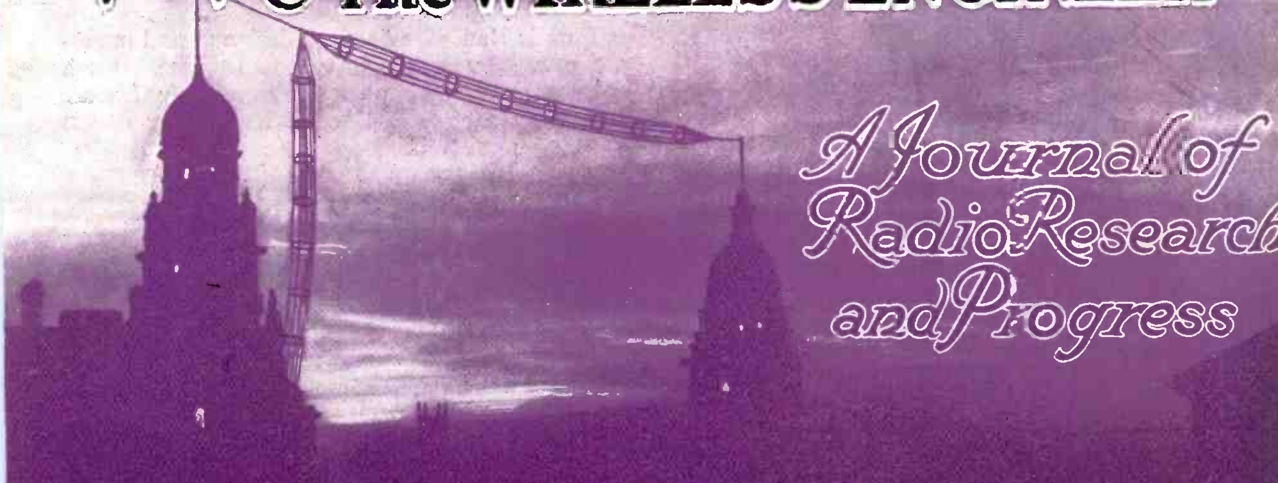
EXPERIMENTAL WIRELESS
& The WIRELESS ENGINEER



A Journal of Radio Research and Progress

Vol. IV
No. 41.

IN THIS ISSUE

FEB.
1927.

1/-

Publishers

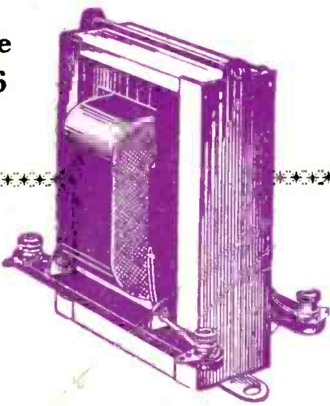
Every circuit is better with IGRANIC RADIO DEVICES

RADIO IGRANIC ELECTRIC Co. Ltd. DEVICES

Igranic-Pacent Super Audioformer

THE Igranic-Pacent Super "Audioformer" has a remarkable amplification curve, making it quite different from all other transformers and giving uniformity of amplification which results in superlative tone qualities. The Igranic-Pacent Super "Audioformer" has a ratio of 1:3 and is suitable for all Stages.

Price 24/6



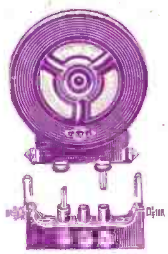
Igranic Radio Devices are designed and manufactured by experts of vast experience. Each Igranic component possesses some unique feature which makes it distinctive and every one is fully guaranteed.

Igranic "Indigraph" Vernier Knob & Dial

The Igranic Indigraph Vernier Knob and Dial is a handsome slow motion dial which greatly facilitates fine adjustment. Two scales of 0 to 100 each are provided reading in opposite directions making the Indigraph suitable for different types of condensers. Space is provided opposite the scale for recording station settings. The metal dial acts as a shield against hand capacity effects.

Price 7/6 each.

Igranic Centre Tapped "Xllos" (Extra Low Loss) Coils



Igranic Centre Tapped "XLLOS" Coils possess special windings of very high efficiency, enclosed in a sealed Bakelite shell which excludes dust and moisture and prevents the coils being damaged, thus preserving absolute constancy in operation.

Igranic Centre Tapped Coils actually contain two separate inductances which may be used singly or may be joined in series to form a single coil to which a centre tapping can be taken.

Made in five sizes for wavelengths from approximately 110 to 3,350 metres.

Prices from **7/- each.** Mounting Base **4/6.**

Igranic Tone Control and Damping Resistance

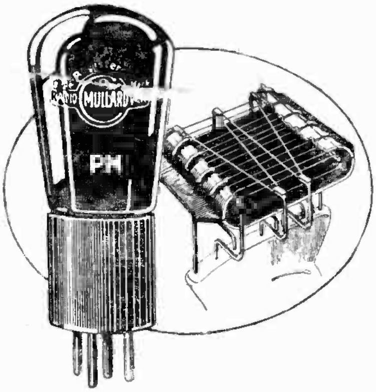
The Igranic Tone Control enables the volume from a receiver to be regulated from the maximum obtainable to a mere whisper of sound. It is easily fitted and connected and gives smooth, silent control over its whole range. The Igranic Tone Control is particularly useful for multi-valve receivers as it enables the volume to be reduced when receiving the local, or powerful stations.

Price: with 1½" Indigraph Knob and Dial **6/6.**
with Plain Knob only .. .. **5/6.**

WRITE FOR THE NEW IGRANIC CATALOGUE List No. T209.

IGRANIC ELECTRIC Co. LTD.
149, QUEEN VICTORIA STREET, LONDON
WORKS: ELSTOW ROAD, BEDFORD

Valve Set Owners Are Fast Learning This Secret*



Sectional view of P.M.5 showing generous proportions of P.M. Filament

* the secret of increased range and greater economy in the operation of their radio receivers

It must have struck you at one time or the other that the radio results of certain of your friends who have sets based on the same circuit and the same number of valves, were better than those from your own receiver. The answer to the following question will give you the key to the secret of improved reception :
" How copious is the emission given by the filaments of your valves over a range of filament temperatures ? "

Why great emission makes all the difference

When a valve filament gives a copious and sustained emission at the correct filament temperature, a rich field of power is placed under your control which enables the best conditions to be secured to deal with the incoming signals, so that your receiver is adjusted to suit the particular circumstances existing at the time.

The local station may be tuned in purely and strongly with the minimum of energy expended because valves that possess a huge emission are able to function perfectly at considerably less than their full capacity.

Then, as you reach out for more distant stations or weaker signals, you are able to adjust the operating energy of your high emission valves, particularly in the detector stage, to suit the exact demands for ideal reception. It will be realised that by the use of Mullard P.M. valves with their abundant electron emission you will save upkeep costs since your receiver will only consume minimum energy from your batteries.

A valve filament that has up to 5½ times the emission surface of an ordinary filament

To no one so much as the owner of Mullard P.M. Valves is the truth of this boon of great emission so apparent. The wonderful P.M. Filament—the foundation of the famous series of Mullard P.M. Valves—is so generous in its dimensions that the emission surface is immense. This remarkable fact is due to the length of the P.M. Filament being up to 3 times that of an ordinary filament, and its greater diameter. These two factors are responsible for the supreme efficiency of the Mullard P.M. Filament which possesses an emission surface 5½ times more effective than an ordinary filament.

A Government Test

Convincing proof of the high emission of the wonderful P.M. Filament was recently given by the 1000 hours' test report of the National Physical Laboratory. This proved that the emission of Mullard P.M. Filaments was so abundant and consistent that an 18/6 Mullard P.M. Valve was still worth 18/- after 1000 hours' continuous life test, equivalent to a year's broadcasting service.

Bring your radio receiver up to the highest pitch of efficiency by installing Mullard P.M. Valves with the wonderful P.M. Filament and remember they consume absolutely minimum current.

Ask any radio dealer for full information.

For 2-volt accumulator
THE P.M.1 H.F. 0·1 amp. **14/-**
THE P.M.1 L.F. 0·1 amp. **14/-**
THE P.M.2 (Power) 0·15 amp. **18/6**
For 4-volt accumulator or 3 dry cells
THE P.M.3 (General Purpose) 0·1 amp. **14/-**
THE P.M.4 (Power) 0·1 amp. **18/6**
For 6-volt accumulator or 4 dry cells
THE P.M.5x (General Purpose) 0·1 amp. **14/-**
THE P.M.6 (Power) 0·1 amp. **18/6**
Super power valves for last L.F. stage
THE P.M.254 (4 volts, 0·25 amp) **22/6**
THE P.M.256 (6 volts, 0·25 amp. **22/6**
These prices do not apply in Irish Free State

Mullard
THE · MASTER · VALVE

ADVT. THE MULLARD WIRELESS SERVICE CO. LTD., MULLARD HOUSE, DENMARK STREET, LONDON, W.C.2

Details

"Take care of the pence and the pounds will take care of themselves," is an adage well worth considering if you want really fine Radio reproduction. Small details, especially where anode and filament currents are concerned, unless carefully checked, frequently ruin an evening's programme. Economical operation of your Set is only possible by correct adjustment of filament, plate and grid voltage.

See that your low and high tension supply is absolutely correct—test it with a reliable High Resistance Instrument, that is, a Weston Voltmeter with a sensitivity of 125 ohms per volt. Weston Model 506. Pin Jack Voltmeter is designed specially to measure accurately both filament and plate voltage, but will prove of great service for ordinary continuity tests. It is another of the wide range of WESTON products that are now recognised as standard throughout the world, and it reveals that same excellence of design and workmanship for which the name WESTON has been famous since 1888.

WESTON Pin Jack Voltmeter

Price complete with testing cables **£2 : 10 : 0**

WESTON

STANDARD THE WORLD OVER

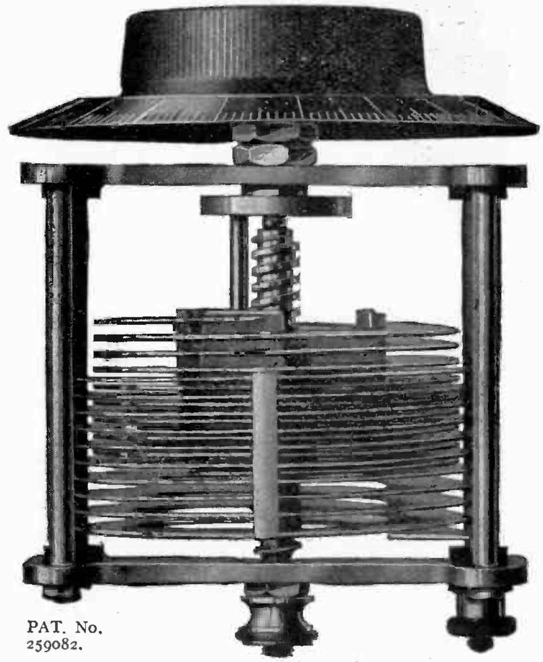
Pioneers since 1888

Weston Electrical Instrument Co. Ltd.
15, Gt. Saffron Hill,
London, E.C. 1

A CONDENSER
4 FEET IN DIAMETER

would only be equal to ten complete turns of the dial of the

M·A·P
STRETLINE CONDENSER



PAT. No. 259082.

Its main advantages are its continuous 3600° dial readings. Ten complete turns of the dial are the equivalent of an ordinary Condenser fitted with a dial four feet in diameter. The standard capacity of the Condenser is .0005. The selectivity obtained with this Condenser is such that there is no previous standard by which it can be compared. One degree on the standard Condenser of the orthodox type is spread out over twenty degrees on this Condenser, and it is possible with this Condenser used in a well designed circuit to separate without difficulty any Stations which can be separated.

Altogether this Condenser gives an entirely new meaning to tuning. It resolves it into a perfectly simple operation and the average person has no difficulty without any technical knowledge or skill in tuning in distant stations which on the standard type of Condenser used to-day are extremely difficult.

Calibration charts on request.

PRICE 21/- EACH

(·0005)

SOLE AGENTS WANTED IN ALL TOWNS

M·A·P Co., 246, Gt. Lister Street, BIRMINGHAM.

THE OFFICIAL ORGAN of the RADIO SOCIETY OF GREAT BRITAIN

EXPERIMENTAL WIRELESS
and The WIRELESS ENGINEER

A Journal of Radio Research and Progress

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

VOL. IV. No. 41. FEBRUARY, 1927. MONTHLY.

CONTENTS OF THIS ISSUE.

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

Published Monthly, on the first of each month.
Editorial Offices: 139-40, FLEET STREET, LONDON, E.C.4. Telephone: City 4011 (3 lines).
Advertising and Publishing Offices: DORSET HOUSE, TUDOR STREET, LONDON, E.C.4.
Telegrams: "Experiwyr, Fleet, London." Telephone: City 2847 (13 lines).

COVENTRY: Hertford St. Telegrams: "Cyclist, Coventry." Telephone: 10 Coventry.
BIRMINGHAM: Guildhall Buildings, Navigation St. Telegrams: "Autopress, Birmingham." Telephone: 2970 and 2971 Midland.
MANCHESTER: 199, Deansgate. Telegrams: "Iliffe, Manchester." Telephone: 8970 and 8971 City.

Subscription Rates, Home and Abroad: One Year, **13/6**; six months, **6/9**, post free; single copies, **1/1½** post free.

EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

Vol. IV. FEBRUARY, 1927. No. 41.

Editorial.

The Performance of Amplifiers.

IN this issue we publish an article under this title by Mr. P. K. Turner in which he discusses the method of plotting the amplification curves of any device over a wide range of frequencies. Most of our readers will by now be quite familiar with the logarithmic or piano-keyboard method of plotting the frequencies as abscissæ. Since the change of pitch from 100 to 200 is musically the same as a change from 1,000 to 2,000, in that the change is an octave in each case, there is no need for the latter interval to be spread out over a base 10 times as long as the former. It gives a false impression of the distribution represented by the ordinates over the musical range. On the logarithmic scale each octave occupies the same extent of base line as on the piano keyboard. Very similar reasons may be adduced for plotting the amplification to a logarithmic scale. Doubling the loudness would then give the same change of ordinate whatever the initial value.

Mr. Turner gives curves of amplification at various frequencies of three sets, one a typical better-class English set, the second a set made by the firm with which the author is associated—giving naturally a better curve than the first—and thirdly a laboratory set. The author is quite fair, however, and points out that in the first set quality has been sacrificed somewhat to get range, and, moreover, that the quality as judged by broadcast reception was much better than one might expect from the curve.

There is one point, however, about all the tests to which we would draw attention and that is, that although they were obtained on sets consisting of a detector and two amplifying valves, for the purposes of these tests the connections were modified so that the first valve acted as an amplifier, thus converting the set into a three-valve amplifier. Why the author adopted this peculiar procedure does not appear from the article. It would have been more convincing if the audio-frequency tests had been made on the stages designed for audio frequencies, or if it were considered essential to use all three valves, the detector could have been supplied with a radio-frequency voltage of constant amplitude but modulated at various frequencies. This would have greatly complicated the measurements, however. The curve of Fig. 1 makes one curious to know what component of the set was responsible for the badness of the curve.

Radio-Frequency Measurements.

OF all the books published during 1926, the most important to the radio experimenter was probably Moullin's *Radio-Frequency Measurements* — described as a Handbook for the Laboratory and a Textbook for the Advanced Student.

As we felt sure that many of our readers who attempt accurate measurement of the varied magnitudes involved in their experimental work would consult the pages of this book, we decided to ask an expert in this subject to read the book and prepare a critical review of it for *E.W. & W.E.* Nobody has a more intimate, complete, and up-to-date knowledge of the theory and practice of high-frequency measurement than Mr. D. W. Dye of the National Physical Laboratory, and we have therefore much pleasure in publishing in this issue his review of Mr. Moullin's book.

Quality in Broadcast Reception.

THIS subject has recently been brought into prominence owing to one or two men of eminence in the musical world publishing statements which are far from complimentary to those who, like ourselves, are so deficient in musical taste that we actually enjoy a good broadcast performance of a Beethoven symphony or a Wagner overture. We can understand and sympathise with Sir Thomas Beecham when, in his disappointment and disgust, he looks around for something to kick and lights upon broadcasting. But surely he made his sad experiences in the financing of Grand Opera before broadcasting was dreamt of! The difficulties of making grand opera and high-class concerts a financial success may have been increased by broadcasting, but it is too early to give any definite judgment on the question. Mr. Ernest Newman, well known as a pungent and fearless musical critic, has also made an attack on wireless music from what one paper described as his lofty pinnacle in the *Sunday Times*. "The only people," he says, "who have a right to be heard on the subject of wireless music are perfectly impartial and disinterested musicians. In a matter of transmission of music by wireless only the musician's hearing, which is rather different from that of the scientist, is worth taking into consideration. What does the average scientist or wireless 'fan' know about orchestral timbres?" To which we would reply that the average scientist knows as much or more about these matters as the average impartial musician. It is a branch of science and one which has received considerable attention during the last few years.

No one would maintain that the reproduction obtained from even the best loudspeaker is perfect; it is not; but it is far too good to call for cheap jibes at the musical taste of the people who enjoy it. The progress made since the inception of broadcasting has been very great and still continues. We are living in a wonderland where millions of people hear the very best music several times every week and are learning to appreciate it and enjoy it—people who for the most part would never have heard it and to whom Beethoven, Mozart and Wagner would have been mere names. Surely this should be a cause for rejoicing rather than for criticism of the imperfections necessarily associated with such a novelty.

The Design of a Heterodyne Type Low Frequency Generator.

By H. L. Kirke.

As a certain amount of interest has been displayed in the design and performance of heterodyne type low frequency generators, it is thought that the details of design, and the experiments leading up to design, will be of use to those wishing to construct such instruments.

The author, and some members of his staff, commenced work on the design of a generator of low frequency currents just over two years ago, for use in connection with measurement work on Lines, Transmitters, Amplifiers, etc., used in broadcasting. The required performance was as follows :—

1. Maximum output 0.5 watt.
2. Frequency range 50 to 10,000 cycles.
3. Constant output over frequency range.
4. Waveform, close approximation to sine wave.

Various direct methods were tried, *i.e.*, a valve oscillating at the frequency required, but it was found that if the required performance was to be closely adhered to the apparatus would be unwieldy and far from simple in operation. It was therefore decided to carry out some experiments with the heterodyne method.

Two oscillators were constructed, working round about 4,000 metres, one variable in frequency, one fixed, the outputs connected to a rectifying detector and the resultant low frequency passed through a suitable amplifier. The output was measured by means of a slide back valve, which will be described later. The degree of harmonics present was determined by means of an A.C. bridge, in which the fundamental frequency was balanced out ; under these conditions it was possible to estimate roughly the amount of harmonic present in different arrangements, at any rate relatively.

It was necessary to use some form of aperiodic coupling between the H.F. generators and the detector, in order that the amount of H.F. applied to the detector should not change with frequency. Untuned coupling coils were employed for this and found satisfactory.

Various forms of detector were tried, grid-leak, crystal and anode rectification. It was found that anode rectification was by far the best from the point of view of freedom from harmonics, but at the same time great care had to be taken that there was no grid current in this detector, otherwise it was little better than the crystal or the grid-leak. Even by using the anode rectifier the harmonics were rather stronger than desirable.

The next step was the improvement of the high frequency waveform. In this connection it is of interest to note that harmonics can only occur in the resultant rectified current if both the high frequency carriers have harmonics. Also that in heterodyne reception, if one current is stronger than the other, the resultant rectified current is proportional to the weaker of the two (assuming a linear rectifier). Let A represent the amplitude of the strong carrier and B the amplitude of the weak, then peak amplitude of the combined carrier wave varies between $A+B$ and $A-B$. The peak value of the resultant rectified current (low frequency) will be proportional to the difference between the two, *i.e.*,

$$(A+B)-(A-B)=2B.$$

That is to say for a linear detector the amplitude of the rectified beats is unaltered by a change in amplitude of the stronger carrier. The same applies to a non-linear detector, provided that the one carrier is sufficiently strong to sweep right over the non-linear portion on to the straight portion of the detector characteristic, and that the amplitude of the weaker carrier is not sufficient to cause the instantaneous value of the resultant rectified current (D.C.) to reach a non-linear portion of the characteristic.

Now a rectifier arranged in this manner will not of itself introduce any harmonics into the resultant low frequency output, as the waveform of the low frequency output will be a copy of the envelope of the high frequency input.

The next consideration is the elimination of harmonics in the low frequency output due to other causes, the chief of which are harmonics in the high frequency currents. It can be shown very simply that if both the high frequency currents contain harmonics then the resultant low frequency current will also contain harmonics, but if the harmonics are eliminated from one of the high frequency currents then the low frequency currents will contain no harmonics.

