation circuit [giving relaxation oscillations] and that the phenomenon to be analysed is periodically switched in and set going by means of a "trip" relay at definite points on the time axis. A modification of the "Kallirotron" is used as the "trip" relay (*see* Feb. Abstracts, p. 107) ; this possesses the advantage that it can be fed from the same voltage source as the flash circuit which produces the time base oscillations. Some oscillograms of acoustic and electric transients are given as illustrations of the practical usefulness of the method.

CHARACTERISTICS OF THE OSCILLOGRAPH-GALVANOMETER. SOME PRACTICAL CONSIDERATIONS IN THE DESIGN AND APPLICATION OF THE OSCILLOGRAPH-GALVANOMETER VIBRATOR.—V. S. Thomander. (*Journ. Franklin Inst.*, Jan., 1932, Vol. 213, No. 1, pp. 41–55.)

"The paper describes the mechanical characteristics of the vibrator for any periodic phenomena, so that the mechanical error due to the vibrator may be eliminated from the oscillogram and the true phenomena determined." The optimum damping, as summarised by the vibrator lag, response and transient characteristics, is found to be 70% of the critical value. A method is given for determination, in the field, of vibrator response and damping. Curves for obtaining these data are given.

THE CATHODE RAY OSCILLOGRAPH [AND THE WESTERN ELECTRIC TUBE No. 224].—J. B. Johnson. (*Journ. Franklin Inst.*, Dec., 1931, Vol. 212, No. 6, pp. 687–717.)

This paper gives a general account of the fundamental principles and historical development of the cathode ray oscillograph, and discusses some problems of the development and operation of the Western Electric tube No. 224.

A LINEAR TIME-BASE OSCILLATOR FOR CATHODE-RAY OSCILLOGRAPHY.—Appleton and Builder. (*See* abstract under "Propagation of Waves.")

CATHODE-RAY OSCILLOGRAPH TIMING AXIS [NEON TUBE, INDIRECTLY-HEATED TETRODE AND TRANSFORMER CIRCUIT].—F. T. Brewer. (*Electronics*, Dec., 1931, pp. 222–223.)

"As the potential across the condenser builds up, the beam is moved across the screen with a speed proportional to the plate current of the tetrode, and inversely proportional to the capacity, because the potential across the condenser is also across one set of plates . . . Since the condenser is connected in the plate circuit of the tetrode, its speed of charge may be controlled quite accurately by controlling the plate or charging current by adjusting the grid bias . . . Since the breakdown and cut-off voltages of the neon tube are close together, as well as fairly high, the portion of the curve used is practically straight, thus giving practically uniform motion of the beam across the screen . . .

"A vernier adjustment is necessary on the bias of the tetrode in order to adjust the speed or frequency accurately. Even then it is sometimes difficult to keep the timing axis exactly in step with the source of potential which is connected to the other set of plates. Further to facilitate keeping the two in step, the [40/1 ratio] transformer has been placed in the circuit so that a small voltage from the source will tip the neon tube off at the instant the source potential comes to a peak value and the condenser is charged to the proper voltage. The voltage supplied by the secondary of the transformer should not be too great, however, or it may tend to break down the neon tube at the wrong time. In all cases, the primary impedance of the transformer should be high. Then, to work properly, the waves should be put on the screen so that the peaks come at the ends."

UNTERSUCHUNG DER ZEITKREISAUSLÖSUNG EINES KATHODENOSZILLOGRAPHEN BEI UNWILLKÜRLICHEN AUSGLEICHVORGÄNGEN (Investigation of Time Base Release in the Cathode Ray Oscillograph by Involuntary Transient Phenomena).—K. Girod. (*Archiv f. Elektrot.*, 12th Oct., 1931, Vol. 25, No. 10, pp. 695–704.)

From the author's summary :—The present paper is concerned with the investigation of Rogowski's time base "trip" circuit. A simplified circuit arrangement is developed which fulfils all requirements. The apparatus required in addition to the time-base circuit consists simply of a triple-sphere spark gap and a short coupling lead (or a coupling condenser).

A SELF-STOPPING D.C. THYRATRON CIRCUIT [USING A GLOW-DISCHARGE TUBE].—H. J. Reich. (*Electronics*, Dec., 1931, p. 240). *See* also Feb. Abstracts, p. 98 (Weiller).

THE EFFECT OF MECHANICAL DISTURBANCE ON A NEON LAMP [DEMONSTRATION].—T. J. Dillon and C. M. Lovett. (*Proc. Physical Soc.*, 1st Jan., 1932, Vol. 44, Part 1, No. 241, p. 101.)

RUSSIAN PAPERS ON THE MAGNETIC BEHAVIOUR OF IRON, POWDERED IRON COMPOUNDS, ETC., IN HIGH- AND LOW-FREQUENCY FIELDS : INCLUDING MAGNETOSTRICTION AND MAGNETON RESONANCE.—Malov, Volkova, Arkadiew and others. (Summaries in *Physik. Ber.*, 1st November, 1931, Vol. 12, pp. 2428 and 2431.)

ÜBER DEN EINFLUSS DES ELASTISCHEN SPANNUNGSZUSTANDES AUF DIE GRÖSSE DER ANFANGSPERMEABILITÄT (The Influence of the Condition of Elastic Strain on the Value of the Permeability at Low Magnetising Forces).—M. Kersten. (*Zeitschr. f. tech. Phys.*, No. 12, Vol. 12, 1931, pp. 665–669.)