Consider two high frequency currents of frequency f_1 and f_2 having harmonics of $2f_1$ and $2f_2$, etc., respectively. Now f_1 and f_2

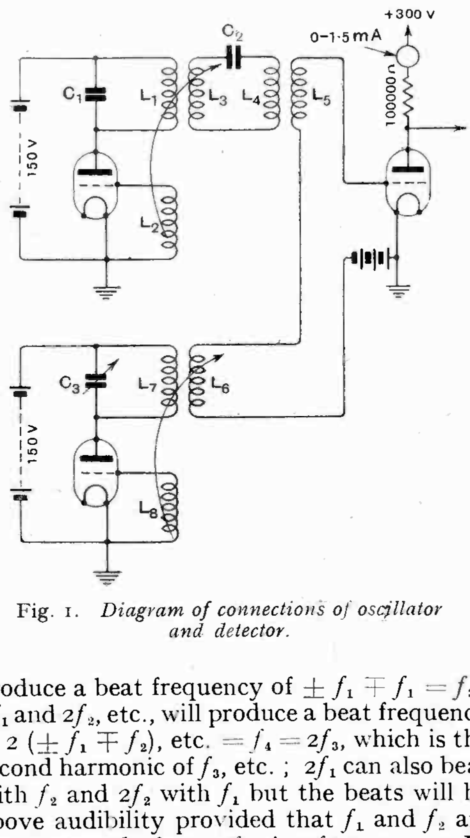


Fig. 1. *Diagram of connections of oscillator and detector.*

produce a beat frequency of $\pm f_1 \mp f_1 = f_3$; $2f_1$ and $2f_2$, etc., will produce a beat frequency of $2(\pm f_1 \mp f_2)$, etc. $= f_4 = 2f_3$, which is the second harmonic of f_3, etc.; $2f_1$ can also beat with f_2 and $2f_2$ with f_1 but the beats will be above audibility provided that f_1 and f_2 are far removed from f_3 in frequency. If, however, f_1 contains no harmonics, then $2f_2$, etc., has no complementary harmonic $2f_1$ of f_1 to beat with, in which case there will be no harmonics in the resultant low frequency current.

The next consideration is constant output at all frequencies. It has been shown above that if one high frequency is small compared with the other, and that the stronger one is arranged to sweep well over the non-linear portion of the detector characteristic, then the amplitude of the low frequency rectified current will be proportional to that of the weaker high frequency current. From this it will be seen that if the frequency of the weaker high frequency current is not varied, its amplitude should remain constant, therefore the amplitude of the resultant rectified low frequency current will be constant at all frequencies. The variation of frequency of the stronger carrier will probably produce variations of amplitude which, however, will not cause a variation of the amplitude of the low frequency output, provided that the variations of H.F. input amplitude are not sufficient to cause the rectifier to become non-linear.

It is convenient, therefore, to pass the fixed frequency currents through filter circuits, to remove harmonics as the adjustment of the filter circuits can be fixed. Very weak coupling can be used as the amplitude required is small compared with that of the variable frequency current.

The production of harmonics by grid current in the detector, as mentioned above, is due to the fact that the grid circuit of the detector is not tuned to the high frequency input, any non-linearity in the grid circuit will therefore produce harmonics in the high frequency currents and consequently in the low frequency output of the detector, as has already been explained. If it could be arranged that the input circuit consisted of a highly resonant (*i.e.*, very lightly damped) circuit, then any harmonics would be passed to earth very freely; in practice, however, this cannot be done, as the input circuit to the detector must be aperiodic to obtain constant amplitude output at all frequencies.

Fig. 1 shows circuits embodying the above principles.

The circuit on the top left is the fixed oscillator, the values L_1 C_1 were chosen so that oscillations generated were as free as possible from harmonics, C_1 being about 0.005μF for a wavelength of 4,000 metres. Larger condensers and smaller inductances could conveniently be used provided that lower resistance coils were used. L_3, the intermediate coupling coil, consists of a few turns of wire, loosely coupled to L_1. L_3 C_2 L_4 are tuned to the same frequency as L_1 C_1 and should constitute a very low damped circuit. L_5 was a few turns tightly coupled to L_4 at the earth end. L_7 C_3 constitute the variable frequency oscillator C_3, being actually a fixed condenser of about 0.005μF plus three variable condensers in parallel, one of 0.00025μF capacity to adjust the zero, one of 0.00025μF to adjust the frequency difference (*i.e.*, resultant low frequency) up to 3,000 cycles, and another of 0.001μF for frequencies up to 10,000 cycles.

The valves used for the oscillators were L.S.5B's, but valves of similar characteristics worked very well. An L.S.5B has a resistance of 30,000 ohms, and a μ value of 20.

It was found necessary to have considerable separation between the two oscillators to prevent one from pulling the other; the actual separation being about 5 ft. Three sets of H.T. and L.T. batteries were used for the first instrument built, one for each oscillator and one for the detector and low frequency amplifier. It was necessary to use separate batteries to prevent pulling.

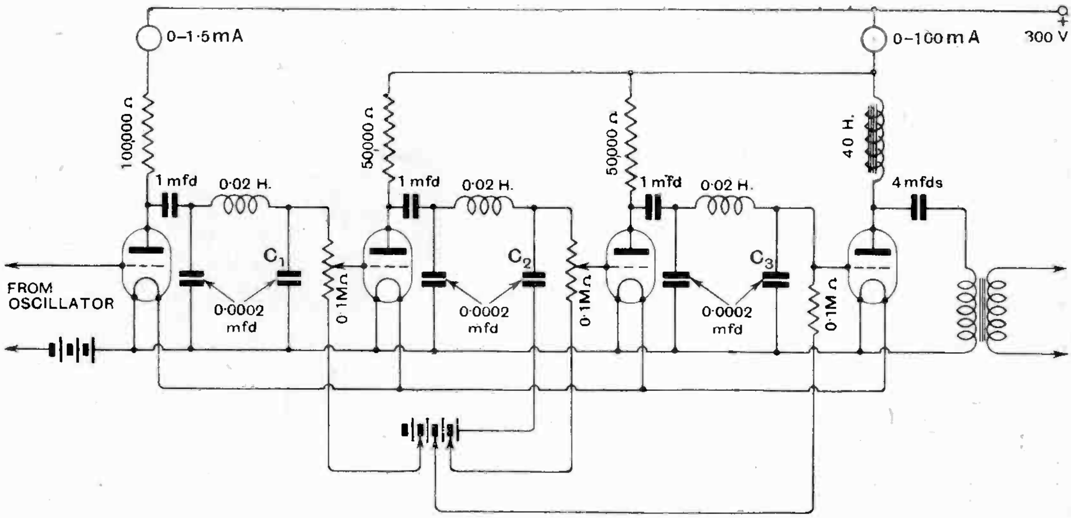


Fig. 2. *Diagram of connections of detector and L.F. amplifier. The output stage may consist of a number of valves in parallel.*

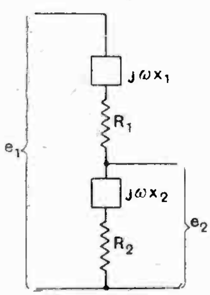


Fig. 3.

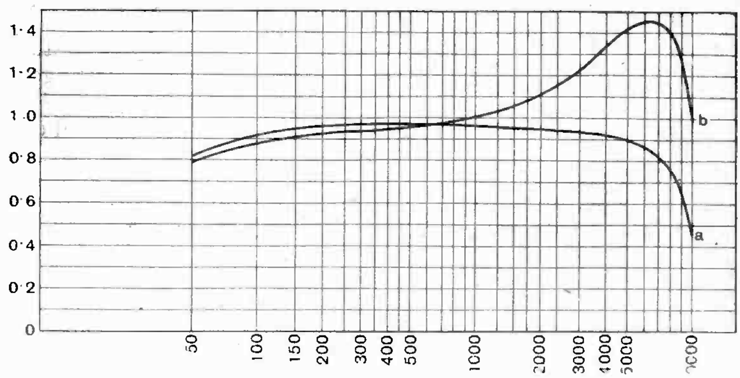


Fig. 4. *Curve showing effect of reactively and non-reactively wound potentiometer. a = non-reactively wound and b = reactively wound.*

The Low Frequency Amplifier.

As the range of frequencies to be covered was large, and constancy of output over the frequency range important, resistance capacity amplification was used throughout, and low resistance valves (6,000 ohms, μ value 6) in order to obtain very linear characteristics, and so freedom from harmonics. Volume control was obtained by a wire wound potentiometer used as a grid-leak to one or more stages, the total value being 100,000 ohms, having 14 tappings, one potentiometer having a stud to stud ratio of 1 : 2, another having a ratio of 1 : 1.05. From this any known value of output relative to a known maximum could be obtained. For a detector valve the L.S.5B was found best, it having a sharper bend than most valves. The anode resistance was 100,000 ohms, the H.T. 300 volts. The anode current was adjusted by means of the grid bias, so that with no H.F. input it was about 0.3 to 0.4 milliamps, the H.F. input bringing the feed up to about 1 milliamp; 300 volts was used throughout in order that sufficient output could be obtained without introducing non-linearity. It was found necessary to insert H.F. chokes and

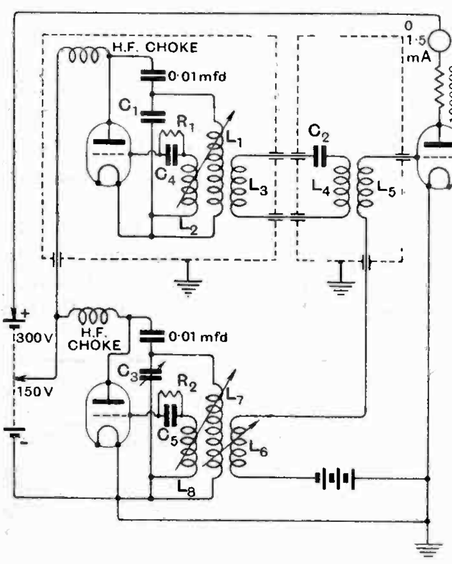


Fig. 5. *Diagram of connections of portable model oscillator unit.*

bypass condensers in the intervalve coupling, to prevent the carrier frequencies getting through the low frequency amplifier; these were approximately 0.02 henry and 0.0002μF respectively, and are shown in Fig. 2. It is necessary to adjust the values fairly carefully, in order not to alter the output frequency curve, a too high value of inductance producing a "tip up" of the high frequencies when the choke and grid filament capacity approach resonance. This

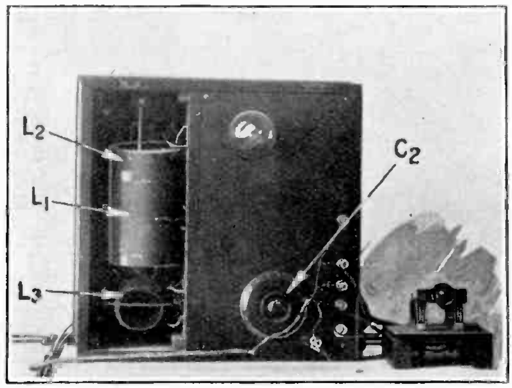


Fig. 6. *Fixed oscillator and filter circuit of first experimental model. The letters refer to Fig. 1.*

is analogous to resonance in an inter valve transformer due to magnetic leakage and capacity. The effect can be reduced by altering the value of grid-leak resistance and/or the condensers C_1 C_2 C_3 (Fig. 2).

It was also found necessary to take great care that the volume control potentiometers were non-reactive, as reactance in the windings may cause the output to vary with frequency and to vary differently for different settings of the potentiometers.

If a potentiometer is reactively wound, the ratio of reactance to resistance may vary with different settings of the potentiometer, if this happens the frequency characteristic will vary with different settings, as follows: In a potentiometer, as shown in Fig. 3, the ratio of output E.M.F. e_2 to input E.M.F. e_1 at any frequency $\omega/2\pi$ will be :—

$$\frac{e_2}{e_1} = \frac{1}{1 + \dfrac{R_1 + J\omega X_1}{R_2 + J\omega X_2}}$$

Now if

$$\frac{R_1}{J\omega X_1} = \frac{R_2}{J\omega X_2}$$

then the frequency characteristic will be straight, but if the ratio

$$\frac{R_1}{J\omega X_1} \text{ to } \frac{R_2}{J\omega X_2}$$

is not constant over the whole range of the potentiometer, then the frequency characteristic will *not* be constant. Fig. 4 shows the effect of a reactively wound potentiometer.

the potentiometers should be of the order of 50,000—100,000 ohms and 44 S.W.G.—Eureka wire, silk covered, may conveniently be used.

If it is desired that the frequency characteristics shall be straight at low frequencies

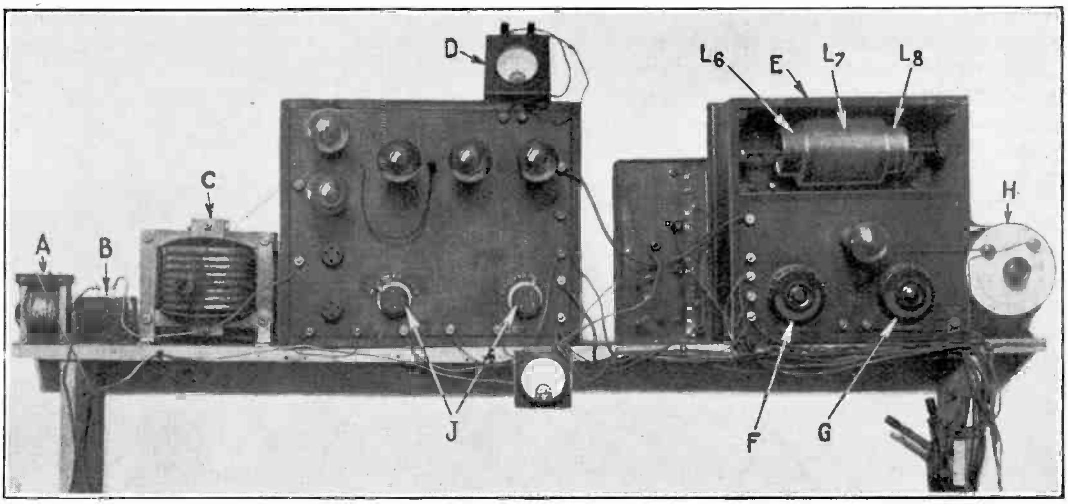


Fig. 6A. *Variable frequency oscillator on right, detector and L.F. amplifier on left. (First experimental model.)* L_6, L_7 *and* L_8 *refer to Fig.* 1. F, G *and* H *comprise the variable part of* C_3 *(Fig.* 1*).* D = *shunted galvanometer for detector feed.* J = *Potentiometers.* C = *Anode feed choke.* B = *Output condenser.* A = *Output transformer.*

A convenient method of winding potentiometers is to use a bobbin with a large number of sections, arranging that the resistance between each stud on the potentiometer shall be split up into several sections, alternate sections should then have the direction of winding reversed. The total resistance of

of the order of 50 p.p.s., then intervalve condensers should be not less than 1μF capacity each.

A portable form of heterodyne generator was also constructed, in which the H.F. oscillator circuits were screened. Great care must be taken that the circuits are effectively

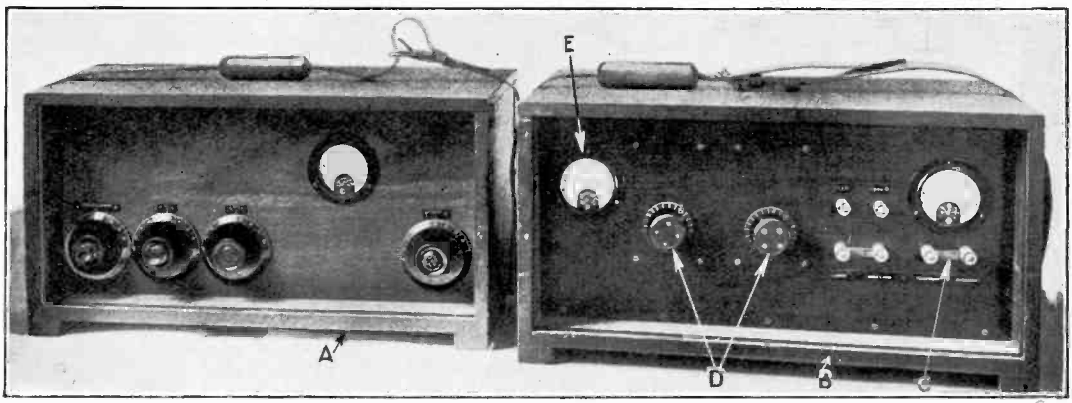


Fig. 7. *Front view of portable model. H.F. unit on left, detector and L.F. unit on right.* D = *Potentiometers.* C = *Links for obtaining various types of output.*

screened, and that there is no coupling between the circuits of the fixed frequency oscillator and those of the variable frequency oscillator. Even with a good copper screen, if L_1 is close to L_7 (Fig. 5), as is necessary for compactness, the axes of the coils must be carefully arranged to reduce magnetic coupling to a minimum. Parallel feed was used with the valves as shown in Fig. 5 to prevent the H.F. current flowing through the H.T. battery, so reducing the amount of pulling taken off the 300-volt battery for the H.F. valves, also common L.T. (6 volts). Fig. 6 shows the fixed oscillator and filter circuit; Fig. 6A shows the variable frequency oscillator on the right and the detector and L.F. amplifier on the left. In Fig. 7 the two oscillators and the filter circuit are in the left-hand box, the detector and amplifier in the right-hand box.

A model has since been constructed, the details of which are as follows, the references

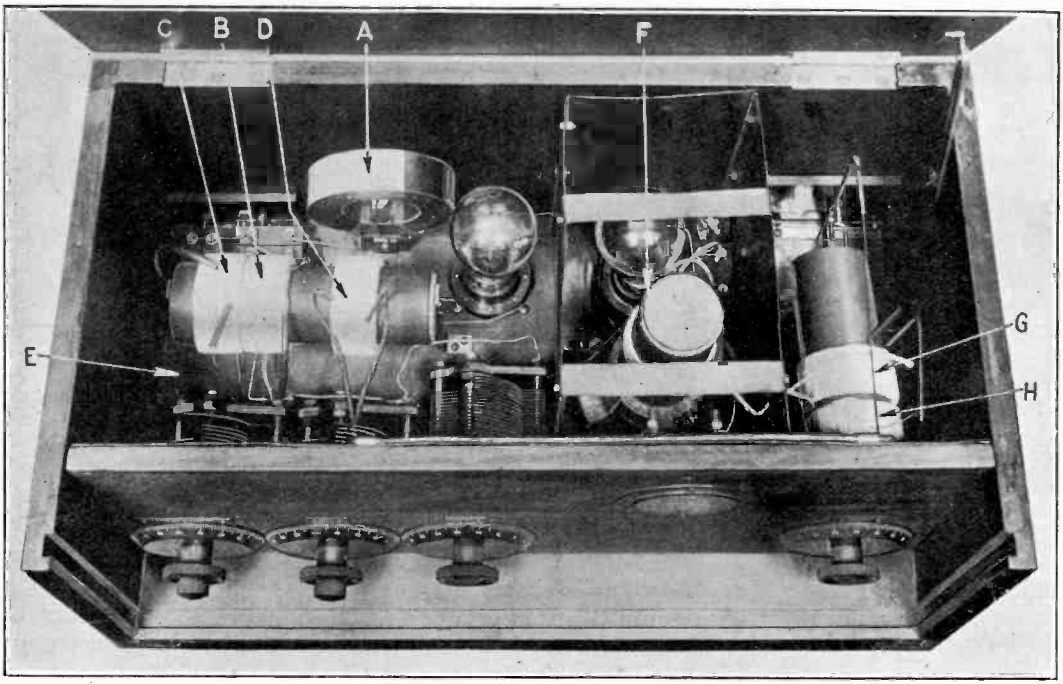


Fig. 7A. *View showing interior of high frequency unit.* A = *Anode choke.* B = L_7. C = L_8. D = L_6. E = C_3 (*variable part*). F = L_1, L_3 *and* L_2. G = L_4. H = L_5. *The references are to Fig.* 5.

due to resistance in H.T. battery. The H.F. chokes should have high inductance and low self capacity. Where constancy of frequency is of importance it has been found an advantage to use grid condensers and leaks in both the H.F. oscillators as shown in Fig. 5 (C_4, C_5, R_1, R_2), C_4 and C_5 are both 0.001μF, R_1 R_2 are both 100,000 ohms. Photographs of the apparatus are shown in Figs. 6 and 7.

Figs. 6 and 6A show the original model and Figs. 7 and 7A the portable model. For the portable model common H.T. was used throughout, the tapping of 150 volts being being to Fig. 5: all coils are 2 in. inside diameter and $\frac{3}{16}$ in. thick, slab wound outwards.

H.F. Chokes, each 3 sections, each 700 turns No. 36 D.W.S.

L_1 and L_7	80 turns	9/40	Each strand S.S.C. and D.S.C. overall.	680μH
L_2 and L_8	40 ,,	,,		170 ,,
L_3	1 turn	,,		
L_4	61 turns	,,		330 ,,
L_5	10 ,,	,,		14 ,,
L_6	15 ,,	,,		30 ,,

C_1 0.005 fixed approx.

C_2 0.01 fixed + 0.001 variable.

C_3 0.005 fixed + 2/0.00025 variable + 1/0.001 variable.

Operation.—As the frequency of the two oscillators is liable to vary with H.T., L.T., temperature, etc., it is necessary to have some means of adjusting them to be relative to each other. This is best done in practice by the zero adjusting condenser. The two tuning condensers are both set at zero, and zero adjusting condenser adjusted until the beat frequency, as indicated by the milliammeter in the detector anode circuit, is zero. The actual movement shown on this meter for frequencies of the order of one or two a second, is an indication of the amount of pulling between the two oscillating valves, *i.e.*, if there is pulling the movement will not be sinusoidal. Frequencies from 0 to 3,000 are obtained by adjusting the first condenser between 0 and 180 degrees. This condenser is then left at 180 degrees and the second condenser varied up to 180 degrees for frequencies up to 10,000. Calibration curves and output frequency curves are shown in Figs. 8 and 9.

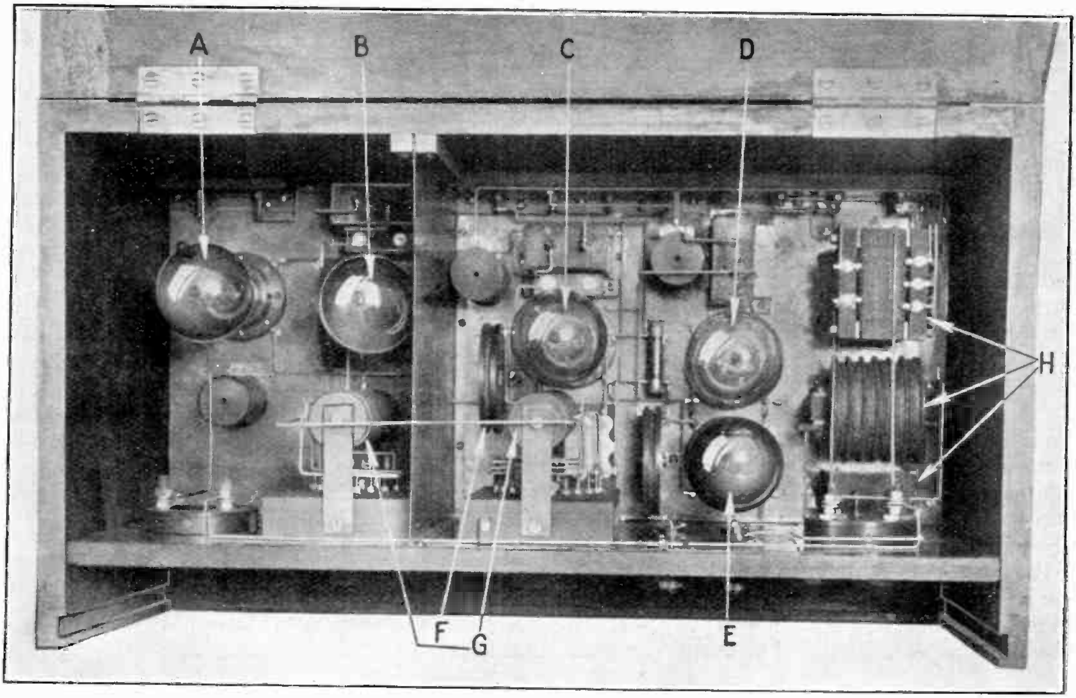


Fig. 7B. *Detector and L.F. amplifier of portable model.* A = *Detector valve.* B = *1st L.F.* C = *2nd L.F.* D *and* E = *Output stage (2 valves in parallel).* F = *H.F. Stopping choke.* G = *Potentiometer bobbins.* H = *Output choke condenser and transformer.*

Constancy of Frequency.

It was found subsequently that the instruments remained sufficiently constant in frequency under the conditions specified above, for all ordinary purposes; at any rate, the changes in frequency were of a minor order compared with the accuracy obtainable by the calibration curve and the condensers.

It was found that the amount of harmonic varied between ½ per cent. and 5 per cent., according to frequency and amount of output required, *i.e.*, linearity of amplifier. This amount has been estimated, not measured directly.

Measurement of Frequency.

Before this apparatus had been constructed a frequency bridge was made and calibrated. Two methods were tried, circuits of which are shown in Figs. 10 and 11. In Fig. 10 a condenser shunted by a resistance is balanced against a condenser in series with a resistance, the balance can only be obtained at one frequency. In Fig. 11 an inductance

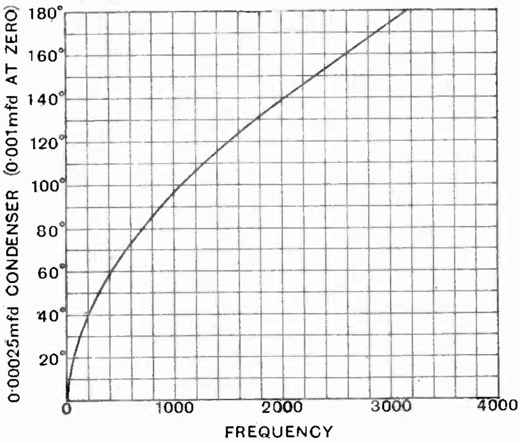


Fig. 8.

and condenser in series form one arm of a Wheatstone bridge. When

$$L.C. = \frac{1}{(2\pi f)^2}$$

the inductance capacity arm is non-reactive, and can be balanced at that frequency as a resistance. This form of bridge was found to be the more satisfactory, and one was built which could be balanced at frequencies from 64 to 8,000 cycles per second. The inductance consisted of a number of power

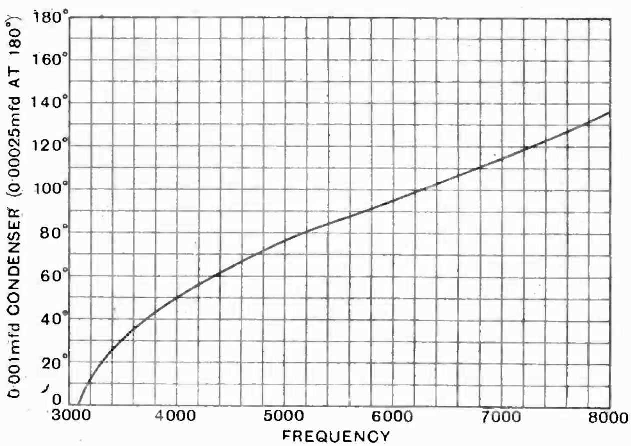


Fig. 8A.

transformer sections, any number of which can be thrown into circuit by means of Kellogg switches. The condensers are preferably of mica, but paper condensers may be used. The actual values used on the bridge were as follows :—

R_1 100 ohms.

R_2 350 ohms.

R_3 400 ohms variable + 25 ohms variable for fine adjustment.

L 0.075, 0.25, 0.55, 1.4, 2.5, and 4.5H.

C 0.01 to 1.5μF in steps of 0.01+a continuously variable 0.01μF condenser, or 0.001 to 1.5μF in steps of 0.001, + a variable 0.001μF condenser.

Calibration.

The instrument was calibrated by means of a standard tuning fork and two separate oscillators, which could be tuned to harmonics of each other. By this means a

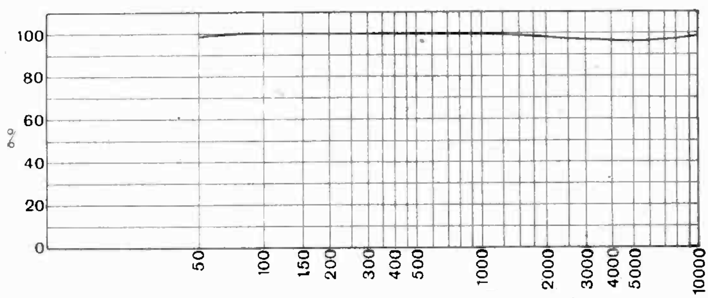


Fig. 9.

number of points were obtained and the calibration curve plotted.

The tuning fork had a frequency of 428 cycles per second. One oscillator was tuned to this frequency by the zero beat method and the bridge adjusted to this frequency and readings taken. The second oscillator was then tuned to twice the frequency and another point taken. The first oscillator was then tuned to one-third the frequency of the second oscillator so that its second harmonic coincided with the fundamental of the second oscillator, and so on.

Intermediate points were taken by means of adjusting the oscillators to notes on a piano. The frequency of the notes being known by counting

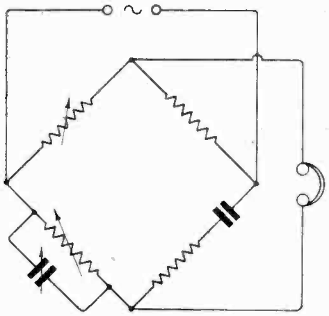


Fig. 10.

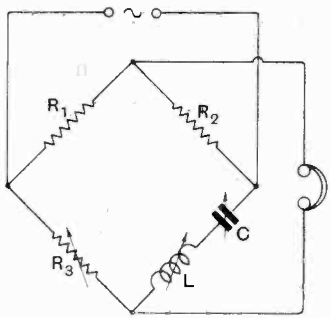


Fig. 11.

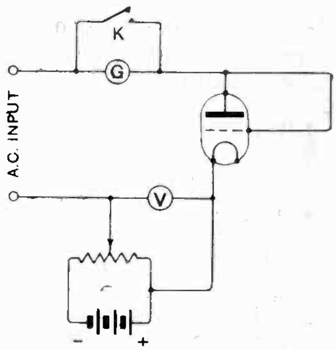


Fig. 12. *Connections of slide back.*

beats between the note of the piano and a tuning fork. While this last method may seem rather crude and unsatisfactory, it was found in practice to be extremely good, provided care was taken.

Measurement of Output by Slide Back.

The slide back as used consisted of a three-electrode valve type D.E.R. with the grid and plate strapped. This was connected as shown in Fig. 12. If the D.C. potential difference across the potentiometer

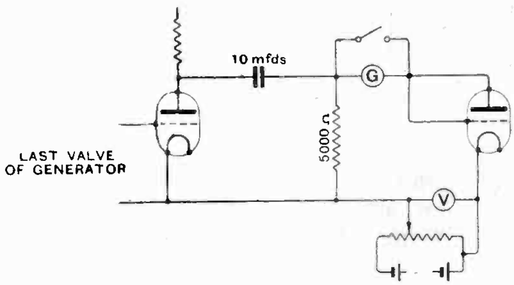


Fig. 13. *Connections of slide back.*

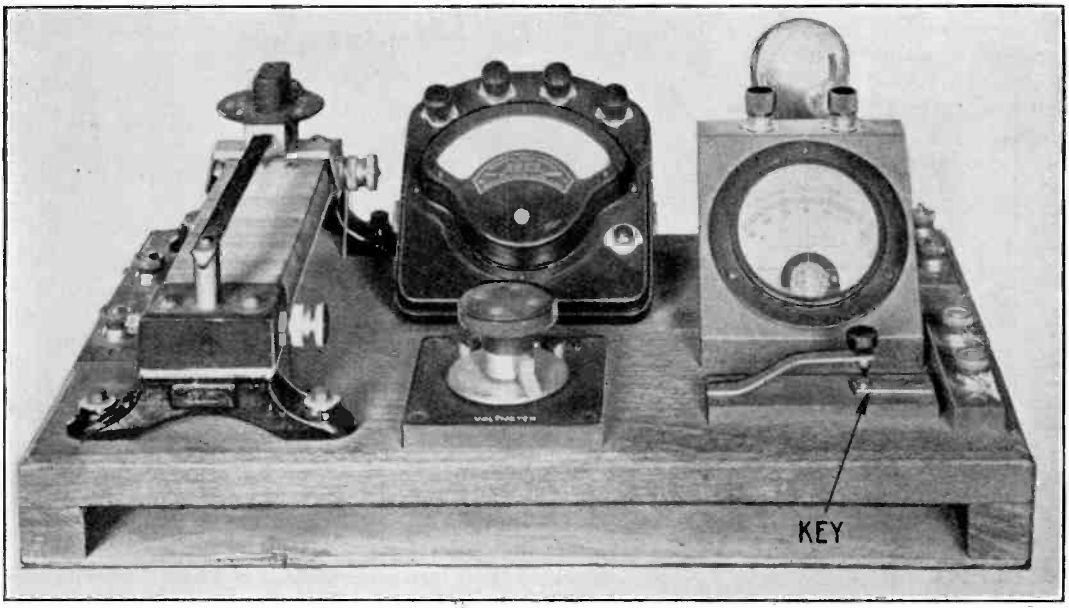


Fig. 14. *View of slide back unit.*

is so adjusted as to be equal to the peak value of applied alternating voltage no current will flow through the valve. The key is used to short circuit the galvanometer, this is used to increase the sensitivity of the instrument, *i.e.*, adjustment of the potentiometer is made until there is no movement in the galvanometer when the key is depressed. A quick-moving galvanometer is essential.

This potential difference is therefore the peak value of the alternating voltage. It should be noted, however, that even with no A.C. a certain small negative potential has to be applied to the anode of the valve to reduce the current to zero. This value should be subtracted from the final value of voltage obtainable.

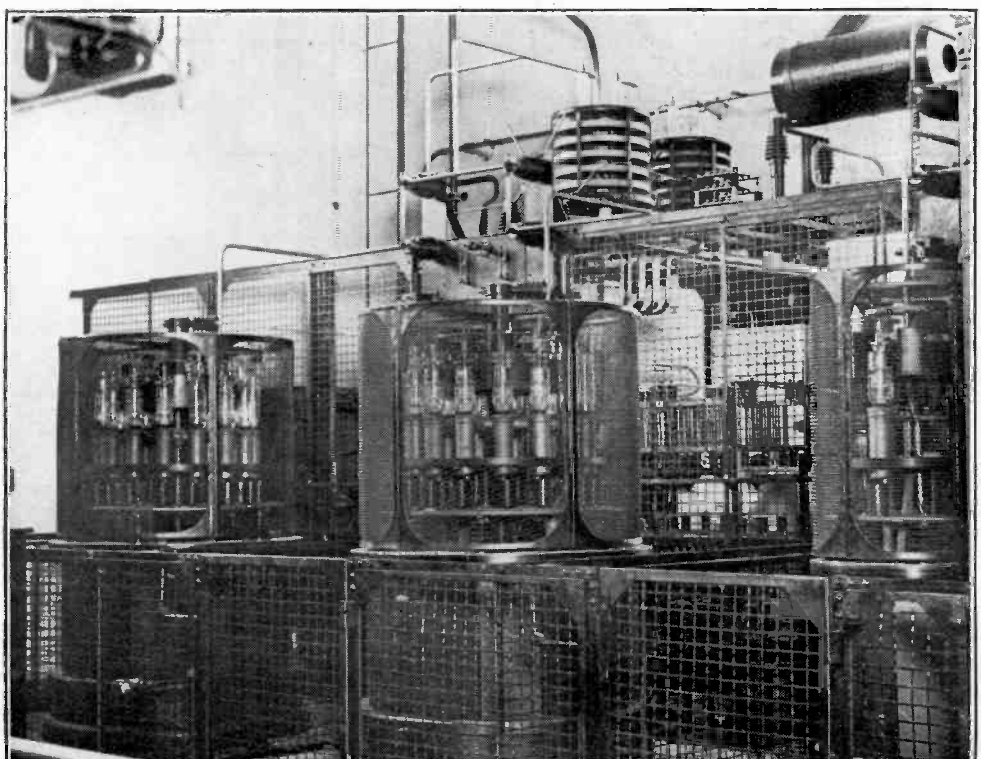
Method of connection to circuit is shown in Fig. 13.

Photograph of the slide back is shown in Fig. 14.

Another method of measuring output is to use a thermo-junction in series with some convenient resistance. This then becomes essentially a voltmeter.

The author wishes to thank Capt. H. J. Round, Messrs. G. M. Wright, M. M. Rust and P. W. Willans for their advice; also Mr. A. B. Howe and other members of his (the author's) staff for their co-operation and assistance.

Transatlantic Telephony Equipment.



The circular valve racks of the transatlantic telephony transmitter installed at Rugby. Each section accommodates sixteen water-cooled valves, the associated apparatus necessary when valves are parallel connected being assembled radially on the platforms.

The Performance of Amplifiers.

By P. K. Turner, A.M.I.E.E.

(*Research Department, Burndept Wireless Limited.*)

WHEN the first performance curves of intervalve transformers were published some two years ago, they were usually plotted to a vertical scale of amplification and a horizontal scale of frequency. It was soon realised, however, that this horizontal scale was quite unsatisfactory. If, as is desirable, the scale extends from zero to 10,000 cycles or thereabouts, the whole of the frequencies between 0 and 1,000—the range over which it is difficult to get the maximum amplification of a transformer—are cramped up on the left-hand side of the resulting graph, and although by carefully examining the graph one can, of course, find out just what the transformer does (assuming the curve to be correct), there is still no doubt whatever that the curve does not give to the eye a true picture of the performance. It is now well realised that such a graph should be plotted to a logarithmic scale of frequency, or, as one may prefer to call it, a simple scale of "pitch," and such is the universal practice nowadays.

Recently, however, the author has been taking some curves of the same nature relating to complete amplifiers, and as a result of this work it would appear that there is need for further modification in this type of diagram.

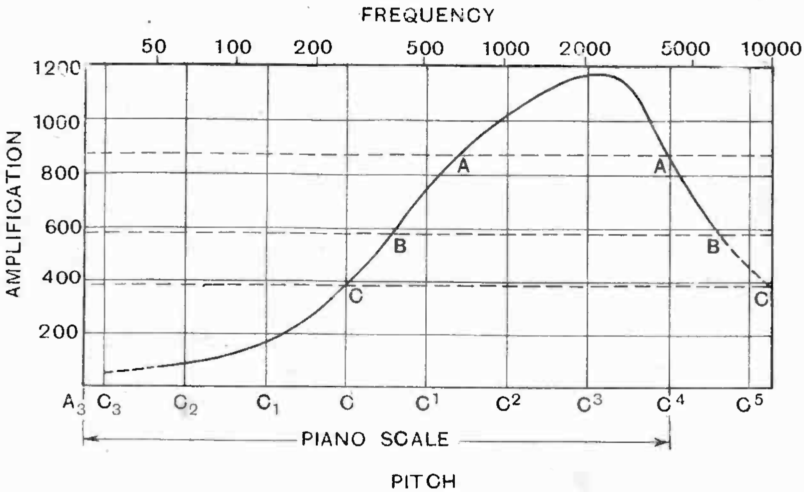


Fig. 1. *Amplification plotted against pitch for a set of indifferent quality. The three lines* AA, BB, *and* CC *indicate respectively amplifications of* 75 *per cent.,* 50 *per cent., and* 33 *per cent. of the maximum.*

For example, Fig. 1 shows the amplification of a commercial set as a function of pitch. This set may be regarded as typical of the general run of better-class English sets: in construction it is pretty much the same as dozens of sets exhibited at the last Olympia Show. Judging from the impression made on the eye by the curve, it would appear to be past all hope of giving a reasonable performance—one would expect to hear nothing except in the neighbourhood of 2,000 cycles. When, however, one comes to examine the curve in detail, one finds that it is much better than it appears, though admittedly it is not good. For example, the smallest difference in amplification which can be perceived, even by a trained ear, without a rapid switch over for comparison, is a drop of 25 per cent. The line *AA* in Fig. 1 corresponds to this drop, and it will be seen that frequencies between about 700 and 4,000 cycles are satisfactorily amplified. This test, however, applies to test work, and is by no means a fair one for a broadcast set in actual use. It will be found that when listening to music it needs a drop in amplification of 50 per cent. before any noticeable impression is made upon the ear. The line performance; it will be seen that in this amplifier the total range of satisfactory performance is from about 250 to 10,000 cycles.

As we have stated above, a critical examination of any form of curve will give corresponding information regarding the component or receiver in question, but it cannot be denied that a curve which looks like Fig. 1 and yet represents a moderately satisfactory performance between 250 and 10,000 cycles is obviously wrong somewhere, for the shape of the curve as it presents itself to the eye would indicate much narrower limits.