A THEORY OF MAGNETIC PERMEABILITY FOR FREQUENCIES RANGING FROM THE X-RAY REGION TO COMMERCIAL A.C.—W. Arkadiew. (*Festschr. z. zehnjährig. Tatigkeit d. Magn. Lab. Moscow*, 1931, pp. 51–60; long summary in *Physik. Ber.*, 15th November, 1931, Vol. 12, p. 2613.)

EINE DIREKTE METHODE ZUR BESTIMMUNG DES STREUFELDES EINES WANDLERS (A Direct Method of Measuring the Leakage Field of a Transformer [Neutralisation of Main Field]).—Brückmann and Engelenburg. (*E.T.Z.*, No. 37, Vol. 52, 1931, pp. 1171–1172.)

DIELEKTRISCHE EIGENSCHAFTEN VERSCHIEDENER GLÄSER IN ABHÄNGIGKEIT DER FREQUENZ UND DER TEMPERATUR (Variation with Frequency and Temperature of the Dielectric Properties of Different Varieties of Glass).—M. J. O. Strutt. (*Archiv f. Elektrot.*, 12th Oct., 1931, Vol. 25, No. 10, pp. 715–722.)

THE THERMAL AFTER-TREATMENT OF BAKELITE FOR PRECISION USES.—Vogt. (*See* abstract under "Acoustics and Audio-frequencies.")

COTTON FOR INSULATION.—R. I. Martin. (*Electrician*, 8th Jan., 1932, Vol. 108, p. 38.)

RADIO-FREQUENCY FILAMENT SUPPLY.—Möckel. (*Funk*, 6th Nov., 1931.)

Cf. Edelstein, Feb. Abstracts, p. 107. Möckel prefers 10-m waves, and heats in this way not only the receiver valves but also the energising oscillator itself, a relay transferring this from mains to r.f. as soon as it starts oscillating. The mains then supply only plate current.

ACCUMULATORS FOR BROADCAST RECEIVERS.—R. Albrecht. (*E.T.Z.*, 7th Jan., 1932, Vol. 53, pp. 11–13.)

After suggesting various reasons for the reaction which he notices towards the battery-driven set, the writer describes briefly some of the latest types of German accumulators, including some for anode supply.

AN APPLICATION OF THE CIRCLE DIAPHRAGM TO THE DESIGN OF ATTENUATION AND PHASE EQUALISERS.—Rust. (*See* under "Properties of Circuits.")

AUTOMATIC CURVE ANALYSER.—C. G. Abbot. (*See* abstract under "Atmospherics and Atmospheric Electricity.")

A NOTE ON A MERCURY RHEOSTAT.—W. B. Mann. (*Journ. Scient. Instr.*, Nov., 1931, Vol. 8, pp. 362–363.)

1 mm. shift gives a resistance change of 0.0015 ohm; still finer adjustment would be possible by a micrometer device.

A NEW TYPE OF NON-UNIFORM CABLE [IMPEDANCE PER UNIT LENGTH INCREASING LINEARLY WITH DISTANCE].—M. Federici. (Summary in *Physik. Ber.*, 15th November, 1931, Vol. 12, p. 2616.)

With application to the new submarine cable for high-speed telegraphy between Belgium and Lisbon, sections of which have the property in question.

THE MEASUREMENT OF FLUORESCENCE BY MEANS OF THE PHOTOELECTRIC CELL.—R. Toussaint. (*Comptes Rendus*, 16th Nov., 1931, Vol. 193, p. 933-934.)

A NEW CHARGING ROD FOR STATIC ELECTRICITY [MERCURY IN EVACUATED GLASS TUBE].—J. I. Hopfield. (*Review Scient. Inst.*, Nov., 1931, Vol. 2, pp. 756–758.)

STATIONS, DESIGN AND OPERATION.

PROPAGATION OF THE BROADCASTING WAVES [345–441 METRES] IN JAPAN.—Takata and Itow. (*See* under "Propagation of Waves.")

PREVENTION OF FADING IN BROADCASTING BY USE OF AERIAL SYSTEM OF ORDINARY HEIGHT AND GREAT HORIZONTAL SPREAD.—Harbich and Hahnemann. (*See* abstract under "Aerials and Aerial Systems.")

THE MODULATION SYSTEM OF THE RUSSIAN 100 KW. STATION AT SCHTSCHELKOWO.—Wigge. (*See* under "Transmission.")

THE PRESENT STATUS OF WIRED WIRELESS BROADCASTING ON POWER LINES.—G. Squier. (*Electrician*, 4th Dec., 1931, Vol. 107, p. 779.)

Note on a recent paper. "Superimposed upon the 60 cycle power transmission plant, without interference, was a 13 kc. carrier current stepped up . . . to deliver three separate programmes simultaneously into the homes of subscribers from the standard light fitting, on frequencies of 26, 39 and 52 kc. per second. The complete equipment, designed, manufactured and tested for 270 000 homes, was now ready for shipment to Cleveland, Ohio."

BROADCAST REPEATERS: A DISCUSSION OF THE REQUIREMENTS OF LINE-AMPLIFIERS USED FOR PROGRAMME TRANSMISSION OVER BROADCASTING LAND-LINES.—Vogel. (Summary in *Sci. Abstracts, Sec. B.*, November, 1931, Vol. 34, p. 627.)

THE PONTOISE RADIOTELEGRAPH STATION.—Veaux. (*Génie Civil*, 28th Nov., 1931, Vol. 99, pp. 541–547.) *See* also Abstracts, February, p. 111, and 1931, p. 149.

INTERCONTINENTAL RADIOTELEPHONE SERVICE FROM THE UNITED STATES.—J. J. Pilliod. (*Bell Tel. System Monograph B*-604, 17 pp.)