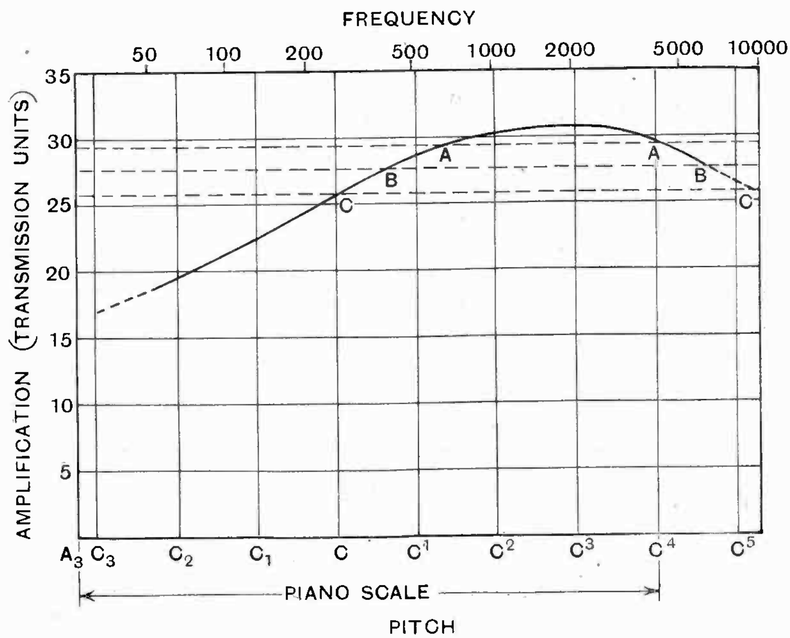


Fig. 2. *The same set as Fig.* 1. *"Gain" in Transmission Units against pitch. Lines* AA, BB, CC *and have the same meaning as in Fig* 1. *It is obvious that this curve conveys to the eye a truer picture than that of Fig* 1.

BB in Fig. 1 represents this drop, and it will be seen that on this basis the set in question has a range of from 400 to 6,000 cycles approximately. But even this is a criterion on the severe side: a considerable amount of testing has shown that there is no obvious defect in the amplification (as regards domestic use) until the actual magnification falls to a third of the maximum. Line *CC* in Fig. 1 represents this, and may be regarded as the real limit of reasonably satisfactory

The writer would therefore suggest the adoption of what is already standard telephone practice, *i.e.*, that the vertical scale should be made logarithmic also. There is no doubt that the difference of impression made on the ear by two different volumes of sound is a matter of their ratio and not of their absolute difference; if we exhibit the performance with the vertical scale in "Transmission Units" (which in practice corresponds to a logarithmic scale in which the logarithms are multiplied by 10, so that a thousandfold amplification is equal to 30 T.U.) we do get a much more reasonable curve. Fig. 2 shows a curve of the same set plotted in this manner, and it will be seen that the general appearance of the curve is much more consistent with the effective range. Without measurement, one might estimate by eye quite reasonably that its range of satisfactory performance would be approximately that which it actually possesses.

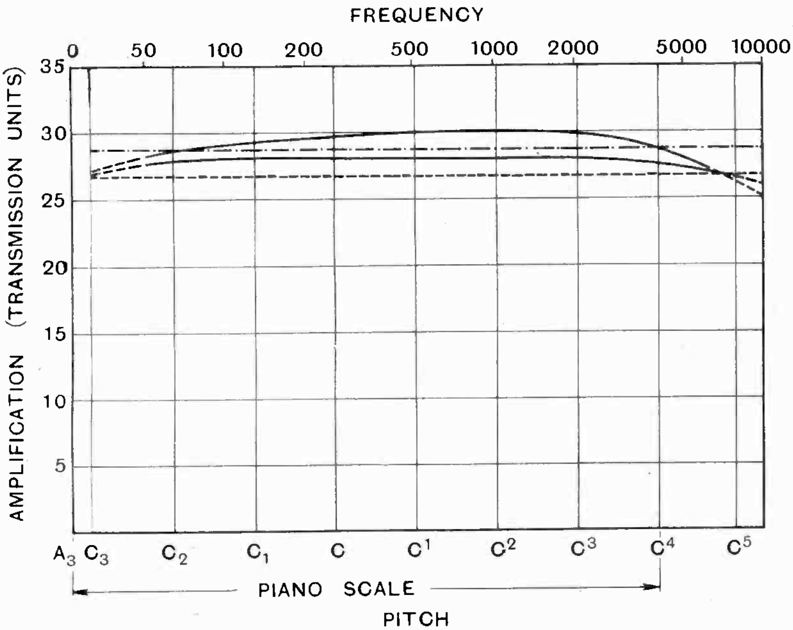


Fig. 3. *"Gain" against frequency for two sets of good performance. Upper curve, Burndept Ethophone III., Mark IV. Lower curve, laboratory-built resistance-coupled set. Chain dotted line represents 75 per cent. of full amplification for upper curve. Dash line represents same percentage for lower curve.*

It may be of interest to see for comparison what really well-designed apparatus could do, and the author therefore has shown in Fig. 3 the performance of a resistance-coupled amplifier of laboratory type, specially made to give good reproduction at the cost of sensitivity, and of a standard 1926-7 commercial three-valve set. It will be seen that the resistance-coupled set—which was measured mainly as a check upon the accuracy of the method—gives a range of frequencies between about 30 and 7,000 cycles with less than a 25 per cent. drop. The total amplification amounts to approximately 28 T.U., or in the neighbourhood of 630-fold. This performance is naturally better as regards frequency range than that of the commercial set, for which an amplification of 30 T.U. or 1,000-fold was absolutely necessary to satisfy the public demand as to the range of a three-valve set. It will be noticed that the latter has a range extending from about 70 to 4,000 cycles with a 25 per cent. drop and from about 30 to 7,000 cycles with a 50 per cent. drop. Unfortunately, measurement below 40 or above 6,000 becomes so difficult that the author has been obliged to extrapolate* the curves beyond these points. It would appear, however, that the commercial set will have a range before noticeable loss is observed of from approximately

* This extrapolation has not been done at random. It is known that the shape of such a curve at both extremes of the frequency range corresponds to a comparatively simple equation, the constants of which can be found from the values of the circuit components. Some of these latter, *e.g.*, stray capacities, are unknown, but can be found from readings actually made at high and low frequencies.

16 to 11,000 cycles, and even for the most critical ear a range of 30 to 7,500.

There are, however, still two traps in estimating the performance of a set from curves of this kind, both of which lead to an under-estimate of the set's performance in most cases. First one must remember that amplification curves of this kind are taken with a pure note supplied to the receiver. In practice, of course, the receiver is supplied with notes containing large quantities of harmonics, and owing to the non-linear response of the ear the impression of the fundamental is invariably conveyed to the brain by the Tartini difference tones. It may be estimated, therefore, that any set will give an impression of reproducing notes about an octave lower than those which it actually does give, although the reproduction of such notes will be not quite accurate.

set, and, second, the output from it. The diagram of connections is shown in Fig. 4, and it will be seen that with the switch *A* in the uppermost position the Moullin voltmeter is connected to a 2,000 ohm resistance, which, in turn, is linked to the audio source via the regulating potentiometer *B*. This latter was adjusted until the Moullin voltmeter showed exactly one volt. A twentieth of this voltage was thus applied to the first valve of the set by means of the resistances *C*. A loud-speaker of the type for which the set was designed was included in the output circuit, and also a resistance *R* of the order of 100 to 1,000 ohms. With the switch *A* in its bottom position, the Moullin voltmeter measured the voltage across this resistance, which was adjusted until the reading was the same as before, *i.e.*, one volt. From the value of *R* it is easy to calculate

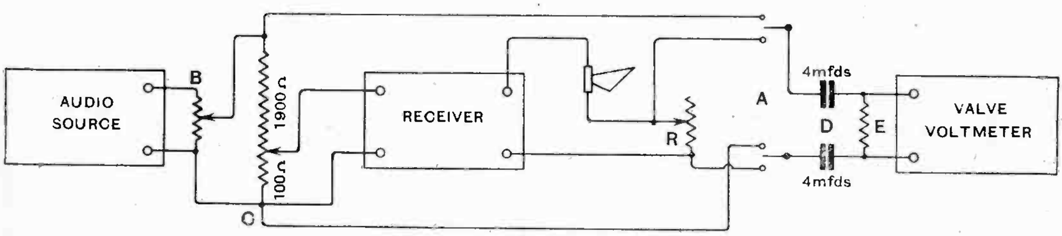


Fig. 4. *Theoretical diagram of connections for the measuring circuit.*

Secondly, the measurements were made (as is noted below) on a low-frequency input. It is notorious that both the use of a grid rectifier and the use of tuned circuits preceding the amplifier tend to accentuate the low notes to a certain extent, and therefore improve the performance in the bass.*

The method of measurement by which the results were obtained is extremely simple in theory, although not quite so easy to carry out in practice. For these measurements, which were all on three-valve sets, the first or rectifying valve had the grid lead connected to a point one volt below the negative end of the filament, so that it would amplify instead of rectify. A Moullin voltmeter was used to measure first the input to the

* The author hopes before long to show some results, based on a slightly different procedure, which will take account of these factors.

the alternating current in the anode circuit of the last valve, making a correction if necessary for the loss in the condensers *D* and leak *E* which isolate the voltmeter. (In practice this correction was never more than 0.1 per cent., and it was therefore neglected.)

An independent measurement was then made of the resistance and reactance of the loud-speaker over the whole range of frequency involved; to its resistance there were added the A.C. resistance of the valve and also *R*, so that the total impedance of the anode circuit was known, and from this and the current already found the total generated voltage in the output circuit was calculated. The figure of magnification given in the curves represents the ratio of this output voltage to the constant input voltage of 0.05 volt.

Mathematics for Wireless Amateurs.

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

(*Continued from page* 28 *of January issue.*)

7. The Continuity of Functions.

THE idea conveyed by the group of symbols $y = f(x)$ has already been explained, but it has been considered hitherto from what may be described as the static point of view, *i.e.*, we have thought of y as a number the value of which depends in some specified manner on the value assigned to the independent variable x. ("Independent variable," by the way, is rather a mouthful. From now on we will use the older name "argument" instead. It is less explicit, but its meaning should be quite clear at this stage.) The other and rather more important aspect of the matter is suggested by the phrase "the *behaviour* of a function." It is, as it were, the dynamic aspect, and is concerned not so much with individual values of the function but rather with the succession of values corresponding to a continuous variation of the argument. Putting it in graphical terms, we are going to consider the shape and other characteristics of the line which represents the variation of y with x. The ideas we shall meet in doing so are among the most important in the whole of mathematics, and must be taken seriously by anyone who wants to cultivate a mathematical habit of mind as distinct from a specious fluency in the tricks of the trade.

To fix ideas we will specify the function in the form

$$y = 10^{\frac{1}{x-1}} + 1.$$

The graph, or picture, of this function is given in Fig. 15 for a range of values of the argument from $x = -20$ to $x = +20$. (Any such range of values is called "an interval" of values of the argument.) The most noticeable feature of the curve is that it appears to break up into two parts, the left-hand part terminating abruptly at the point for which $x = 1$, while the right-hand part seems to come flying sheer down out of the blue, after the manner of an aeroplane attacking an observation balloon, "flattening out" along the line for which $y = 2$. It is clear that something very drastic happens to y when x is given the value 1, and a more detailed examination of this region will be made later. Everywhere else the curve is a smooth, unbroken, continuous line without any sharp angles or sudden changes in direction, showing that y changes gradually

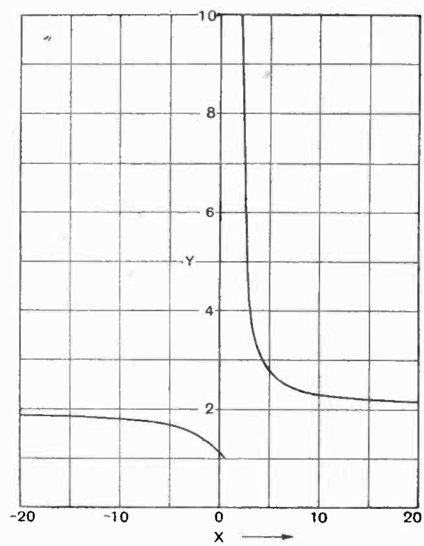


Fig. 15. *Graph of* $y = 10^{\frac{1}{x-1}} + 1$.

with x without any sudden jumps from a small to a large value or *vice versa* for a small change in x. Variation of this character is described as "continuous," and the function is said to be "continuous" through any such interval. On the other hand, a point at which there is an abrupt transition in value, such as occurs when x is given the value 1, is described as a point of "discontinuity," and the function is said to be "discontinuous" at any such point. It is obvious that in carrying out operations with a function one must look out for such points, for certain operations which may be quite legitimate and safe in a region of continuity might lead to disastrous conclusions if the functions has a point of discontinuity in the interval concerned. To quote an example from Professor Whitehead, a man who walked over the edge of Shakespeare Cliff on the assumption that the height of the ground above sea level was a continuous function of his distance from Dover, would be dead before he had time to rearrange his ideas on the subject.

The continuity or otherwise of a function is therefore a matter of practical importance. That being so, we must try to find some exact description of what we mean by continuity, some test which can be applied over any region in which there is cause to suspect irregularity of conduct on the part of the function; for although the above preliminary account conveys the general idea, those readers of this series who have acquired the fastidiousness in thinking which is essential for mathematics will certainly not be satisfied by so vague and woolly a description. "Gradually," for instance — what does "gradually" mean in terms of the fundamental ideas of mathematics? The practical man might be tempted to reply that the variation of y is gradual over any region in which a small change in x produces a correspondingly small change in y. But what does "small" mean? This is probably where the practical man begins to get annoyed; but we can't help it. Common sense is *not* enough. It is essential to realise that there is no abstract quality of absolute largeness or smallness in numbers, or indeed in anything else, for all magnitude is relative. Even in ordinary conversation the word "large" is so vague as to be meaningless apart from its context, stated or implicit. When the Englishman says, "That is a large apple," he means that it is large compared with, *i.e.*, larger than, the average apple of his experience, and when the American replies, "Large! Call that a large apple?" he is presumably thinking of the pumpkin-sized affairs which he has no doubt could be found growing on his uncle's farm in California, if he had an uncle in California. Here is one and the same thing called large by one person and small by another, and such examples could be multiplied indefinitely to show that "large" and "small" are no more than current and convenient abbreviations for "larger than" and "smaller than." This is equally true of mathematics, which is, after all, no more than an idealisation of experience. Of two numbers, one can be smaller than, equal to, or larger than the other, and those are the only fundamental ideas about number which can be admitted in the description of a mathematical conception. Our description of continuity must, therefore, dispense with any absolute "large" or "small" and employ only those fundamental ideas about number on which the whole science of mathematics is based.

First we need some word which will serve to distinguish a point of a function from a restricted interval of values containing the point, *i.e.*, extending on either side of it. The word used is "neighbourhood." Notice particularly that a statement cannot be made about the neighbourhood of a point unless there is a finite interval of values, containing the point, of which the statement is true. Notice further that a statement made about the neighbourhood of a point may or may not be true of the point itself. Nothing is said about that when the neighbourhood is mentioned. It is in fact a very useful feature of the word "neighbourhood" that it distinguishes between the point and some restricted interval of values containing the point. Now take the function we are considering, *i.e.*,

$$y = 10^{\frac{1}{x-1}} + 1.$$

For the value 3/2 for x it is very easy to show that the value of y is 101; but we cannot say that the function has the value 101 in the neighbourhood of $x=3/2$, for there is no finite *interval* of values of x containing 3/2 of which this is true. But we can say that in the neighbourhood of $x=3/2$ y differs from 101 by less than .1, or, another way of saying the same thing, approximates to 101 within a standard of .1, because a finite interval of values of x can be found for which this is true. By a simple calculation which need not be detailed, it can be shown that y approximates to 101 within a standard of .1 for all values of x between 1.4999 and 1.5001. In the present instance we could be more exact still, and say that y approximates to 101 within a standard of .00001 in the neighbourhood of $x=3/2$, because again a finite interval of values containing 3/2 can be found for which this is true, though of course it will be a very much smaller interval than before. Actually, however small the standard of approximation be taken, it can be shown that y approximates to 101 within that standard in the neighbourhood of $x=3/2$, and we can say at once that y approximates to 101 in the neighbourhood of $x=3/2$ within *every* standard. This is exactly what is meant by continuity. Expressed more formally the statement becomes: A function $f(x)$ is continuous for a value a of the argument when in the neighbourhood of the point for which $x=a$ its value approximates to $f(a)$ (*i.e.*, its value at a) within every standard. The full beauty of this definition will not perhaps be realised all at once, but it will repay thinking about, for it is a fine example of the precision of mathematical thought. A lawyer experienced in the difficulty of clothing ideas in words would recognise it with delight as a perfect fit.

The function we have been considering will pass this test at every point except that for which $x=1$, and is therefore said to be everywhere continuous except at $x=1$. It is not, of course, suggested that every function one encounters must be scrutinised all over with this sort of microscope. One soon becomes able to tell by inspection where critical variation is likely to occur. Such points will, generally, but not invariably, be associated with values of the argument for which zeros or infinities appear in some part of the functional expression. This does not make the matter academic, for though it is true that infinities do not occur in real life they frequently occur in the functions that we use as a convenient approximate representation of some particular slice of real life that we may be contending with. For instance, neglecting the resistance in a high frequency circuit calculation, may be both legitimate and convenient in general, but, by freeing the function of its ballast it may introduce the possibility of extravagant acrobatics for certain critical values of the frequency or of the circuit constants, and it is necessary to be prepared for such happenings.

8. Limits.

We will now consider the behaviour of the above function when x is given the value 1, and in order to see more clearly what is happening at this point we will examine the region with a magnifying glass. In other words, we will tabulate values of x and y through a restricted interval of values containing 1.

x	y
.9	$10^{-10}+1$
.99	$10^{-100}+1$
.999	$10^{-1000}+1$
1.0	?
1.001	$10^{1000}+1$
1.01	$10^{100}+1$
1.1	$10^{10}+1$

This shows that as the value 1 for x is approached from the less than 1 side y approxmiates more and more closely to 1. On the other hand, if the value 1 for x is approached from the greater than 1 side, y increases continually, and the closer x becomes to 1 the greater the value of y. The first set of values would lead one to suppose that y becomes 1 when x is 1, but the second set suggests that y becomes greater than any finite number when x is 1; but the function is single valued everywhere else, *i.e.*, for any given value of x there is only one value of y. Why then should it assume a sort of dual personality at this point? The answer is that it does not. At this point, on the contrary, it has no defined value at all, for it becomes

$$y = 10^{\frac{1}{1-1}} + 1 = 10^{\frac{1}{0}} + 1$$

and 1/0 is not a number at all. We saw in para. E4 of Section 3 (August, 1926) that the whole structure of mathematics would collapse if 1/0 were treated as if it were a number subject to the ordinary laws of arithmetic. This, then, is the first thing to notice about this point—that the function has no defined value at all when x is 1. But from the tabulated values it is clear that y has a definite value when $x=1-h$, however small h may be *provided it is not actually zero*. Moreover, it is clear that y can be made to approximate to 1 within any desired standard, however small, by assigning a sufficiently small value to h. Under these conditions the function is said to have a finite limit when x tends to 1, although it has no defined value at all when x *is* 1. The idea can be expressed in various ways in symbols; for instance,

$$\lim_{h \to 0} f(1-h) = 1$$

which is quite explicit, or again

$$\lim_{x \to 1-0} y = 1$$

or

$$\lim_{x \to 1-0} f(x) = 1$$

where $x \to 1-0$ is taken to mean that the value 1 for x is approached from the less than 1 side. Notice particularly that in any case such as this, where the function has no defined value for a given value of the argument but nevertheless approaches a finite limit as the argument approaches this value, this finite limit is never actually reached, although the function can be made to approximate to it within any desired standard. This idea of a limit is of the utmost importance in mathematics, and has been the subject of much criticism and research, particularly in recent years. Unless the reader understands it thoroughly he can never hope for anything better than a dangerous rule of thumb knowledge of the calculus, so he is advised to go over this part again and again if necessary, until the understanding of it is assured. The formal statement of the idea is usually expressed in some such way as this: A function $f(x)$ is said to have a limit L for a value a of its argument if for every quantity k another quantity h can be found such that when x differs from a by less than h, $f(x)$ differs from L by less than k. This has always seemed to the writer a case where the definition was much harder to understand than the idea it defined. The reader need not stick over this definition, but must make sure of appreciating the idea as illustrated in the above example.

In the example quoted the limiting value is never actually reached, since the function has no defined value at the point; but the actual definition of a limit does not exclude the possibility of the limit of a function being the same as its value at the point concerned. In fact, if the reader has really understood the definition of continuity, he will see that it requires that the function shall have a finite limit for the given value of the argument, that limit being the same as the value of the function at the point. In general, however, the rather difficult conception of a limit is substituted for the simpler idea of the value only where it is really necessary, that is where the value does not exist.

So much for the behaviour of the above function when x tends to $1-0$. The behaviour on the other side of this point is quite different, though a somewhat similar idea is involved. The tabulated values show that y increases very rapidly as x approaches 1 from the greater than 1 side, and the reader should have no difficulty in seeing that y can be made to exceed any finite number by bringing x sufficiently near to 1. This is conveniently, though perhaps not very happily, expressed by saying that the limit of y under these conditions is infinity, *i.e.*,

$$\lim_{x \to 1+0} y = \infty$$

which really means that y has no finite limit at all and continues to increase without limit as x approaches 1.

Yet another kind of limit, the antithesis of infinity, is illustrated by this function. (It was chosen, of course, because of its versatility in this direction.) What happens when x becomes very large compared with 1? The index of the ten is $1/(x-1)$, and it is clear that as x becomes larger and larger this index will become smaller and smaller. By making x sufficiently large compared with 1, $1/(x-1)$ can be made smaller than any fraction of unity, however small. *It can never be made zero by increasing x*, but it can be made to differ from zero by as little as we please by making x large enough compared with 1. Here, then, the conception of limit comes in again, and we say that the limit of $1/(x-1)$ is zero when x tends to infinity, *i.e.*,

$$\lim_{x \to \infty} \frac{1}{x-1} = 0$$

It is sometimes stated in text-books that there are two kinds of zeros in mathematics, the absolute algebraic zero arrived at as the difference of two equal numbers, *i.e.*,

$$a - a = 0$$

and another kind arrived at, or rather never quite arrived at, as the limit of $1/a$ when a is increased indefinitely, *i.e.*,

$$\underset{a \to \infty}{lt.}\ 1/a = 0\ ;$$

but the idea of a multiplicity of zeros has never seemed to the writer at all necessary or helpful. The limit in the above expression is the absolute algebraic zero, but it is important to remember that this limit is never actually reached.

Since
$$\underset{x \to \infty}{lt.}\ \frac{1}{x-1} = 0$$

it follows that

$$\underset{x \to \infty}{lt.}\ 10^{\frac{1}{x-1}} = 10^{\circ} = 1$$

and that

$$\underset{x \to \infty}{lt.}\ 10^{\frac{1}{x-1}} + 1 = 2$$

i.e.,

$$\underset{x \to \infty}{lt.}\ f(x) = 2$$

Under these conditions the line representing the function is said to approach the line $y=2$ asymptotically, *i.e.*, it gets closer and closer to it as x is increased but never actually reaches it. It is tangential to it but the point of contact is at infinity.

In an exactly similar manner it can be shown that

$$\underset{x \to -\infty}{lt.}\ f(x) = 2$$

so that we have for this function the four limiting conditions :—

$$\underset{x \to -\infty}{lt.}\ f(x) = 2$$

$$\underset{x \to 1-0}{lt.}\ f(x) = 1$$

$$\underset{x \to 1+0}{lt.}\ f(x) = \infty$$

$$\underset{x \to \infty}{lt.}\ f(x) = 2$$

Now we come to a case which occurs very frequently in practical analysis and which might cause considerable perplexity to a person who had not assimilated the above ideas on limits. Take the function

$$y = F(x) = \frac{x^2 + 2x - 3}{x^2 + 3x - 4}$$

In general the value of this function for any value of the argument can easily be calculated by ordinary arithmetic, but when $x=1$ we have

$$y = F(1) = \frac{1 + 2 - 3}{1 + 3 - 4} = \frac{0}{0}$$

Now $0/0$ is a group to which no meaning can be attached in terms of the fundamental conceptions of arithmetic. What then are we to do about this? In the first place, since the two quadratic expressions vanish when x is 1, it follows that each is divisible exactly by $(x-1)$ (see para. A5 of Section 6). With this clue it is easy to express the function in the form

$$F(x) = \frac{(x-1)(x+3)}{(x-1)(x+4)}$$

and now obviously we can divide the top and bottom of this fraction by $(x-1)$, so that

$$F(x) = \frac{(x+3)}{(x+4)}$$

and therefore when $x = 1$

$$F(x) = \tfrac{4}{5}$$

All very plausible, isn't it—and quite wrong. It just shows how careful one has got to be. The top and bottom of the fraction can only be divided by $(x-1)$ on the condition that $(x-1)$ is *not* zero, *i.e.*, on the condition that x is *not* 1. Otherwise we are dividing top and bottom by zero, which, as we have seen, is definitely not legitimate under any circumstances whatever, so that just precisely the case in which it is essential to divide through by $(x-1)$ is the one in which it cannot be done. However, let us stop short just on the edge of the precipice, instead of falling over it, *i.e.*, put $x = 1 + h$ instead of 1, h being a small quantity compared with 1. Then

$$F(x) = F(1+h) = \frac{h(4+h)}{h(5+h)}$$

and since h is not zero

$$F(x) = F(1+h) = \frac{(4+h)}{(5+h)}$$

and this is true, however small h may be as long as it is not zero. Now by making h small enough, the fraction can be made to differ from 4/5 by as little as we please. In other words, the limit of the fraction when x tends to 1 is 4/5. Therefore, although $F(x)$ has no defined value when x *is* 1, it has a definite limit when x *tends to* 1, that limit being 4/5, *i.e.*,

$$\underset{x \to 1}{lt.} F(x) = 4/5$$

Moreover, since the whole of the above reasoning can be repeated when $x = (1 - h)$ with the same result, the limit is the same for either direction of approach, *i.e.*,

$$\underset{x \to 1 \pm 0}{lt.} F(x) = 4/5$$

What are we to say about the continuity of the function through this critical point? It is a difficult question to answer, and, as a matter of fact, the writer cannot give a definite answer himself and has not been able to get any authoritative general statement on the point. The difficulty is that the function certainly does not satisfy the continuity test at the point, since it has no defined value; nevertheless, it will be found that the function can be plotted as a perfectly smooth and apparently continuous line through this point, and moreover it satisfies the continuity definition if the *limit* when x tends to 1 be substituted in the definition for the *value* when $x=1$. Actually it is very unlikely that any error will arise in practice from assuming that this function, or any of the very large number of similar functions that are involved in practical mathematics, is continuous through this undefined and indeterminate point, but in the absence of any certainty in the matter any operations which involve the assumption of continuity will have to be carried through with some degree of mental reserve.*

So much for "continuity," "value," and "limit,"—or, at least, so much for an elementary introduction to these difficult but intriguing ideas. It may have seemed wordy and excessively fine drawn, but it is necessary all the same for, as Prof. Whitehead has pointed out, "large parts of mathematics as enunciated in the old happy-go-lucky manner were simply wrong." It is even probable, or at least possible, that the refinements of modern mathematics may prove insufficient in some directions. In any case, an excess of precision, if it is a fault at all, is a fault in the right direction, and is worth pursuing not only for its own sake but for the mental training it involves. There is no room for slipshod thinking in mathematics.

* This may seem unsatisfactory. It certainly is incomplete—but then, as the Philosopher says in *The Crock of Gold*, "Perfection is Finality. Finality is Death." It is part of the fascination of mathematics that it still leaves scope for research, and ever will do so, even within the limits of an elementary text-book.

Examples.—Continuity and Limits.

1. Show that the function

$$y = \frac{a + bx}{c + dx}$$

is discontinuous when $x = -c/d$. Find the limits of y when $x \to -(c/d) \pm 0$ and when $x \to \pm \infty$.

2. Find the points of discontinuity of

$$y = \frac{x^2 - 3x + 2}{x^2 - 7x + 12}$$

and find the limits of y when $x \to 3 \pm 0,\ 4 \pm 0, \pm \infty$.

3. Find the limits when $x \to a \pm 0$ of

$$y = \frac{x^2 - (a + b)x + ab}{x^2 - (a + c)x + ac}$$

4. Find the limits of

$$y = \frac{x^3 - 6x^2 + 11x - 6}{2x^3 - 14x + 28x - 8}$$

when $x \to 1 \pm 0,\ 2 \pm 0,\ 4 \pm 0.$

5. Find the limit when $x \to \infty$ of

$$y = \frac{ax^2 + bx + c}{mx^3 + nx^2 + px + q}$$

6. Find the limit of

$$\frac{\sqrt{x} - \sqrt{a} + \sqrt{x - a}}{\sqrt{x^2 - a^2}}$$

Answers to Examples in January Issue.

1. (a) $x = 3,\ y = 4,\ z = 5.$ (b) $x = y = z = 1.$ (c) $x = y = 0,\ z = 10.$
2. $w = 1,\ x = 2,\ y = 3,\ z = 4.$
3. $x = a + b,\ y = a + 2b,\ z = a + 3b.$
5. (a) 10. (b) 112/65.

Some New Coil Impedance Diagrams.

By W. A. Barclay, M.A.

IN the present article the writer proposes to describe some results to which he has been led by the application of the method of Alignment to elementary wireless theory. As already stated in these pages, the Alignment Principle, a comparatively recent development of mathematics, is becoming more and more widely recognised as an instrument of singular efficacy and utility in the field of computation; while its beautiful generality and adaptability render it equally suited to the hardly less useful domain of geometrical illustration. The basic nature of the method—the alignment of certain points to which are attached numerical values of the variables represented—is fundamentally geometrical; and while the Principle itself is in essence a "shorthand" notation by which such alignments, where they exist, can be automatically detected, the results obtained by it can always be proved independently by the more cumbrous methods of ordinary analysis. In the sequel use will be made of elementary cartesian co-ördinate geometry to supply such "proofs" where necessary.

The interesting article on "Graphical Methods" by Mr. F. M. Colebrook (*E.W. & W.E.*, December, 1924) is doubtless still fresh in the minds of readers. In this article Mr. Colebrook described how, given a combination of resistance and reactance in parallel, a graphical process may be used to give the equivalent values of resistance and reactance which, if placed in series,

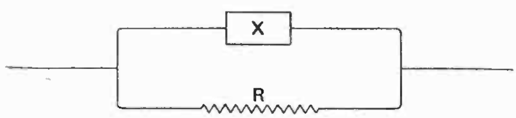


Fig. 1.

would give the same effective impedance at the working frequency. In so far as what follows is really an extension of Mr. Colebrook's method to the more general case of a reactance in parallel with an impedance, it may be well briefly to recapitulate his procedure. For the circuit of Fig. 1, where at a frequency of $\omega/2\pi$ we have a reactance X in parallel with a resistance R, we employ the construction of Fig. 2. Taking rectangular axes OX, OY, we set

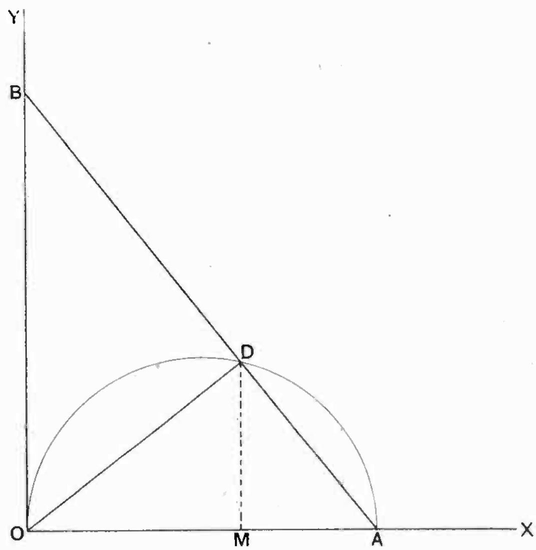


Fig. 2.

out on OX a length $OA=R$, and on OY a length $OB=X$. On OA describe a semicircle cutting AB in D. Draw DM perpendicular to OA. Then the effective resistance R_0 is represented by OM, the effective reactance X_0 by MD, and their vector combination, the effective impedance, by OD. The proof is simple, and readers are referred to the article in question for it.

We now proceed to consider the ubiquitous inductance coil and shunt tuning condenser of so many wireless circuits. We shall take R and L to represent the resistance and inductance of the coil, and C for the value of the shunting capacity. If an E.M.F. of frequency $\omega/2\pi$ is placed across the combination shown in Fig. 3, the numerical values of the reactances offered by the inductance and condenser are respectively ωL and $1/\omega C$. It should be stated at the outset that no account will here be taken of the variation of H.F. resistance with frequency. This variation, of course, is of no importance at the lower frequencies. At radio frequencies, however, R will imply the H.F. resistance at the working frequency.

Apart altogether from considerations of H.F. resistance, the combination of inductance, capacity, and resistance of Fig. 3

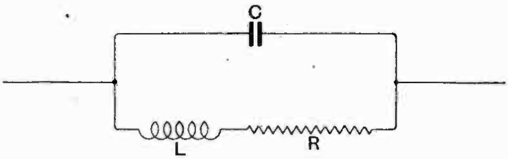


Fig. 3.

varies enormously in its behaviour at different frequencies. For example, we may consider the windings of an L.F. transformer, which have both inductance and self-capacity. Whereas at audio frequencies the inductance predominates, at radio frequencies the self-capacity exercises the greater effect, and the transformer behaves as a condenser. The question of finding equivalent series values for a combination of this nature is thus complicated by the fact that the effective reactance at the given frequency may be either inductive or capacitative. A ready means of determining its nature as well as its amount is, however, available, and is described below.

Fig. 4a.

Fig. 4b.

Our problem is, then, to replace the circuit of Fig. 3 by either of those shown in Figs. 4a or 4b, in which the effective values L_0, R_0 or C_0, R_0 are to be found. As in any event the combination of Fig. 3 must be represented by one or other of Figs. 4a or 4b, we shall consider these two cases separately.

It may be shown that if a voltage $e=E\sin\omega t$ be impressed across the combination of Fig. 3, the total line current through the system is

$$i=E\left\{\frac{R}{R^2+\omega^2L^2}\sin\omega t-\left(\frac{\omega L}{R^2+\omega^2L^2}-\omega C\right)\cos\omega t\right\} \qquad (1)$$

If now we impress the same voltage across the circuit of Fig 4a, we obtain for the line current,

$$i_0=E\left\{\frac{R_0}{R_0^2+\omega^2L_0^2}\sin\omega t-\frac{\omega L_0}{R_0^2+\omega^2L_0^2}\cos\omega t\right\} \qquad (2a)$$

Equating those constituents of (1) and (2a) which are in the same phase relation, we find that for $i_0=i$ we must have,

$$\frac{R}{R^2+\omega^2L^2}=\frac{R_0}{R_0^2+\omega^2L_0^2}$$

and

$$\frac{\omega L}{R^2+\omega^2L^2}-\omega C=\frac{\omega L_0}{R_0^2+\omega^2L_0^2}$$

whence, solving for R_0 and ωL_0,

$$R_0=\frac{R}{(1-\omega^2CL)^2+\omega^2C^2R^2} \quad \ldots \quad (3a)$$

$$\omega L_0=\frac{\omega L(1-\omega^2CL)-\omega CR^2}{(1-\omega^2CL)^2+\omega^2C^2R^2} \quad \ldots \quad (4a)$$

Again, if the equivalent circuit is that of Fig. 4b, a voltage of $e=E\sin\omega t$ impressed on it will give a line current

$$i_0=E\left\{\frac{R_0}{R_0^2+\frac{1}{\omega^2C_0^2}}\sin\omega t+\frac{1/\omega C_0}{R_0^2+\frac{1}{\omega^2C_0^2}}\cos\omega t\right\} \qquad (2b)$$

which, when compared with equation (1), yields

$$\frac{R}{R^2+\omega^2L^2}=\frac{R_0}{R_0^2+\frac{1}{\omega^2C_0^2}}$$

and

$$\frac{\omega L}{R^2+\omega^2L^2}-\omega C=-\frac{1/\omega C_0}{R_0^2+\frac{1}{\omega^2C_0^2}}$$

whence, solving for R_0 and $1/\omega C_0$,

$$R_0=\frac{R}{(1-\omega^2CL)^2+\omega^2C^2R^2} \quad \ldots \quad (3b)$$

$$-\frac{1}{\omega C_0}=\frac{\omega L(1-\omega^2CL)-\omega CR^2}{(1-\omega^2CL)^2+\omega^2C^2R^2} \quad \ldots \quad (4b)$$

By multiplying equations (4a) and (4b) throughout by ωC and adding unity, we obtain the expressions

$$1+\omega^2 CL = 1-\frac{C}{C_0} = \frac{1-\omega^2 CL}{(1-\omega^2 CL)^2+\omega^2 C^2 R^2}$$

from which, by using equations (3), we derive

$$\frac{R_0}{R} = \frac{1+\omega^2 CL_0}{1-\omega^2 CL} = \frac{\dfrac{1}{\omega C}+\omega L_0}{\dfrac{1}{\omega C}-\omega L} \quad \ldots \quad (5a)$$

and

$$\frac{R_0}{R} = \frac{1-\dfrac{C}{C_0}}{1-\omega^2 CL} = \frac{\dfrac{1}{\omega C}-\dfrac{1}{\omega C_0}}{\dfrac{1}{\omega C}-\omega L} \quad \ldots \quad (5b)$$

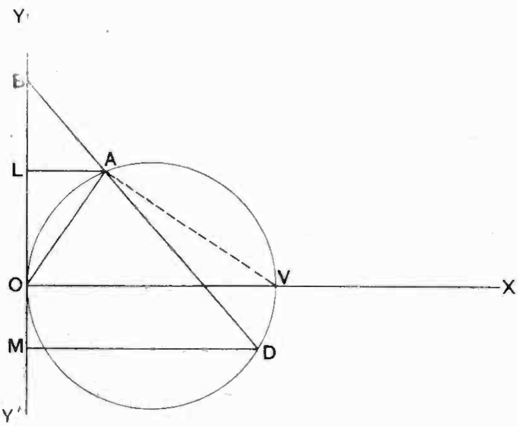


Fig. 5a.

Comparing equations (5a) and (5b) we find that

$$\omega L_0 = \frac{1}{\omega C_0}$$

an apparently anomalous result, which is explained by the fact that L_0 and C_0 cannot both exist simultaneously. The equations (5a) and (5b) are, of course, alternative; if a value of L_0 is found from (5a), the other equation (5b) is inoperative.

These equations (5a) and (5b) express in a convenient form the relations between R, C, L and R_0, C_0, L_0, and are, moreover, capable of a very simple geometrical interpretation as follows: In Figs. 5a, 5b, 5c, taking cartesian axes OX, OY, let the points A and B have co-ordinates $(R,\omega L)$ and $(O,1/\omega C)$. Then the point D whose co-ordinates are the effective values of resistance and reactance for the combination will be found in alignment with A

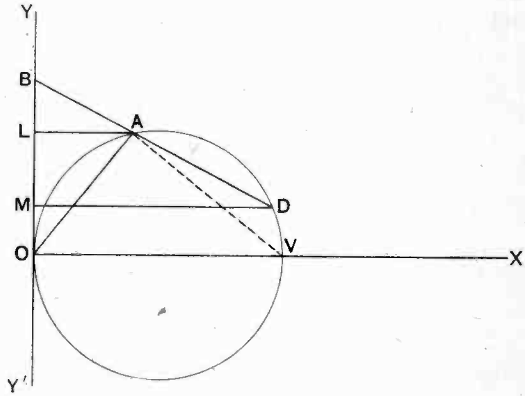


Fig. 5b.

and B. Moreover, if the effective reactance is inductive, D will be situated *beneath* OX, as in Fig. 5a; if capacitative, it will be *above* OX, as in Figs. 5b and 5c.

By drawing AL, DM, perpendicular to OY, we may easily verify these statements. In the similar triangles BMD, BLA,

$$\frac{MD}{LA} = \frac{MB}{LB} = \frac{OB-OM}{OB-OL} \quad \ldots \quad (6)$$

If, now, in Fig. 5a, OM is taken as $-\omega L_0$, while in Figs. 5b, 5c, it is taken as $1/\omega C_0$,

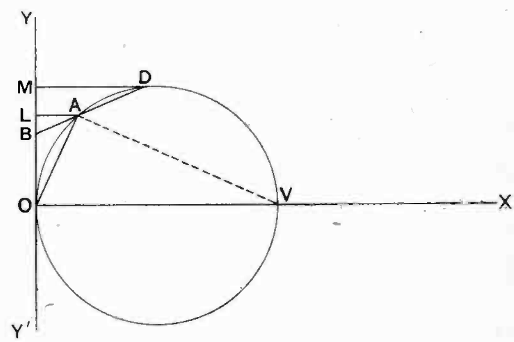


Fig. 5c.

and if $MD=R_0$ throughout, we find that the above equation is a geometrical interpretation of equations (5a) and (5b).