From author's synopsis:—"Extent of ship-to-shore radio telephone service from the United States is outlined. Arrangements for service to Buenos Aires and Rio de Janeiro are described. . . .

Proposed short-wave system for operation with Bermuda and proposed new long-wave system to supplement existing facilities to Europe are mentioned. A description of the new radiotelephone transmitting and receiving stations now being erected at Dixon and Point Reyes, Calif., respectively, is given " [see same writer, Jan. Abstracts, p. 52].

WIRELESS AT SEA.—(*Elec. Review*, 4th December, 1931, Vol. 109, p. 842.)

New P. & O. liners are to be equipped with 2 kw. transmitters for long, medium and short-wavelengths, and receivers covering the whole commercial range, with additional units for strengthening weak signals and reducing interference. Direction finders are also being fitted.

NEW OVERSEAS RADIO-TELEPHONE EXTENSIONS.—A. A. Oswald. (*Bell Lab. Record*, Nov., 1931, Vol. 10, No. 3, pp. 66–70.)

NEW RUSSIAN RADIO " FIVE-YEAR PLAN."—Wigge. (Summary in *Electronics*, November, 1931, p. 205.)

The *Funk* article here summarised gives very full details of the new Plan, which is greatly extended as compared with the original. Special attention is given to the " set-less " reception of broadcasting, it being intended that 75 % of the listeners shall have no receivers of their own, an alternative pair of programmes being distributed by wire.

THE NEW RUSSIAN RADIO FIVE YEARS PLAN.—(*E.T.Z.*, 5th Nov., 1931. Vol. 52, pp. 1392–1393.)

FRENCH BROADCASTING'S GIGANTIC CONSTRUCTIONAL PROGRAMME. (*Die Sendung*, 2nd Oct., 1931, Vol. 8, p. 805.)

COMMERCIAL WIRELESS. — Chetwode Crawley. (*Wireless World*, 30th December, 1931, Vol. 29, pp. 730–732.)

A record of the year's progress.

SINGLE WAVELENGTH SYSTEM [OF DUPLEX RADIOTELEPHONY, ON THE " OLYMPIC "].—I. T. and T. Company. (*Electrician*, No. 2772, Vol. 107, 1931, pp. 85–86.)

APPLICATION OF PRINTING TELEGRAPH TO LONG-WAVE RADIO CIRCUITS.—A. Bailey and T. A. McCann. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2177–2190.)

GENERAL PHYSICAL ARTICLES.

ENERGY FLUCTUATIONS IN A RADIATION FIELD.—W. Heisenberg. (*Leipziger Ber.*, No. 1, Vol. 83, 1931, pp. 3–9 ; summary in *Physik. Ber.*, 15th Nov., 1931, Vol. 12, pp. 2499–2500.)

THE EFFECT PRODUCED BY A CLOUD OF ELECTRONS ON THE STRUCTURE OF THE DE BROGLIE WAVE.—Szczeniowski and Infeld. (*Comptes Rendus Krakau*, No. 6, 1931, p. 3 ; short summary in *Physik. Ber.*, 15th November, 1931, Vol. 12, p. 2610.)

SUR QUELQUES DIFFICULTÉS DE LA THÉORIE DES QUANTA (Some Difficulties of the Quantum Theory).—J. Solomon. (*Journ. de Phys. et le Rad.*, Oct., 1931, Vol. 2, Series 7, pp. 321–340.)

ELECTRODYNAMIC MASSES IN QUANTISTIC ELECTRODYNAMICS.—E. Fermi. (Long summary in *Sci. Abstracts, Sec. A.*, Nov., 1931, Vol. 34, p. 1004.)

ELECTRODYNAMICS AND THE THEORY OF QUANTA. J. Solomon. (*Ann. de Physique*, Dec., 1931, Vol. 16, pp. 411–502.)

DIELECTRIC CONSTANT AND CONTACT POTENTIAL. T. Takéuchi. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, p. 1082.)

" The author has attempted to introduce the term of induced dipoles into the expression of refractivities of the electronic wave and has suggested some methods of determining the dielectric constants of metals *via* the photoelectric and thermoelectronic effects."

EXPERIMENTS ON THE GLOW DISCHARGE.—G. Valle. (Summary in *Sci. Abstracts, Sec. A.*, Dec., 1931, Vol. 34, p. 1089.)

THEORETICAL STUDY OF INDUCED CURRENTS [WITH AN APPLICATION TO INSTRUMENT DESIGN].—M. Biot. (*Ann. de Bruxelles*, No. 2, Vol. B51, 1931, pp. 94–127 : summary in *Physik. Ber.*, 15th November, 1931, Vol. 12, pp. 2614–2615.)

NOTE ON " THE EFFECT OF PIEZOELECTRIC OSCILLATION ON THE INTENSITY OF X-RAY REFLECTIONS FROM QUARTZ."—S. Nishikawa, Y. Sakisaka and I. Sumoto. (*Phys. Review*, 1st Sept., 1931, Series 2, Vol. 38, No. 5, pp. 1078–1079.)

A letter giving a short preliminary description of experiments whose results agree with those of Fox and Carr (*cf.* 1931 Abstracts, p. 570).

MISCELLANEOUS.

NOTICE TO AUTHORS—SOME NOTES ON THE WRITING OF SCIENTIFIC PAPERS [INCLUDING THE TREATMENT OF MATHEMATICAL EXPRESSIONS].—(*Journ. Scient. Instr.*, Nov., 1931, Vol. 8, pp. 365–368.)