It will be noted that three possible cases arise. If $1/\omega C>\omega L$, the position of D

may be either above or below the axis OX, *i.e.*, the resulting effective reactance may be either inductive or capacitative, or indeed, zero should D happen to lie on OX. (See Figs. 5a and 5b.) If, however, $1/\omega C < \omega L$, the position of D will always lie above OX, and the effective reactance is in this case capacitative. (See Fig. 5c.)

It remains now to show how the position of the point D may be easily and rapidly determined. Draw AV perpendicular to OA to meet OX in V. On OV as diameter describe a circle which, since the angle OAV is right, will cut the line AB in A. The other point in which AB meets the circle is D, the required point of "effective" values, as may be shown as follows:—

Since OV is a diameter, OB is a tangent.

$$\therefore \quad BA \cdot BD = BO^2$$

$$\therefore \quad BD = \frac{BO^2}{BA}$$

$$\text{Again,} \quad \frac{MD}{LA} = \frac{BD}{BA} = \frac{BO^2}{BA^2}$$

$$\therefore \quad MD = LA \cdot \frac{BO^2}{BA^2} = \frac{R \cdot \frac{1}{\omega^2 C^2}}{\left(\frac{1}{\omega C} - \omega L\right)^2 + R^2}$$

$$= \frac{R}{(1-\omega^2 CL)^2 + \omega^2 C^2 R^2} \qquad (7)$$

$$= R_0, \text{ by equation (3a).}$$

D is thus the point on AB whose x-co-ordinate is R_0. Hence D is the required point.

We are now in a position to study at first hand, and without the necessity for tedious algebraical analysis, the numerical effect upon R_0, ωL_0, $1/\omega C_0$, of changes in the value of $1/\omega C$ due to variation of capacity in shunt with any given coil. For the frequency $\omega/2\pi$, we can plot the position of the point A the co-ordinates of which $(R, \omega L)$ represent its resistance and reactance at this frequency. Further, by means of the construction given, we can always draw the circle which represents the locus of the possible "effective" points D. From this construction it will be seen that the dimensions of this circle depend solely on the constants of the coil, and are quite independent of the tuning capacity. The particular "effective" point corresponding to any given shunt capacity is found in alignment with A and the value of such shunt capacitative reactance taken on the axis of Y. It is to be noted that the distinction between the reactances represented by D, according as this point is situated in the upper or lower quadrants XOY, XOY' holds only for "effective" reactance values. The reactances of the constituents of the given combination are always set out in the upper quadrant XOY.

As the shunt capacity across the coil is varied, the point B representing its reactance $1/\omega C$ will move along the axis OY, while the point D travels along the circle. In particular, when D reaches the axis OX,

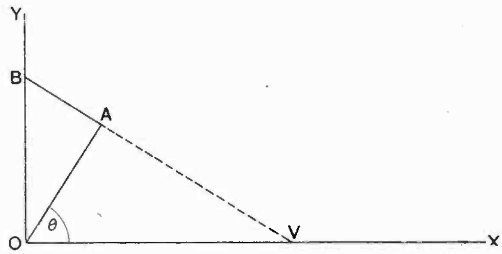


Fig. 6.

it coincides with V. The effective reactance is now zero, the circuit is said to be "tuned" to the working frequency, and its effective resistance R_0 is seen to be a maximum and equal to the diameter of the circle OV. From this circumstance arises a simple construction for obtaining the capacitative reactance necessary to tune a coil to a given frequency. (See Fig. 6.) If through A, the point $(R, L\omega)$, be drawn a line AB perpendicular to OA to meet the Y-axis in B, the distance OB will represent the shunt capacitative reactance $1/\omega C$ to obtain resonance. The numerical value of R_0 at resonance is obtained by putting ωL_0 or $1/\omega C_0 = 0$ in equations (5a) or (5b). We then have,

$$\frac{R_0}{R} = \frac{1}{1-\omega^2 CL} \qquad \ldots \quad (8)$$

The denominator of this fraction is not, of course, zero. To obtain resonance in the circuit of Fig. 3, the capacitative reactance of the condenser must be greater than the inductive reactance of the coil. This is shown by the gradient of the line AB, which, in order that D coincide with V, must be negative, *i.e.*,

$$\frac{1}{\omega C} > \omega L$$

For the resonant condition, also, the numerators of equations (4) will vanish, so that we have

$$\omega L(1 - \omega^2 CL) = \omega C R^2 \quad \ldots \quad (9)$$

i.e.,
$$\frac{1}{\omega C} = \omega L + \frac{R^2}{\omega L} \quad \ldots \quad (10)$$

and eliminating ωC by means of (8), taking angle $AOX = \theta$,

$$R_0 = R\left(1 + \frac{\omega^2 L^2}{R^2}\right) = R \sec^2\theta \quad (11)$$

Equation (11) is a convenient expression for the maximum effective resistance which obtains at resonance, and gives, moreover, the diameter of the circle of our construction. It thus appears that a line drawn through A perpendicular to OA intercepts on the axes OX and OY lengths equal respectively to the effective resistance at resonance, and the necessary shunt capacitative reactance to produce resonance.

From equation (10) we can determine numerically what is otherwise evident geometrically, whether the effective reactance of the coil is inductive or capacitative, the equation itself being the condition for zero reactance. From equations (4a) and (4b) we see that if

$$\omega L(1 - \omega^2 CL) > \omega C R^2$$

i.e., if
$$\frac{1}{\omega C} > \omega L + \frac{R^2}{\omega L} \quad \ldots \quad (12)$$

the effective reactance is inductive (Fig. 5a), while if

$$\frac{1}{\omega C} < \omega L + \frac{R^2}{\omega L} \quad \ldots \quad (13)$$

the effective reactance is capacitative (Figs. 5b and 5c). In all cases the effective values are read as the co-ordinates of D. From (13) it is obvious *a fortiori* that if

$$\frac{1}{\omega C} < \omega L$$

the effective reactance is always capacitative. If, however,

$$\frac{1}{\omega C} > \omega L$$

the graphical construction provides a simple means of determining the nature as well as the magnitude of the effective values.

Many other interesting relations between R, ωL, $1/\omega C$, and the effective values R_0, ωL_0, or R_0, $1/\omega C_0$, may be derived at sight from the diagrams. For example, the points A and B may be so situated that D coincides with A. (See Fig. 7.) In this case the line AB is a tangent to the circle at A; the effective resistance is equal to the resistance of the coil, while the effective reactance is equal in amount to the inductive reactance of the coil, but is capacitative in character. If the tuning capacity be now increased, B approaches O, and D will travel along the arc from A towards O. The effective resistance decreases, while the changes in the effective reactance may

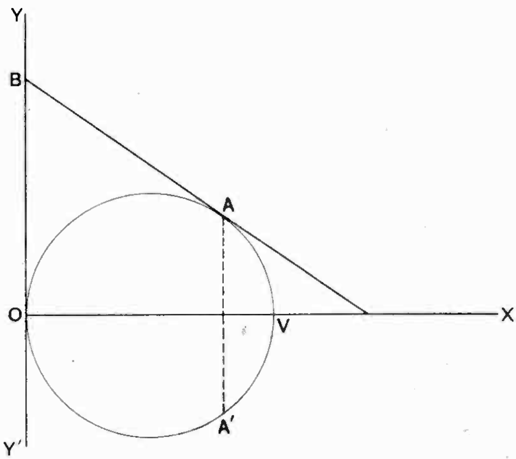


Fig. 7.

be traced on the diagram. On the other hand, as the shunt capacity is decreased, the point D travels through the resonance point V, and finally approaches a limiting position A', the image of A in OX. At this point, of course, the effective values of the combination are simply those of the unshunted coil itself, the point B being at infinity.

Again, the line AB may be parallel to OX. This indicates, it will be seen, that the inductive reactance of the coil, the shunt reactance of the condenser, and the effective reactance of the combination are all numerically equal, the latter being necessarily capacitative. (See Fig. 8.) From the properties of the circle, it will also be observed that the square of this magnitude is equal to the product of the resistance of the coil and the effective resistance of the combination.

Further, we may revert to the case discussed by Mr. Colebrook to which reference

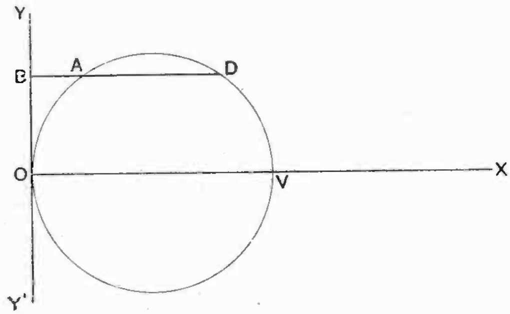


Fig. 8.

was made at the outset. Our coil is here replaced by a pure resistance, shunted as usual by a capacity. The point A is now situated on OX, and the necessary circle described upon OA as diameter, the effective point D being obtained by intersection with AB. The procedure shown in Fig 2 is thus a particular case of the present method.

In conclusion, it may be said that the present discussion is limited entirely to the case of the coil, with shunt condenser. The method described is, however, capable of considerable extension, and is likely to be of much practical value in dealing with various combinations of impedances.

It should be mentioned that since the co-ordinates of D above represent the effective resistance and reactance of the coil and shunt condenser in both magnitude and direction, the line OD may be regarded as their vector resultant, and represents in magnitude and phase the effective impedance of the combination. It should be carefully noted, however, that the lines OA and OB for the constituents of the original combination cannot thus be vectorially combined. The reactances represented by A and B are 180° out of phase, so that to be treated as vectors they would require to be shown in opposite quadrants and not, as in these diagrams, in similar phase relationship.

Book Received.

THE WAY TO TRUE RADIO REPRODUCTION.—A 24-page pamphlet issued by Messrs. Ferranti, price 1s. Diagrams are given of a number of receiving sets with numerical data of the various components. Hints are given as to the choice of valves, the effect of wrong anode and grid voltages on the quality of reproduction, the dangers of overloading the last valve or the loud-speaker and, of course, the danger of using any but a Ferranti transformer. Useful tables of valve characteristics add to the usefulness of the pamphlet.

Catalogue Received.

The Great Northern Telegraph Co., Ltd., Copenhagen (5, St. Helens Place, London, E.C.3). This Company possesses a factory for the manufacture of electrical instruments. The Catalogue covers the whole range of telegraph apparatus and instruments such as galvanometers, Wheatstone bridges, standard condensers, etc., used in connection with telegraphic work. The Catalogue is beautifully illustrated with photographic reproductions of the various instruments.

Valve Nomenclature and Standardisation.

The Telefunken Company announce that in future the type-numbers given to their valves will not be mere arbitrary numbers but will indicate the filament voltage and current. The first two of the three figures give the current in hundredths of an ampere, whilst the third gives the approximate voltage for which the valve is suitable. The letters which precede the number indicate the application for which the valve is designed; thus RE064 is a receiving valve (Röhre=valve; Empfänger=receiver) taking 0.06 ampere at 4 volts. They also announce that they are giving up the special Telefunken socket and adopting the standard European socket for their valves.

Unipivot Galvanometers.

From the Cambridge Instrument Co., Ltd., 45, Grosvenor Place, London, S.W.1, we have received an interesting brochure (list No. 160) describing Unipivot instruments for D.C. measurements. The list deals chiefly with the well-known Unipivot Galvanometers and other accessories, which have proved of considerable usefulness in scientific and industrial work ever since the introduction of the Unipivot principle in 1903.

The essential feature of this design is that the moving coil is supported on one pivot only; this results in a diminution of pivot friction. A further advantage of the design is that it is unnecessary to level the instruments which are thus particularly suitable for installation on board ship and moving vehicles.

Simple Resonance Curves and their Modification by Valve Circuits.

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

Introduction.

IN the present article a vector treatment of simple resonance curves is described, by means of which the resonance curves in cases where there is only one tuned circuit, which may be associated with a valve with or without reaction, may be predicted, or by which, if the resonance curve is obtained experimentally by varying the frequency, the effective decay factor of the circuit can be found. Incidentally the conditions for maintenance of oscillations by a valve, when the oscillatory circuit is connected either to the grid or to the anode, are arrived at.

Contents.

1. Series impedance—resonance curves and circles—circle and straight line instruction to find decay factor.
2. Parallel resonance—valve amplifier with tuned anode—conditions for oscillation—the anode tap.
3. Oscillatory circuit connected to grid—conditions for oscillations.

1. If a constant electromotive force e is introduced into an oscillatory circuit

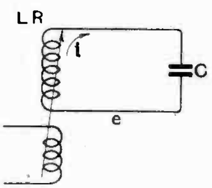


Fig. 1. *An electromotive force* e *induced into a simple oscillatory circuit as above, produces a current* i *such that*

$$i = \frac{e}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{e}{Z}$$

having inductance L, capacity C, and total high frequency resistance R (Fig. 1), the magnitude of the current i is given by the expression

$$i = \frac{e}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} \quad .. \quad (1a)$$

and its phase angle ϕ with regard to that of e which is regarded as standard is given by

$$\tan \phi = - \frac{\omega L - \frac{1}{\omega C}}{R} \quad .. \quad (1b)$$

Both of these expressions are contained in the one statement

$$\left.\begin{aligned} i &= \frac{e}{R + j\left(\omega L - \frac{1}{\omega C}\right)} \quad .. \\ \text{or} \quad i &= \frac{e}{Z} \quad .. \quad .. \quad .. \end{aligned}\right\} (2)$$

where $Z = R + j\left(\omega L - \frac{1}{\omega C}\right)$ is the complex impedance of the oscillatory circuit, and is drawn as shown in Fig. 2. Or $= R$ is drawn horizontally to the right and $rP = \left(\omega L - \frac{1}{\omega C}\right)$ is drawn vertically from r, since $\left(\omega L - \frac{1}{\omega C}\right)$ is multiplied by j in equation (2), meaning

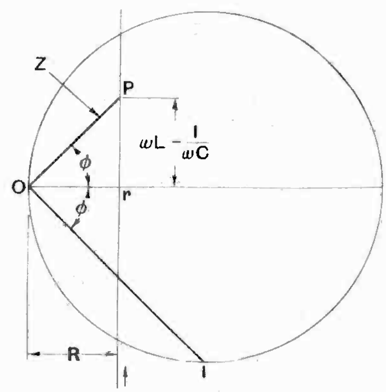


Fig. 2. *Showing how the complex impedance* Z *of the oscillatory circuit is composed of the resistance* R *with the reactance* (ωL — 1/ωC) *added at right angles. Since the current* i *in the circuit varies as the reciprocal of the impedance, it must be represented as such in the diagram.* OP *represents the impedance and* OI *the current in the circuit, and the locus of the point* I, *as the frequency* ω/2π *of the induced E.M.F. varies, is the circle shown.*

that the length $\left(\omega L - \frac{1}{\omega C}\right)$ is rotated through 90° counter clockwise from the horizontal.

Complex expressions such as

$$R + j\left(\omega L - \frac{1}{\omega C}\right)$$

can be dealt with algebraically in exactly the same way as any other expressions, the meaning to be ascribed to j being $\sqrt{-1}$. Thus

$$j^2 = -1,\ j^3 = j^2,\ j = -1\ \sqrt{-1} = -j.$$

Geometrically multiplication by j^2 indicates rotation through 90° twice, or rotation through 180°, and by j^3 rotation through 270°, which brings us to the same position as multiplication by $-j$, or rotation in the negative direction, *i.e.*, clockwise through 90°.

Now, in Fig. 2 we could also have drawn the complex OP by drawing a line at an angle ϕ and marking along it a length

$$OP = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = |Z|,$$

the verticals indicating that the numberical size of the complex Z is intended and not the actual complex. The angle ϕ is obviously determined by $tan\phi = \frac{\omega L - \frac{1}{\omega C}}{R}$.

So we have two ways of writing Z, either $|Z|\ \underline{/\phi}$ or $R + j\left(\omega L - \frac{1}{\omega C}\right)$, and we can easily change from one way to the other, as above if R and $\left(\omega L - \frac{1}{\omega C}\right)$ are known, and by

$$R = |Z|\ cos\ \phi \text{ and } \left(\omega L - \frac{1}{\omega C}\right) = |Z|\ sin\ \phi$$

if $|Z|$ and ϕ are known.

The algebra of multiplying or dividing is simplified by converting complexes to the form $|Z|\ \underline{/\phi}$, for then $|Z_1|\ \underline{/\phi_1} \times |Z_2|\ \underline{/\phi_2}$

$$= |Z_1| \times |Z_2|\ \underline{/\phi_1 + \phi_2}$$

and

$$\frac{|Z_1|\ \underline{/\phi_1}}{|Z_2|\ \underline{/\phi_2}} = \frac{|Z_1|}{|Z_2|}\ \underline{/\phi_1 - \phi_2}$$

and so on. For adding and subtracting the form $R + jX$ is best, when $(R_1 + jX_1) + (R_2 + jX_2) + = (R_1 + R_2) + j(X_1 + X_2)$, etc., *i.e.*, the terms without j (called the real terms) and those with j (called the imaginary terms) are added separately.

As a special case of dividing we have the reciprocal

$$\frac{1}{|Z|\ \underline{/\phi}} = \frac{1}{|Z|}\ \underline{/-\phi}$$

which is often written

$$\frac{1}{|Z|}\ \overline{\backslash \phi},$$

the inverted angle sign indicating that the angle is to be multiplied by -1.

In equation (2) $i = e/Z$, therefore, to find the vector i, e being considered of standard phase, *i.e.*, having a zero angle, we have

$$i = \frac{e}{|Z|\ \underline{/\phi}} = \frac{e}{|Z|}\ \underline{/-\phi},$$

or we draw OI at an angle ϕ below the horizontal and of length $e/|Z|$, or if we draw it equal to $1/|Z|$, it represents the current in the oscillatory circuit per volt of electromotive force applied.

It is evident that the position of P, and therefore of I, depends upon the value of ω. Assuming that the resistance R remains constant, P will evidently lie always upon the vertical line through r. When ω is very small $(\omega L - 1/\omega C)$ has a large negative value, and P is at a great distance below r. When ω is very large $(\omega L - 1/\omega C)$ has a large positive value and P is a great distance above r. When ω is such that

$$\omega L - \frac{1}{\omega C} = O \left(\text{or } \omega = \frac{1}{\sqrt{LC}}\right)$$

P coincides with r. As ω increases, therefore, from a small value P starting from a great distance below r travels upwards through r. This is indicated by the arrow.

Now let us trace the corresponding changes of the point I. When P is far below r the angle rOP will be nearly 90°, so that the angle of I (rOI) will be nearly 90° drawn upwards, and the length OI, which is equal to $1/OP$, will be very small. Thus I, when ω is very small, is very near O but almost vertically above it. As P moves upwards to r, the angle of OI will decrease from 90° to 0, while its length will increase from 0 to its maximum value$=1/R$. With P moving above r, *i.e.*, with positive angle, I will have a negative angle increasing to 90°, while the length of OI will decrease to 0. I will in fact move round a circle with diameter $1/R$ in a clockwise direction starting from 0 as ω is increased from a very small value.

That the locus of I is a circle is seen from the fact that

$$OI = \frac{1}{Z} = \frac{1}{R} \cos \phi,$$

which is the equation of a circle of diameter $1/R$ in polar co-ordinates.

If now in the circuit of Fig. 1 we measure

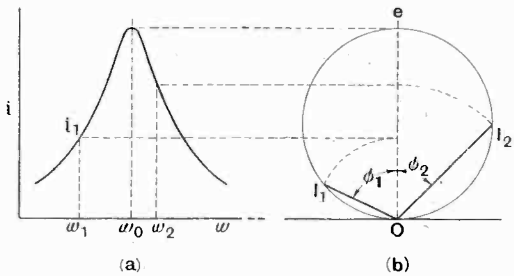


Fig. 3. *Showing* (a) *how the current in the circuit alters as the frequency $\omega/2\pi$ of the induced E.M.F. is varied : and* (b) *how the current may be represented by chords of a circle.*

the current i for various values of ω we obtain the well-known resonance curve of Fig. 3(a). We have measured only the magnitude of the current which is generally only half the story in an alternating current circuit. We cannot measure the phase angles. But from our resonance curve, knowing that it is to be derived from a circle, we can work backwards and find the phase angles graphically. The diameter of the circle is the maximum value of the current, so the circle is drawn accordingly at b (Fig. 3). At the maximum value (at ω_0) the current and volts are in phase, so the electromotive force vector is drawn along the diameter Oe. At any other ω value ω_1 a vertical is drawn to meet the resonance curve in i_1, a horizontal is drawn through i_1 to meet Oe in 1, and with centre O and radius $O1$ an arc is drawn to meet the circle in I_1. Then OI_1 is the current vector for the frequency corresponding to ω_1, and its phase angle is $eOI_1 = \phi_1$. At an angular frequency ω_2 past the resonance value the current vector found in the same way is OI_2, and the angle ϕ_2 is negative. Thus for any value of ω we can find the corresponding value of ϕ.