NEW REMARKS ON FERMAT'S LAST THEOREM.—L. Pomey. (*Comptes Rendus*, 12th Oct., 1931, Vol. 193, pp. 563–564.)

NOTE ON THE HEAVISIDE EXPANSION FORMULA.—J. M. Dalla Valle. (*Proc. Nat. Acad. Sci.*, 15th Dec., 1931, Vol. 17, pp. 678–684.)

AUSTRALIAN RADIO RESEARCH BOARD, REPORT FOR YEAR ENDING 30TH JUNE, 1931.—(*Journ. Council for Scient. & Indus. Res., Australia*, Nov., 1931, Vol. 4, No. 4, pp. 244–250.)

(*See* under " Propagation of Waves " and " Atmospherics and Atmospheric Electricity.")

The Work of the Radio Research Board.—(*Wireless Engineer*, Jan., 1932, Vol. 9, pp. 1–2.)

Editorial on the Board's "Report for the Period ended 31st December, 1930."

Annual Report of the Director of the Bureau of Standards, 1930–31. (Summary in *Electrician*, 15th January, 1932, Vol. 108, p. 74.)

Fifth Pacific Science Congress, June, 1933: Preliminary Programme of Papers and Authors.—(*Fifth Pacific Science Congress, Bulletin No.* 3, November, 1931.)

The 27 Radio papers include contributions on the correlation of radio phenomena and sunspot, magnetic and electric phenomena: the dispersion of beam radiation: the low attenuation of short waves in long-distance transmission: absorption effect inside channels in the British Columbia coast: effect of aurora on short waves: discrepancy of frequency between carrier waves when sent and when received, etc., etc.

Review of Progress: Radio Telegraphy and Radio Telephony.—A. S. Angwin. (*Journ. I.E.E.*, Jan., 1932, Vol. 70, pp. 145–152.)

Radio Legislation in the U.S.A.: The Legal Basis for Broadcasting in Germany: The Regulation of Television.—Loucks: Hoffmann: Smith. (*Journ. of Air Law*, Oct., 1931, Vol. 1, pp. 572–580: 491–498: 499–507.)

The Great German Radio and Phono Show.—A. Harnisch. (*Zeitschr. f. Hochf: tech.*, Dec., 1931. Vol. 38, pp. 232–233.)

Including mention of the temperature stabilisation of quartz oscillators by the use of a sensitive bolometer (enclosed in the same glass container as the quartz) in a bridge circuit: the out-of-balance current is amplified and passed through a heating coil. A constancy of frequency of 5×10^{-6} is thus attained.

A 150 kw. transmitting valve is also mentioned. The emission is from a tube of niobium, heated by radiation from a coaxial filament.

The German P.O. quartz-controlled 7-metre transmitter is another selected item. The quartz has a frequency corresponding to a 42 m. wavelength. "Later it was found possible, by suitable choice of grinding, to make single-wave piezoelectric oscillators out of tourmalin down to a wavelength of 1.2 metre" (Straubel).

Some Electrical Instruments at the Faraday Centenary Exhibition, 1931.—R. W. Paul. (*Journ. Scient. Instr.*, Nov., 1931, Vol. 8, pp. 337–348.)

The Exhibit of Testing Apparatus and Machines held in connection with the Annual Meeting of the American Society for Testing Materials.—H. V. Cadwell. (*Review Scient. Instr.*, Nov., 1931, Vol. 2, pp. 665–737.)

The Physical and Optical Societies' Exhibition. (*Electrician*, 8th and 15th January, 1932, Vol. 108, pp. 31–33 and 69–71.)

Scheme of Ursigram Transmissions by French Radiotelegraph Stations, from 1st January, 1932. (*L'Onde Élec.*, December, 1931, Vol. 10, pp. i to x.)

Second Meeting of the International Technical Consulting Committee on Radio Communication (C.C.I.R.), Copenhagen, 1931. (*Proc. Inst. Rad. Eng.*, Dec., 1931, Vol. 19, pp. 2219–2249.)

The twenty-one opinions which were unanimously approved at the meeting are given, together with fourteen questions for consideration at the third (Lisbon) meeting to be held at some later date.

The Work of the Physikalisch-Technischen Reichsanstalt in 1930. (*E.T.Z.*, 24th Dec., 1931, Vol. 52, pp. 1581–1582.)

Including diagram and description of the equipment for the quick absolute measurement of the standard tuning fork.

Die Nachrichtenträger in der Fernmeldetechnik (Communication Carriers in the Technique of Distant Communication).—F. Lubberger and M. Schleicher. (*Zeitschr. V.D.I.*, 19th Dec., 1931, Vol. 75, No. 51, pp. 1527–1530.)

". . . We have discussed five methods of carrying news: telegraph signals, and the partial change of amplitude, frequency, modulation and phase angle. The question whether this exhausts all possibilities must be answered in the negative. One can employ as carrier the phase displacement between current and voltage in an alternating current, altering the various values in such a way that the power, given by the product $EI \cos \phi$, remains constant while the phase angle changes."

The Present Position of High-Frequency Telephony on High-Tension Lines.—W. Pinski. (*Zeitschr. f. Fernmeldetech.*, No. 3, Vol. 12, 1931, pp. 37–40.)

Measurements of the Mutual Induction between Lines with Ground Return, in Skillingaryd.—H. Klewe. (*E.N.T.*, Dec., 1931, Vol. 8, pp. 533–538.)

Oscillations due to Corona Discharges on Wires.—R. E. Tarpley, J. T. Tykociner and E. B. Paine. (*Phys. Review*, 15th June, 1931, Series 2, Vol. 37, No. 12, pp. 1689–1690.)

Geophysical Prospecting by 10–30 Metre Waves.—W. Stern. (Summary in *Sci. Abstracts, Sec. A.*, Nov., 1931, Vol. 34, p. 949.)

Sterilisation of Milk by High-Pitched Sound Waves.—Gaines and Chambers. (*See* under "Acoustics and Audio-frequencies.")

Applications of the Schlieren Method of Photography [for Making Gases Visible by Presence of Discontinuities in Density].—D. B. Gawthorp. (*Review Scient. Instr.*, Sept., 1931, Vol. 2, pp. 522–531.)

See also Strong, under "Measurements and Standards."

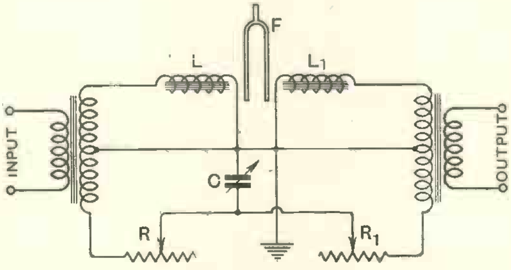
Some Recent Patents.

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.

SELECTIVE RECEPTION.

Application date, 8th July, 1930. *No.* 358137.

In order to eliminate heterodyne interference in a super-selective circuit for carrier-wave telegraphy or telephony, a constant-frequency tuning-fork is used as a coupling for the carrier frequency, and provision is made to apply an out-of-phase component to balance out any undesired heterodyne note. As shown, a coil L energises the fork F from the upper part of the imput transformer, the fork frequency being passed to the output transformer by a coil L_1. The lower part of the input coil will contain an out-of-phase component of any disturbing frequency, and this is applied to the output transformer at the appropriate balancing strength through adjustable resistances R, R_1 and a variable condenser C.



No. 358137.

Patent issued to G. Priechenfried and J. Robinson.

SHORT-WAVE GENERATORS.

Convention date (Germany), 13*th August,* 1929. *No.* 360063.

Relates to the production of ultra-high-frequency oscillations by the Barkhausen-Kurz method, where the generated frequency depends upon the time period of "pendular" movements occurring in the electron stream. A four-electrode valve is employed and positive voltages are applied to both grids, each grid being connected to one of the other electrodes through a tuned two-wire circuit. The arrangement allows of the production of frequencies higher than the critical limits normally determined by the applied voltage and the interelectrode spacing.

Patent issued to H. E. Hollmann.

MAGNETRON GENERATORS.

Convention date (U.S.A.), 28*th August,* 1929. *No.* 358185.

A magnetron of the split-anode type, in which a longitudinal filament is normally mounted between a pair of segmental anodes, is adapted for the generation of short waves, of the order of a few metres, by making the anodes flat, instead of curved, and mounting them substantially "end on" to the filament. This reduces the inter-electrode capacity to a minimum, and tends to keep the anode surfaces at a uniform temperature. A solenoid mounted outside the tube applies a magnetic "control" field, which regulates the velocity of electron movement, the resulting oscillations being fed to a tuned circuit branched across the two anodes.

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

SIGNALLING SYSTEMS.

Convention date (Germany), 28*th April,* 1930. *No.* 357479.

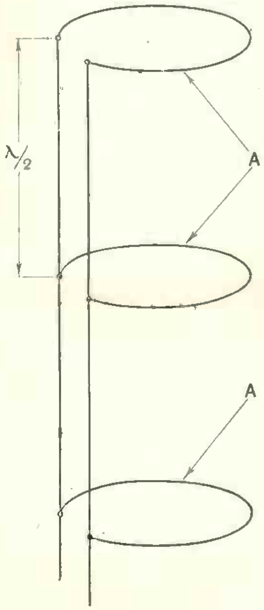
A carrier wave is both phase-modulated and amplitude-modulated by the same signal frequency. It is shown mathematically that in each case one pair of the resulting side-band frequencies are identical, and can be used to augment each other, whilst the remaining side-band frequencies are of opposite phase and cancel out in combination. The resulting radiation can be arranged to consist either of the carrier and a single side-band, or of a single side-band only.

Patent issued to Telefunken Gesell. für Drahtlose Telegraphie m.b.H.

TRANSMITTING AERIALS.

Convention date (Germany), 6*th February,* 1930. *No.* 358372.

In order to ensure a substantially uniform field distribution, suitable for broadcast transmission, a number of separate radiating elements A are arranged one above the other and are connected to a common feed-line L. Each radiator A is bent into substantially circular or polygonal form, the overall wire length of each being half a wavelength. They are spaced vertical apart by the same distance.



No. 358372.

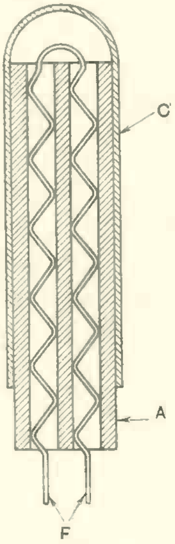
Patent issued to Telefunken Ges. für Drahtlose Telegraphie m.b.H.

INDIRECTLY-HEATED VALVES.

Application date, 1st August, 1930. *No.* 360036.

In order to ensure good thermal contact between the "hairpin" heater and the cathode of a mains-driven valve, the heater-filament *F* is crimped or corrugated, as shown, and both legs are fitted into tubes formed in an insulating cylinder *A*, over which the metallic cathode *C* fits with a spring grip. The arrangement allows the use of a lower filament temperament and so minimises the risk of "hot spots"; it also allows for free expansion under heat.

Patent issued to Standard Telephones & Cables, Ltd.