Now in the case of the sharp resonances met with in wireless work there is a very simple relation between ω and ϕ.

We have seen (1(b) or Fig. 2) that

$$\tan \phi = -\frac{\omega L - \frac{1}{\omega C}}{R}$$

Differentiating with respect to ω we have

$$\frac{d \tan \phi}{d\omega} = -\left(\frac{L}{R} + \frac{1}{\omega^2 CR}\right)$$

$$= -\frac{L}{R}\left(1 + \frac{1}{\omega^2 CL}\right) = -\frac{L}{R}\left(1 + \frac{\omega_0^2}{\omega^2}\right)$$

Now, when the resonance is very sharp most of the circle is described with only a small change of ω, so that ω is always very nearly ω_0 and ω_0^2/ω^2 very nearly one. And then

$$\frac{d \tan \phi}{d\omega} = -\frac{2L}{R} \text{ or } \frac{d\omega}{d \tan \phi} = -\frac{R}{2L}$$

$$= -a \quad \dots (3)$$

where $a = R/2L =$ the decay factor of the circuit. Even when the resonance is not sharp this holds for the resonance value.

If, therefore, we plot a curve of ω against $\tan \phi$, this curve will be practically a straight line, whose slope will give us the decay factor of the circuit.

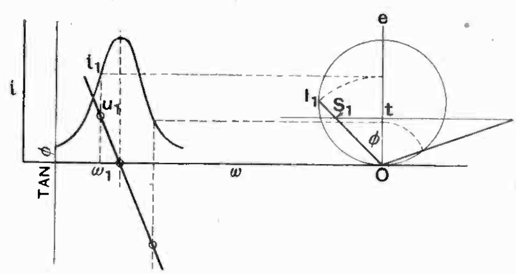


Fig. 4. *Showing how to obtain the decay factor* R/2L *of an oscillatory circuit from its resonance curve. The slope of the line showing the relation between* tan ϕ $\left(\textit{which equals} -\frac{\omega L - 1/\omega C}{R}\right)$ *and* ω *gives the decay factor.*

The easiest way to draw this curve of $\omega/\tan \phi$ is indicated in Fig. 4. On the circle diagram a length Ot is measured along Oe equal to one, to any convenient scale, and the current vector OI, cuts the horizontal through t in S_1. Then since $\tan \phi = St/Ot = St$ to the same scale that makes $Ot = 1$, the length St set up vertically at ω_1, on the resonance curve diagram gives a point μ_1 on the curve of ω against $\tan \phi$.

Generally it is not possible in a wireless circuit to measure i directly without introducing the resistance, which is probably considerable, of an ammeter, but the same information can be obtained by measuring the voltage across the condenser. If this is done with a valve voltmeter with sufficient negative grid bias, the circuit constants are not appreciably affected and the volts read are sufficiently nearly directly proportional to the current.

Further, if instead of varying the frequency of the supply, the condenser of the oscillatory circuit is varied, the same considerations as above apply if $\omega_0 = 1/\sqrt{LC}$ takes the place of ω. Fig. 5 gives an experimentally obtained resonance curve showing the root of the valve voltmeter reading (*i.e.*, figures proportional to the volts) across the condenser plotted against the $1/\sqrt{C}$, which is proportional to the value of ω_0. The inductance of the circuit was 5,000 μH and the angular frequency of the supply 7.87×10^5.

From the construction carried out on the curve we have for the slope of the line

$$\frac{d\dfrac{1}{\sqrt{C}}}{d\tan\phi} = \frac{.0032}{4} = .0008 \ (C \text{ in } \mu\mu\text{F}).$$

Now

$$\omega_0 = \frac{1}{\sqrt{L}} \times \frac{1}{\sqrt{C}} = \frac{1}{\sqrt{5{,}000 \times 10^{-6}}} \times \frac{10^6}{\sqrt{C}}$$

$$= 14.1 \times 10^6 \times \frac{1}{\sqrt{C}}$$

$$\therefore \frac{d\omega_0}{d\tan\phi} = \alpha = .0008 \times 14.1 \times 10^6 = 11{,}300$$

and $R = \alpha \times 2L = 11{,}300 \times 2 \times 5{,}000 \times 10^{-6}$
$= 113$ ohms.

A small decay factor means not only a larger voltage available at the resonant frequency, but what is of even greater importance in these days of an already crowded ether, greater selectivity, that is a greater ratio of the current in the circuit at the resonant frequency to that with the same applied volts at any other frequency. The circle, besides having a larger diameter, is described with a smaller change of ω.

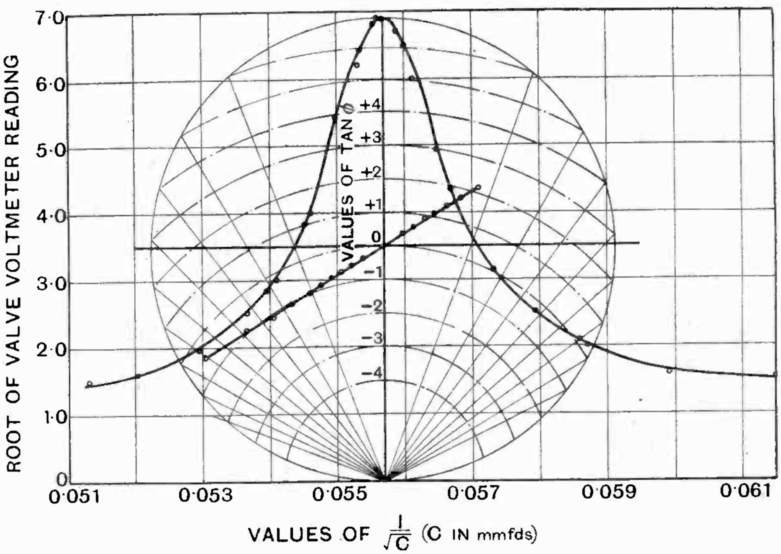


Fig. 5. *Actual determination of the decay factor from an experimentally obtained resonance curve.*

A standard resonance curve applicable to any simple circuit can be drawn as in Fig. 6. We have

$$i = \frac{e}{R + j\left(\omega L - \dfrac{1}{\omega C}\right)}$$

Now $\left(\omega L - \dfrac{1}{\omega C}\right) = \omega L\left(1 - \dfrac{1}{\omega^2 LC}\right)$

and since $\omega_0^2 = \frac{1}{LC}$

$$\left(\omega L - \frac{1}{\omega C}\right) = \omega L\left(1 - \frac{\omega_0^2}{\omega^2}\right)$$

$$= \omega L\left(1 - \frac{\omega_0}{\omega}\right)\left(1 + \frac{\omega_0}{\omega}\right)$$

$$= 2L\,(\omega - \omega_0),$$

since ω_0/ω is very nearly 1 in all wireless applications.

So we may write

$$i = \frac{e}{R + j2L\,(\omega - \omega_0)}$$

and since at resonance $i_R = \frac{e}{R}$

$$\frac{i}{i_R} = \frac{1}{1 + j\frac{2L}{R}(\omega - \omega_0)} = \frac{1}{1 + j.\frac{\omega - \omega_0}{a}} \qquad (4)$$

Take $OA = 1$ in. $= 1$ and mark vertically along AB various points to represent $\omega - \omega_0/a$ to the same scale. Then rays such as OC are

$$\left(1 + j\,\frac{\omega - \omega_0}{a}\right),$$

To convert the abscissæ to ω we must multiply by a and the greater a the greater the frequency change before the ratio i/i_R is reduced to a half, say. For instance, if $a = 1{,}000$, 1 in. of the abscissa represents 1,000 in the ω scale, and the current is halved if ω is off resonance by 1,700. But if $a = 5{,}000$, 1 in. $= 5{,}000\ \omega$ and a change in ω of 8,500 is required to halve the current. In the case of parallel resonance (Fig. 7) the voltage across the parallel inductance and condenser follows the same law as the current in the series resonance case. For the parallel impedance Z_p we have

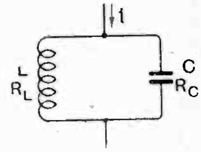


Fig. 7. *A simple parallel resonance circuit.*

$$Z_p = \frac{\left(R_L + j\omega L\right)\left(R_c - \frac{j}{\omega C}\right)}{R_L + j\omega L + R_c - \frac{j}{\omega C}}$$

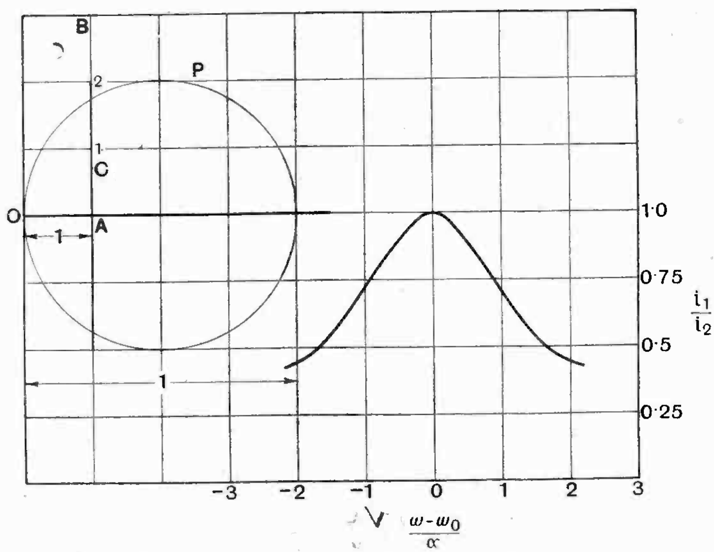


Fig. 6. *A standard resonance curve which is applicable to any simple circuit, in which* $w_0 = \frac{1}{\sqrt{LC}}$ *and* a = R/2L *as before.*

and these continued to cut a circle drawn along OA as diameter to some suitable scale (in this case 4 in. $= 1$) give the values of i/i_R as OP. OP is plotted against $\omega - \omega_0/a$ on the right of the figure.

where R_L and R_c are the resistances of the inductance and condenser respectively.

Writing $Z = R_L + R_c + j\omega L - j/\omega C =$ the series impedance round the oscillatory circuit, and neglecting in the numerator R_L

C

in comparison with $j\omega L$, and R_c in comparison with $-j/\omega C$, we have

$$Z_p = \frac{L}{CZ} \quad .. \quad .. \quad (5)$$

If we have a constant current i, reckoned of standard phase, through the circuit, the voltage across the circuit is

$$Z_p i = \frac{L}{CZ} i = \frac{1}{Z} \times \frac{Li}{C},$$

which is of the same form exactly as the current in the series case with constant e. The locus is a circle therefore, and the curve of volts/ω a simple resonance curve with decay factor $R/2L$, where R is the total series resistance $= R_L + R_c$.

The chief wireless interest of such a parallel circuit is in its use in the tuned anode scheme of Fig. 8.

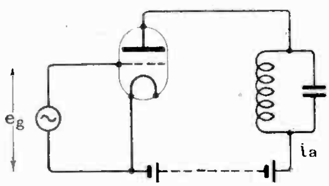


Fig. 8. *Showing the use of a parallel resonance circuit in the anode circuit of a valve.*

We have a voltage e_g applied to the grid resulting in an anode current i_a given by

$$i_a = \frac{\mu e_g}{R_a + Z_p}$$

where R_a is the internal resistance (anode-filament) of the valve and μ its amplification factor. The voltage v available across the tuned circuit is

$$v = i_a Z_p$$

$$= \frac{\mu e_g Z_p}{R_a + Z_p}$$

$$= \mu e_g \frac{1}{\frac{R_a}{Z_p} + 1} = \mu e_g \frac{1}{\frac{R_a C Z}{L} + 1} \quad (6)$$

The voltage amplification is

$$\frac{v}{e_g} = \frac{\mu}{\frac{R_a C Z}{L} + 1} \quad .. \quad (7)$$

which at the resonant frequency is

$$\frac{\mu}{\frac{C}{L} \cdot R R_a + 1}$$

In a typical case of a well-designed circuit, say $C = 1{,}000 \mu\mu F$, $L = 4{,}000 \mu H$, $R = 10$ ohms and $R_a = 25{,}000$ ohms,

$$\frac{C}{L} R R_a = .06$$

and the voltage amplification is $\mu/1.06$, within 6 per cent. of the maximum μ obtainable in this way.

Going back to equation (6) we may write

$$v = \mu e_g \cdot \frac{\frac{L}{R_a C}}{Z + \frac{L}{R_a C}} \quad .. \quad (8)$$

$$= \frac{\frac{\mu L}{R_a C}}{R + \frac{L}{R_a C} + j\left(\omega L - \frac{1}{\omega C}\right)} e_g \quad (9)$$

In this expression the numerator is a constant, and the only j term in the denominator is

$$j\left(\omega L - \frac{1}{\omega C}\right).$$

Resonance occurs therefore as before when

$$\omega^2 = \frac{1}{LC},$$

and the form of vector diagram and of the resonance curve is the same as in the simple oscillatory circuit. The effective decay factor has, however, been increased by the addition of the term $L/R_a C$ to the resistance in the denominator. R has in fact been replaced by

$$\left(R + \frac{L}{R_a C}\right),$$

so that the decay factor is now

$$\frac{R + \frac{L}{R_a C}}{2L} = \frac{R}{2L} + \frac{1}{2 R_a C} \quad (10)$$

In the original circuit the decay factor was

$$\frac{R}{2L} = \frac{10}{2 \times 4{,}000 \times 10^{-6}} = 1{,}200$$

Now

$$\frac{1}{2 R_a C} = \frac{1}{2 \times 25{,}000 \times 1{,}000 \times 10^{-12}} = 20{,}000.$$

So that the effective decay factor is now 21,200, nearly 20 times its original value, and our selectivity is very seriously reduced.

This is where reaction comes in. By reacting back to the grid circuit we can reduce the effective resistance and decay factor without any limit except that imposed by stability. This will give a very material increase in voltage amplification available, and at the same time will greatly increase the selectivity.

Consider the case of back coupling by mutual induction M from the anode coil to the grid coil. The current in the anode coil is very nearly

$$\frac{j\omega L}{Z} i_a ,$$

so that the additional grid voltage produced by the mutual inductance is

$$j\omega M \times \frac{j\omega L}{Z} i_a = -\frac{\omega^2 ML}{Z} i_a.$$

The total grid voltage is therefore

$$v_g = e_g - \frac{\omega^2 ML}{Z} i_a,$$

or if we turn the coil so that M is such as to increase the grid voltage (the sign of M can be made $+^{ve}$ or $-^{ve}$ at will), we may write

$$v_g = e_g + \frac{\omega^2 ML}{Z} i_a,$$

and

$$i_a = \frac{\mu v_g}{R_a + Z_p} = \frac{\mu \left(e_g + \frac{\omega^2 ML}{Z} i_a \right)}{R_a + Z_p}$$

so that

$$i_a \left(1 - \frac{\frac{\mu\omega^2 ML}{Z}}{R_a + Z_p} \right) = \frac{\mu e_g}{R_a + Z_p}$$

$$i_a = \frac{\mu e_g}{R_a + Z_p - \frac{\mu\omega^2 ML}{Z}} \quad \text{.. (11)}$$

and the voltage v available $= i_a Z_p = i_a \frac{L}{CZ}$ is

$$v = \frac{\mu e_g}{\frac{R_a CZ}{L} + 1 - \mu\omega^2 MC} = \frac{\mu e_g}{\frac{R_a CZ}{L} + 1 - \frac{\mu M}{L}} \quad (12)$$

We note in passing that this is infinity when the denominator is 0. This is evidently the condition for self-oscillation to start, *i.e.*,

$$\frac{R_a CZ}{L} + 1 - \frac{\mu M}{L} = 0$$

or, since the oscillations will be at resonance, very nearly, when $Z = R$,

$$M = \frac{1}{\mu}(R_a RC + L) \quad \text{.. (13)}$$

It is clear therefore that placing the oscillatory circuit in the anode of a valve increases its effective damping very considerably, but that this increase may be wiped off by reaction. In the case considered the effective decay factor of 1,200 is increased to 21,200 by the valve, and the greater part of the damping to be wiped off is due to the valve itself. One may well ask therefore why the great demand for "low loss" coils and condensers! The resistance of the circuit can be doubled or even quadrupled without any great effect in its use as a tuned anode.

The less the reaction that is required the more stable will be the adjustment of the circuit. In order therefore to use the tuned anode circuit with high efficiency coils and condensers to the best advantage it is necessary to adopt some scheme in which the effective resistance introduced by the valve itself is reduced. This can be done by including only a portion of the inductance in the anode circuit, as indicated in Fig. 9, which is the same arrangement as the "anode tap" used in oscillating circuits. For the idea of using this arrangement in receiving circuits the author is indebted to Prof. C. L. Fortescue.*

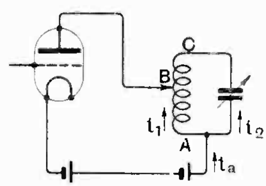


Fig. 9. *Illustrating the use of the "anode tap" in receiving circuits in order to reduce the damping of the oscillatory circuit due to the valve itself.*

Let us suppose that the tap B is placed so that when a current is flowing through the inductance the voltage across AB is b times the voltage across AC. Then neglecting the resistance of the coil and assuming further that the currents i in AB and BC are equal, we know that the effective impedance of $AB = b \times$ impedance of AC; the parallel impedance introduced into the anode circuit is,

$$Z_p = \frac{(\text{Effec. Imped. } AB)\ (\text{Effec. Imped. } BCA)}{\text{Total series impedance.}} \quad (14)$$

* C. L. Fortescue, *Engineering*, 10th Oct., 1919, p. 491, and *Journal of the Radio Society of Gt. Britain*, Vol. VI., p. 15.

$$= \frac{j\omega Lb\left\{(1-b)(j\omega L)-\frac{j}{\omega C}\right\}}{Z}$$

$$= \frac{(j\omega Lb)(-j\omega Lb)}{Z} = b^2\frac{L}{CZ} \quad \ldots \quad (15)$$

Working this out more in detail, let $r_1 l_1$, $r_2 l_2$ be the resistance and inductance of AB and BCA respectively (r_2 includes the condenser resistance) and m the mutual inductance between the coils. Let i_a, i_1 and i_2 be the anode current, and the currents through AB and ACB in order, and v the voltage across AB.

Then

$$i_a = i_1 + i_2$$

$$v = i_1(r_1 + j\omega l_1) - j\omega m i_2$$

$$= i_2\left(r_2 + j\omega l_2 - \frac{j}{\omega C}\right) - j\omega m i_1$$

Whence

$$i_1(r_1 + j\omega l_1 + j\omega m) = i_2\left(r_2 + j\omega l_2 - \frac{j}{\omega C} + j\omega m\right)$$

Write $z_1 = (r_1 + j\omega l_1 + j\omega m)$

$$z_2 = \left(r_2 + j\omega l_2 - \frac{j}{\omega C} + j\omega m\right)$$

Then

$$i_1 z_1 = i_2 z_2 \text{ and } i_1 = i_a - i_2 = i_a - \frac{z_1}{z_2} i_1$$

$$\therefore \quad i_1 = \frac{i_a}{1 + \frac{z_1}{z_2}} \qquad i_2 = \frac{i_a}{1 + \frac{z_2}{z_1}}$$

Now $v = i_1(r_1 + j\omega l_1) - i_2(j\omega m)$

$$= i_a\left(\frac{r_1 + j\omega l_1}{1 + \frac{z_1}{z_2}}\right) - i_a\left(\frac{j\omega m}{1 + \frac{z_2}{z_1}}\right)$$

and $Z_p = \frac{v}{i_a} = \frac{(r_1 + j\omega l_1)z_2 - j\omega m z_1}{z_1 + z_2}$ .. (16)

Now $z_1 + z_2$ is the series impedance of the whole oscillatory circuit,

$$= R + j\left(\omega L - \frac{1}{\omega C}\right),$$

if $R = r_1 + r_2$ and since $l_1 + 2m + l_2 = L$.

Neglecting the resistances in the numerator in comparison with the reactances, we have

$$Z_p = \frac{j\omega l_1\left(j\omega l_2 - \frac{j}{wC} + j\omega m\right) - j\omega m(j\omega l_1 + j\omega m)}{Z}$$

$$= \frac{\frac{l_1}{C} - \omega^2 l_1 l_2 + \omega^2 m^2}{Z} \quad \ldots \quad \ldots \quad (17)$$

We see also that i_1 will $= -i_2$ if $z_1 = -z_2$, *i.e.*, if

$$r_1 + j\omega l_1 + j\omega m = -r_2 - j\omega l_2 + \frac{j}{\omega C} - j\omega m.$$

Again neglecting the resistances, this is true if

$$j\omega l_1 + j\omega l_2 + 2j\omega m - \frac{j}{\omega C} = 0$$

$$\text{or } j\omega L - \frac{j}{\omega C} = 0,$$

which holds at resonance and very nearly round about resonance.