No. 360036.

Convention date (Germany), 10*th December,* 1929. *No.* 360715.

The heating-element runs through the centre of a hollow tube of kaolin, and a sensitised wire cathode is wound spirally around the outer surface of the tube. The grid is a wire of molybdenum or tungsten laid in between the turns and in the same plane as the cathode wire, so that it does not lie directly in the path of the electron stream. The closer spacing of the grid and cathode gives the advantage of a steeper operating characteristic, whilst the rigid mounting ensures freedom from microphonic noise.

Patent issued to A. Salomon and Frey-Radio Gesell. m.b.H.

DRY-CONTACT RECTIFIERS.

Application date, 12*th August,* 1930. *No.* 360960.

The rectifying-couple comprises anode electrodes made of an alloy of 12 parts of aluminium, $\frac{1}{2}$ of manganese, and $87\frac{1}{2}$ of magnesium, covered with a contacting layer formed of a complex compound of barium. A cathode paste is then applied under pressure, consisting of sulphur, selenium, and manganese and antimony sulphides.

Patent issued to R. J. Elsome-Jones.

Convention date (Holland), 7*th March,* 1930. *No.* 361737.

A dry-contact rectifier is characterised by the feature that the anode consists, at least in part, of phosphorous, the cathode being of aluminium coated with a layer of aluminium oxide.

Patent issued to N. V. Philips Gloeilampen Fabrieken.

Convention date (Holland), 8*th March,* 1930. *No.* 361738.

The cathode of the rectifier consists, at least in part, of one of the metals titanium, zirconium, hafnium, or thorium, preferably in the form of a film of one or more of the oxides. For the anode, phosphorus, cuprous sulphide and free sulphur, or copper iodide with free iodine may be used.

Patent issued to N. V. Philips Gloeilampen Fabrieken.

CONSTANT-COUPLING CIRCUITS.

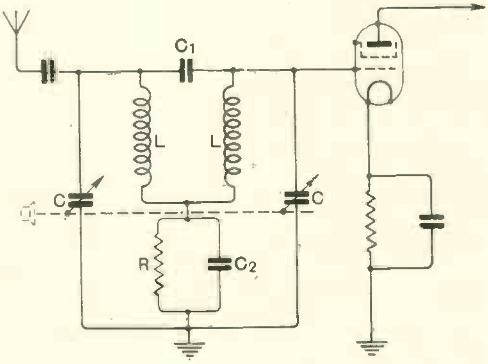
Convention date (U.S.A.), 20*th June,* 1929. *No.* 359890.

Relates to amplifier circuits of the type in which "mixed" capacity and inductance couplings are utilised to ensure a constant transfer of energy, and therefore uniform amplification, throughout the tuning range. According to the invention the output impedances of successive valve stages are made capacitative, over the tuning range, by the connection of a relatively-large neutralising condenser to each plate. The addition to the aerial of a fixed condenser then enables the input and output impedances to be "matched" throughout the chain of valve stages, thus facilitating the application of "ganged" tuning control to a constant-coupled amplifier designed for manufacture by mass-production methods.

Patent issued to Hazeltine Corporation.

Convention date (U.S.A.), 13*th June,* 1930. *No.* 360062.

The coupled circuits of a multivalve amplifier are arranged to give constant amplification throughout the tuning range. As shown, the primary tuned circuit is coupled to the aerial through a series condenser. The high-potential ends of both the tuned circuits *LC* are coupled together through a condenser C_1. The low-potential ends of both the condensers *C* are connected together and to ground, whilst the similar ends of the fixed inductances *L* are joined and connected to ground through a condenser C_2, which may be shunted by a resistance *R* in order to apply a bias to the grid of the first valve. With this arrangement the energy transfer between the circuits diminishes as the signal frequency increases. A similar arrangement may be used for the inter-valve couplings.



No. 360062.

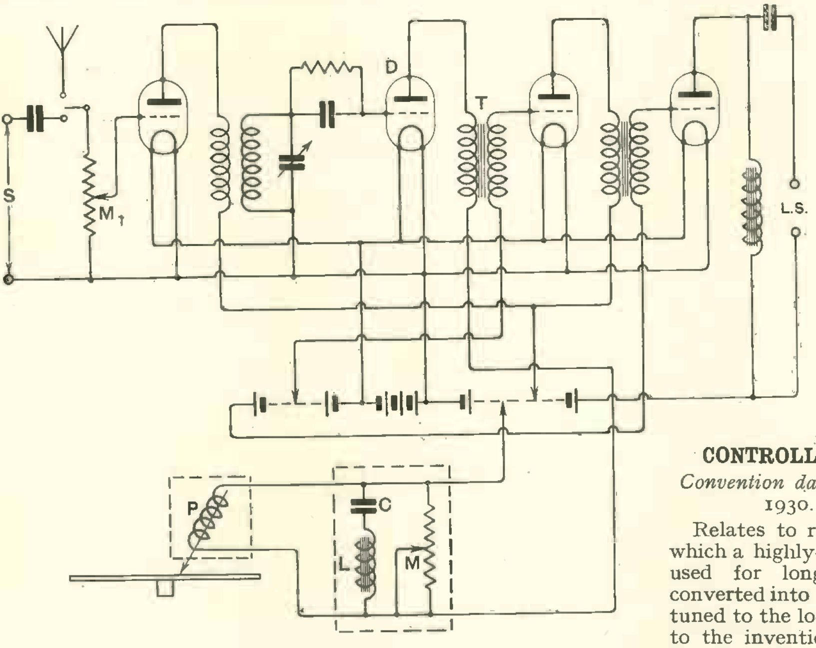
Patent issued to Radio Frequency Laboratories, Inc.

VARIABLE CONDENSERS.

Application date, 25*th July*, 1930. *No.* 359551.

To allow the maximum capacity of a variable condenser to be varied at will, a selector device is arranged to hold one or more of the moving vanes stationary, whilst the remainder are being rotated relatively to the fixed vanes.

Patent issued to Standard Telephones and Cables, Ltd., and P. R. Painton.



No. 357662.

MODULATING SYSTEMS.

Convention date (*Germany*), 2*nd April*, 1929.
No. 358064.

The falling portion of the characteristic curve of a three-electrode valve where the grid carries a high and the plate a lower positive potential is utilised to generate ultra-short waves, which are modulated by connecting a circuit, tuned to a different frequency, either between the plate and cathode or between the grid and cathode. Double modulation is effected by coupling a second lower-frequency source to the tuned circuit.

Patent issued to E. Gerhard.

WIRELESS OR GRAMOPHONE REPRODUCTION.

Convention date (*U.S.A.*), 17*th July*, 1929.
No. 357662.

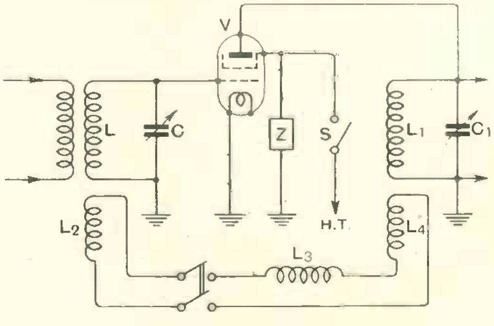
The input from a wireless aerial or from a gramophone pick-up is amplified in the same low-frequency stage without altering the electrical constants of either the radio or gramophone circuits during operation. As shown, the gramophone pick-up P, shunted by a "compensator" circuit L, C is inserted in the plate of the detector valve D. A potentiometer control M enables the input from P to be varied from zero to a maximum. A second potentiometer M_1 affords similar control of the aerial voltage, or of the input from a wired-wireless supply S. The two controls M, M_1 are incorporated in a single knob. Since the change-over from one type of programme to another involves no break in the circuits, the inter-stage transformer T can be designed to match the impedance of the low-frequency stage to either the gramophone or radio-frequency channels.

Patent issued to Kolster Brandes, Ltd.

CONTROLLING SELECTIVITY.

Convention date (*U.S.A.*), 18*th June*, 1930. *No.* 360813.

Relates to receivers of the kind in which a highly-selective input circuit, used for long-distance working, is converted into a band-pass input when tuned to the local station. According to the invention, the *SG* amplifier V is made to function solely as a coupling-condenser between the input circuit L, C, and the output circuit L_1, C_1 by cutting-off the H.T. voltage to the screen-grid, through a switch S, and replacing it by an impedance Z which increases the normally-small interelectrode capacity of the valve V practically to the value of that between the plate and grid of an ordinary triode valve. To secure a band-pass characteristic, the valve coupling through V is supplemented by an inductive link L_2, L_3, L_4 when receiving the local station.



No. 360813.

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

JOURNAL OF SCIENTIFIC INSTRUMENTS

produced by the Institute of Physics with the co-operation of the National Physical Laboratory. The principal English journal devoted exclusively to scientific instruments, their principles, construction and use. Essential to designers, makers and users.

THE SPECIAL EXHIBITION NUMBER.

Is the only journal in which the Twenty-second Annual Exhibition of the Physical and Optical Societies is fully reported.

The different classes of instruments exhibited are dealt with in a series of articles by leading authorities on these subjects, and two of the Discourses given are reported.

The Exhibition Number may be obtained from the publishers, price 2/6 (post free 2/8).

The subscription rate for the yearly volume is £1 10 0 net (post free), payable in advance. Subscriptions should be sent to the publishers.

CAMBRIDGE UNIVERSITY PRESS
Fetter Lane, London, E.C.4 - - - England

PIVASPRING PARK ROYAL INSTRUMENTS

Tested on a special "dithering" machine, which shakes and bumps the instrument continuously. A drastic test proving that the quality of material used and the workmanship is of the best.

Regd. Des. No. 759295

100% BRITISH ALWAYS ACCURATE

SPECIFICATION

High-grade Cobalt Steel Magnet, accurately machined, giving excellent damping and accuracy. First quality Sapphire Jewel bearings. Will withstand heavy overloads without injury.

Zero correctors fitted to all instruments.

Each instrument separately calibrated and scaled.

Park Royal "Pivaspring" Instruments are used by Government Departments.

Full catalogue sent on request.

Type 1¾" M.C.F.	List Price each.
VOLTMETERS 0-300 1,000 ohms per volt - - -	33/9
MILLI-AMMETERS - - - -	30/-

PARK ROYAL
ENGINEERING COMPANY, LIMITED,
Cumberland Avenue, Park Royal, N.W.10.
Telephone: Willesden 2223, 2224 and 4715.

The Wireless and Radio Review World

The weekly journal which keeps its readers thoroughly in touch with all that is happening in wireless. It is in every sense a wireless newspaper, for it records and reviews prevailing theory and current practice in design, and also gives week by week, broadcasting and other general news for everyone concerned with, or interested in wireless broadcasting and reception.

Special features are: Theoretical Articles discussing new principles: Detailed Technical Reviews of Commercial Radio Receivers: Designs for Experimental Receivers specially prepared to illustrate the practical application of new principles in valves, components, or circuit arrangements.

EVERY WEDNESDAY 4d.

SUBSCRIPTION
Home & Canada £1 . 1 . 8, other Countries Abroad £1 . 3 . 10 per annum, post free.

ILIFFE & SONS LIMITED
DORSET HOUSE
TUDOR STREET, LONDON, E.C.4

"Calculation and Measurement of Inductance and Capacity,"

by W. H. Nottage, B.Sc. (1924).

The more generally useful formulæ and methods of measurement of inductance and capacity are here brought together in a convenient form. 224 pages. Over 80 illustrations and diagrams.

Price 7/6 net, by post (home and abroad) 8/- from

ILIFFE AND SONS LTD.,
Dorset House, Tudor St., London, E.C.4,
and leading booksellers. W.E.12

TANNOY
HIGH GRADE
MAINS UNITS.
ALL-ELECTRIC RECEIVERS.
RADIO-GRAMOPHONES.
PUBLIC ADDRESS AMPLIFIERS.
DANCE-HALL REPRODUCERS.

TANNOY PRODUCTS,
1-7, Dalton Street, W. Norwood, S.E.27.

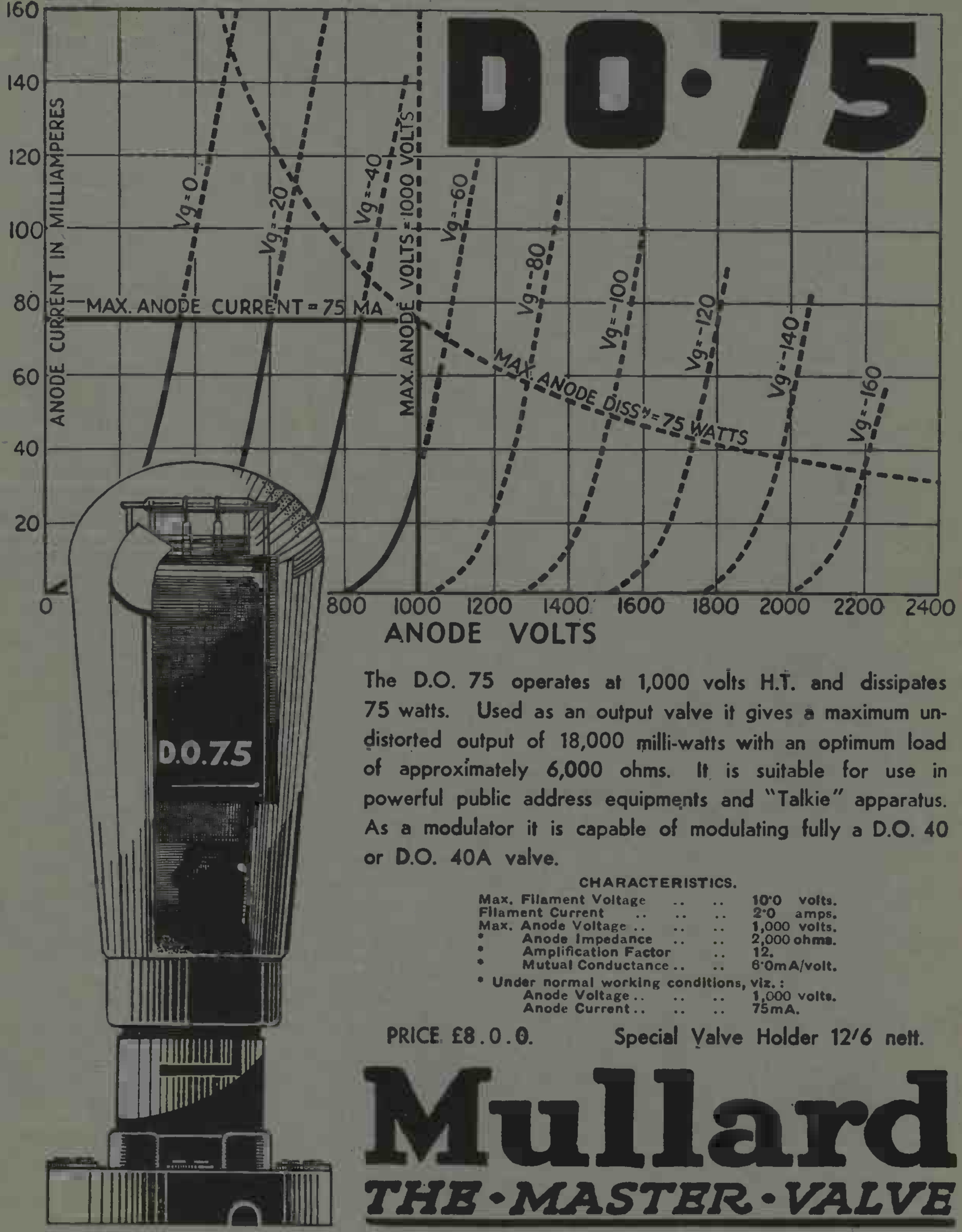
POWER TRANSFORMERS, CHOKES, &c.

for Wireless and other purposes designed and wound to customers' specifications.

Enquiries Solicited.
Very Keen Prices.

Special orders delivered 7 days after receipt of order.

JOHN MELLANBY
Electrical Engineer,
Cambridge Road, Waterbeach, Cambs.



Printed for the Publishers, Iliffe & Sons Ltd., Dorset House, Tudor Street, London, E.C.4,
by The Cornwall Press Ltd., 1-6, Paris Garden, Stamford Street, London, S.E.1.
Sole Agents for Australasia—Gordon & Gotch (Australasia), Ltd.
Sole Agents for South Africa—Central News Agency, Ltd.