So that what we have assumed is that nearly the same current flows in AB as in AC, or the oscillatory current is large compared with the anode current.

We have defined the ratio of the voltage across AB to that across BC as b. That is, with our approximations,

$$b = \frac{j\omega l_1 + j\omega m}{j\omega l_1 + j\omega l_2 + j\omega m} = \frac{l_1 + m}{l_1 + l_2 + 2m}$$

Introducing this into equation (17),

$$Z_p = \frac{\frac{l_1}{C} - \omega^2 l_1 l_2 + \omega^2 m^2}{Z} \text{ and writing } \omega^2 = \frac{1}{LC}$$

$$= \frac{l_1 L - l_1 l_2 + m^2}{CZL} = \frac{l_1(l_1 + l_2 + 2m) - l_1 l_2 + m^2}{CZL}$$

$$= \frac{l_1^2 + 2ml_1 + m^2}{CZL} = \frac{(l_1 + m)^2}{L^2} \cdot \frac{L}{CZ}$$

$$= b^2\frac{L}{CZ} \text{ as before.}$$

Formula (14) can be identified with formula (16) if for the effective impedance of AB we write z_1, and for the effective impedance of BCA we write z_2.

Formula (14) then becomes

$$Z_p = \frac{z_1 z_2}{Z} = \frac{(r_1 + j\omega l_1 + j\omega m)\left(r_2 + j\omega l_2 - \frac{j}{\omega C} + j\omega m\right)}{Z}$$

$$= \frac{(r_1 + j\omega l_1)z_2 + j\omega m z_2}{Z}$$

$$= \frac{(r_1 + j\omega l_1)z_2 - j\omega m z_1}{Z}$$

which is formula (16).

The current in the oscillatory circuit is

$$i_a \times \frac{j\omega Lb}{Z}$$

and the voltage available across the condenser is

$$v = i_a \times \frac{j\omega Lb}{Z} \times \left(-\frac{j}{\omega C}\right)$$

$$= i_a \times b\frac{L}{CZ} \quad \ldots \quad \ldots \quad (18)$$

Now

$$i_a = \frac{\mu e_g}{R_a + b^2\dfrac{L}{CZ}}$$

$$\therefore \quad v = \frac{\mu e_g}{R_a + b^2\dfrac{L}{CZ}} \times b \times \frac{L}{CZ} = \frac{\mu e_g}{\dfrac{CZ}{bL}R_a + b}$$

$$(19)$$

This is a maximum when

$$\frac{CZ}{bL}R_a + b$$

is a minimum, which differentiating with regard to b, is when

$$-\frac{C^2}{b^2L}R_a + 1 = 0 \quad \text{or} \quad b^2 = \frac{CZ}{L}R_a$$

and when the circuit is tuned

$$b^2 = \frac{CRR_a}{L}$$

and we can write

$$v = \mu e_g \frac{\dfrac{bL}{CR_a}}{Z + \dfrac{b^2L}{CR_a}} \quad \ldots \quad \ldots \quad (20)$$

The increase in the decay factor is now

$$\frac{1}{2L}\frac{b^2L}{CR_a},$$

and when b has its optimum value this is

$$\frac{1}{2L}\frac{L}{CR_a} \times \frac{CRR_a}{L} = \frac{R}{2L}.$$

In other words, the best arrangement is that which makes the damping introduced by the valve the same as that of the oscillatory circuit.

In our example above we should have the optimum value of

$$b^2 = \frac{CRR_a}{L} = \frac{1{,}000 \times 10^{-12} \times 10 \times 25{,}000}{4{,}000 \times 10^{-6}} = \frac{1}{16},$$

so that $b = \frac{1}{4}$, or, roughly, one quarter of the coil should be tapped off to the anode.

The voltage amplification without reaction would now be 2μ. Since the decay factor is now only doubled by the valve, instead of being made twenty times as great, the selectivity without reaction is very considerably increased, and the reaction necessary to obtain the best signals is also very considerably reduced.

To find in the case of back coupling the effect of the mutual inductance between grid and anode coils we see as before that the grid voltage is increased by

$$j\omega M \times (\text{oscillatory current}) = j\omega M \times \frac{j\omega Lb}{Z}.i_a,$$

and we can write

$$v_g = e_g + \frac{\omega^2 MLb}{Z} i_a$$

and

$$i_a = \frac{\mu v_g}{R_a + Z_p} = \frac{\mu\left(e_g + \dfrac{\omega MLb}{Z} i_a\right)}{R_a + Z_p}$$

or

$$i_a = \frac{\mu e_g}{R_a + Z_p - \dfrac{\mu\omega^2 MLb}{Z}} \quad \ldots \quad (21)$$

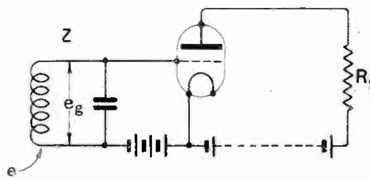


Fig. 10. *Showing the parallel resonance circuit in the grid circuit of the valve.*

and the voltage available across the condenser

$$= i_a \times b \,.\, \frac{L}{CZ}$$

$$= \frac{\mu e_g}{\dfrac{R_aCZ}{bL} + \dfrac{b^2L}{CZ} \times \dfrac{CZ}{bL} - \dfrac{\mu\omega^2 MLb}{Z} \times \dfrac{CZ}{bL}}$$

$$= \frac{\mu e_g}{\dfrac{R_aCZ}{bL} + b - \dfrac{\mu M}{L}} \quad \ldots \quad \ldots \quad (22)$$

and oscillations start when the denominator is zero, or when

$$M = 1/\mu\left(\frac{R_aRC}{b} + bL\right) \quad \ldots \quad (23)$$

3. If the tuned circuit is on the grid side of the valve, so that the condenser of the circuit is connected across the grid and filament, and if suitable negative grid bias is employed and the valve worked along the straight part of its characteristics, then no grid current will flow and the valve will not

damp the oscillatory circuit. Under these circumstances, when there is no reaction, if e is the electro-motive force acting in the oscillatory circuit, and there is a loud resistance R_2 in the anode circuit, we have for the oscillatory current $i=e/Z$ and for the voltage on the grid

$$e_g = \frac{e}{Z} \cdot j\omega L$$

very nearly. The anode current is

$$i_a = \frac{\mu \cdot \frac{e}{Z} \cdot j\omega L}{R_a + R_2}$$

and the voltage available across R_2 is

$$v = \frac{\mu \frac{e}{Z} \cdot j\omega L \cdot R_2}{R_a + R_2} = e \cdot \frac{\mu \cdot j\omega L}{1 + \frac{R_a}{R_2}} \cdot \frac{1}{Z} \qquad (24)$$

which when R_2 is made equal to R_a and the

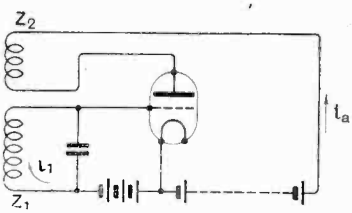


Fig. 11. *Introducing reaction into the grid oscillatory circuit.*

frequency is that of resonance, becomes

$$e \cdot \frac{\mu \cdot j\omega L}{2} \cdot \frac{1}{R} = je \cdot \frac{\mu}{2} \cdot \frac{1}{R}\sqrt{\frac{L}{C}}$$

With our previous example if $\mu = 10$

$$v = e \times \frac{10}{2} \cdot \frac{1}{10}\sqrt{\frac{4{,}000 \times 10^{-6}}{1{,}000 \times 10^{-12}}} = 1{,}000\, e.$$

The voltage amplication is a thousandfold. The decay factor is unaltered as is seen from the fact that in the complete expression for v, $1/Z$ is multiplied by a constant.

If the resistance R_2 is replaced by a tuned anode circuit the resonance curve as ω is varied is no longer a simple one This case it is hoped to deal with in a later article.

If reaction is introduced, say by replacing the resistance R_2 by a coil of inductance L_2 and resistance R_2 (impedance Z_2) coupled with the first coil by a mutual inductance M, then distinguishing the grid oscillatory circuit by the subscript 1, we have for the anode current

$$i_a = \frac{\mu e_g - j\omega M i_1}{R_a + Z_2}$$

since there will be an E.M.F. $j\omega M i_1$ acting in the anode circuit as well as the equivalent voltage μe_g; and for e_g we have the voltage across the condenser, giving

$$e_g = -\frac{j}{\omega C_1} i_1$$

Hence we have

$$i_a (R_a + Z_2) + j\left(\frac{\mu}{\omega C_1} + \omega M\right) i_1 = 0 \qquad (25)$$

and also

$$i_1 Z_1 + j\omega M i_a = e \quad .. \qquad (26)$$

from a consideration of the electromotive forces acting in the oscillatory circuit.

Eliminating i_a from these two equations we find

$$\frac{e - i_1 Z_1}{j\omega M}(R_a Z_2) + j\left(\frac{\mu}{\omega C_1} + \omega M\right) i_1 = 0$$

$$j\frac{Z_1}{\omega M}(R_a + Z_2)\, i_1 + j\left(\frac{\mu}{\omega C_1} + \omega M\right) i_1 = \frac{je}{\omega M}(R_a + Z_2)$$

whence

$$i_1 = \frac{e}{Z_1 + \omega M \left(\frac{\frac{\mu}{\omega C_1} + \omega M}{R_a + Z_2}\right)} \qquad (27)$$

We note that if $M=0$, $i_1 = e/Z_1$ as it should.

The effect of M will depend upon its sign, that is upon the way the coil Z_2 is arranged with regard to the coil of Z_1. If M is positive the effective resistance of the circuit and its decay factor are increased. If M is negative there may be either an increase or a decrease according to the value of M, but there will be a decrease unless M is unusually large. Writing—M for M, we have for the effective impedance

$$Z_1 - \frac{M \cdot \frac{\mu}{C_1}}{R_a + Z_2} + \frac{\omega^2 M^2}{R_a + Z_2}$$

If $\mu M/C_1$ is greater than $\omega^2 M^2$, that is, M less than $\mu/C_1\omega^2 = \mu L_1$ at resonance, there will be a decrease of impedance and effective resistance, but if M is greater than μL_1, an unlikely condition, there will be an increase.

Generally the impedance of the coil L_2 will be much less than R_a, and instead of $R_a + Z_2$ we may write simply R_a.

We then have that the effective resistance of the circuit is

$$R_1 - \frac{\mu M}{R_a C_1} + \frac{M^2}{L_1 C_1 R_a}$$

of which the last term is usually negligible, since M/L_1 will usually be very small compared with μ. Oscillations start when the effective resistance is zero, or when $M = R_1 C_1 R_a/\mu$, in our example

$$\frac{10 \times 1{,}000 \times 10^{-12} \times 25{,}000}{10} = 25\mu\text{H}.$$

The decay factor also will be decreased, by

$$\frac{\mu M}{2 R_a L_1 C_1}.$$

If now, instead of using grid bias, the valve is made to rectify by means of a grid leak there will be grid current flowing through an equivalent valve resistance R_g and there will be damping of the oscillatory circuit by the valve in the same way as when the oscillatory circuit was connected to the anode, and the coupling must be increased to compensate for this. And in the same way that it was found in the anode case to be better to tap off only a portion of the coil to the anode, it may be found that it is better to tap off only a portion of the coil to the grid.

In any of the cases considered, if the voltage or current in the circuits is plotted against ω a simple resonance curve results which when treated by the circle construction described in section 1 will give a straight line, from which the effective decay factor of the circuit arrangement is found.

When two tuned circuits are involved the circle is replaced by a parabola. It is hoped to deal with these cases in a further contribution. It will also be shown that in the wireless circuits in general use, whatever the nature of the coupling, it can be replaced by an equivalent mutual inductance. Thus the coupling effect of the valve capacities, which has been ignored in the preceding notes, can be taken account of by a suitable modification of the values of the mutual inductance.

Matters of Wireless Interest at the Physical Society's Exhibition.

As has been the case in recent years, wireless was again represented at the Seventeenth Annual Exhibition of Apparatus held by the Physical Society and Optical Society at the Imperial College, South Kensington, on 4th, 5th and 6th January, 1927.

Following the practice inaugurated last year, in addition to the usual commercial exhibits, a section was devoted to Research and Experiment, *e.g.*, from Government and other research establishments, this section being further embellished by groups of Lecture Experiments and Famous Historical Experiments.

At the stall of the **Cambridge Instrument Co., Ltd.,** the chief wireless exhibit was a multi-range thermionic voltmeter, a development of the now well-known Moullin, pattern A, instrument. This is designed for the measurement of alternating voltages at high or low frequencies over a wider range than was possible with earlier models. Three ranges are now provided in one instrument, *i.e.*, 0-4, 0-40 and 0-120 volts respectively. Another interesting exhibit was their latest pattern of Three Element Oscillograph, which allows simultaneous records to be obtained from three vibrators. These may be any combination of electrostatic or electromagnetic (Duddell) types. The apparatus was demonstrated in operation along with other apparatus, including an Eccles' valve maintained fork, reed hummer, etc.

Messrs. Creed & Co., Ltd., demonstrated the Creed Start-Stop and Murray Multiplex systems. The former is a typewriter keyboard operated transmitter, received signals being printed directly letter by letter in Roman characters. The Murray Multiplex is on the well-known five-unit channel system.

Among the instruments of **Messrs. Crompton & Co., Ltd. (Chelmsford),** the all test Moving Coil Test Set, and the unique Cell Tester were of interest in wireless work.

The Damard Lacquer Co., Ltd., of Birmingham, showed a number of bakelite and other insulating materials.

Darimont Electric Batteries, Ltd., exhibited the latest forms of this primary cell, which is now constructed so that the depolariser is supplied in a dry state, to be dissolved as required for use.

The Dubilier Condenser Co., Ltd., had their usual extensive display of condensers of all sizes and for all forms of wireless work. Practical interest attached to a series of standard condensers of various forms and high accuracy, and to condensers for transmitting circuits, *i.e.*, for anode feed, high power circuits, smoothers, etc. A large range of receiver condensers were also on view, including the plate by plate model giving smooth variation over a large range. Amongst other sundries a useful mica insulator was shown, and a Neon lamp wavemeter.

Elliott Bros., London, Ltd., showed different patterns of measuring instruments, one of particular interest being a differential cell testing voltmeter of use in localising battery defects due to a particular plate of a cell.

Messrs. Everett Edgcumbe featured several instruments for radio frequencies, both of the thermo-expansion and thermo-couple type. These are also designed for use with iron-cored radio-frequency transformers.

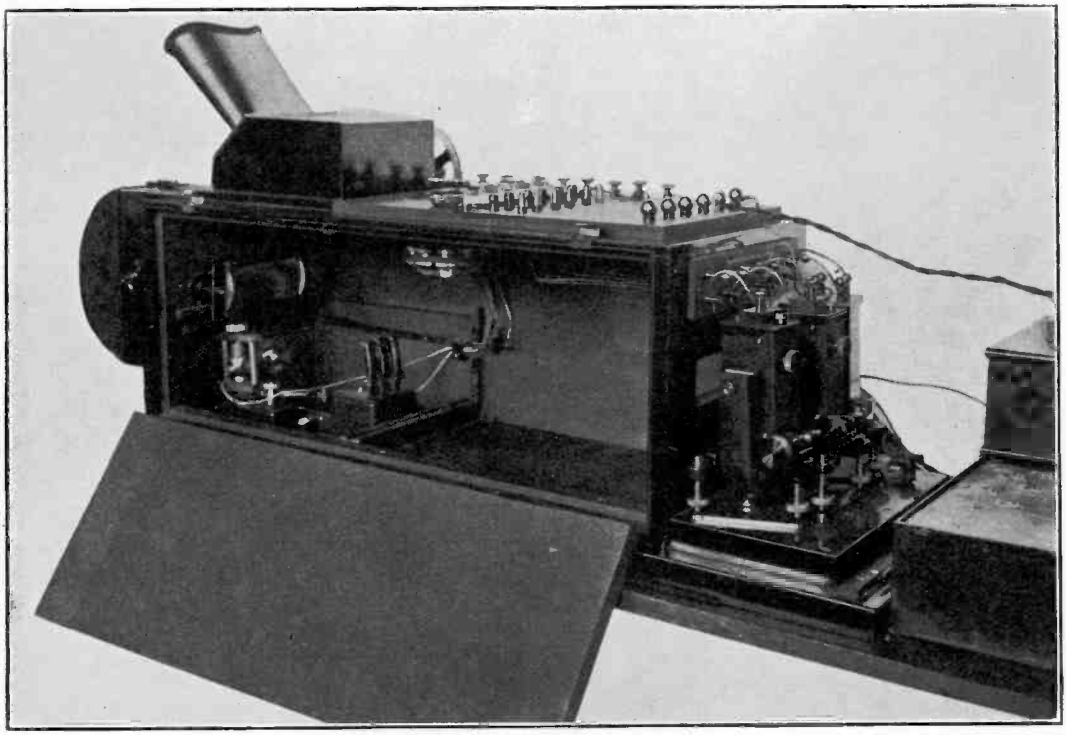
Messrs. Gambrell Bros., in addition to many useful pieces of test apparatus, displayed a series of receivers drawing all voltages, L.T. and H.T., from mains, A.C. or D.C.

Messrs. Adam Hilger and **Messrs. Kelvin Bottomley & Baird** both had quartz crystals on view.

The Igranic Electric Co., Ltd., had a large display of purely wireless interest, including eliminators, a Neutrosonic seven-valve portable receiver, as well as the already well-known supersonic outfit. Amongst other items shown were twin-gang and triple-gang condensers.

The India Rubber and Gutta Percha Works, while showing chiefly telegraph and measuring apparatus; displayed several wireless accessories, including L.F. transformers, loud-speakers, etc.

The Marconiphone Co., Ltd., had on view their well-known "Straight Eight," together with other smaller models, while the **M.O. Valve Co.** had an extensive show of valves of all sizes including components of water-cooled anode valves, and a number of water-cooled anode valves assembled. An interesting exhibit was a low-frequency oscillator, operating at 1 cycle per second. Instruments showed oscillatory current, oscillatory voltage and anode current, enabling the cyclic variations to be readily followed. Various new valves were also on display, including the D.E.P. 215 and K.L. having a separately heated cathode.



Three-element oscillograph. Cambridge Instrument Co., Ltd.

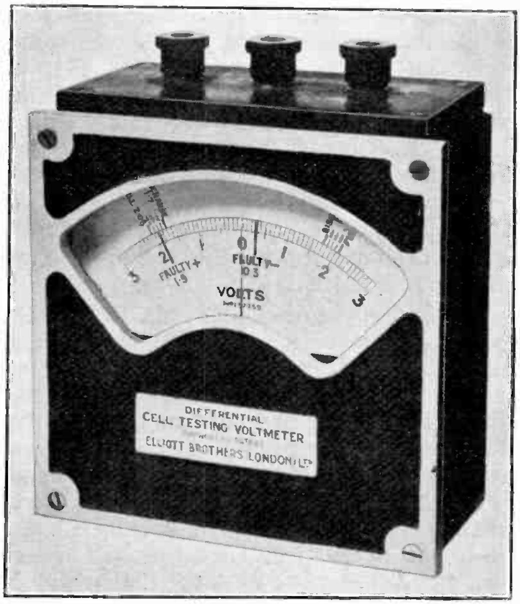
The Mullard Radio Valve Co. and Mullard Wireless Service Co., Ltd., had an extensive display of the well-known P.M. Filament series in 2, 4 and 6-volt groups, parts of valves in various stages of construction, etc. There was also a number of transmitting and (power) rectifying valves, notably the P.M. water-cooled valve. An oscillator at 2.5 metres was also shown in operation.

Measuring instruments of various types were exhibited by **Messrs. Nalder Bros. & Thompson,** and by **The Record Electrical Co., Ltd.,** the latter featuring "Cirscale" instruments, giving a wide (nearly completely circular) scale reading.

Messrs. W. G. Pye & Co., of Cambridge, had a variety of small current galvanometers, while **The Stonebridge Electrical Co.** had also a number of small portable precision instruments of various ranges.

The display of the **Radio Communication Co., Ltd.,** was naturally entirely wireless. Their automatic call device, responding to a series of 4-second dashes, was demonstrated in operation, while another exhibit was a C.W. transmitter of 500-3,000 metres with a sea range of 1,000-1,500 miles, and with provision for I.C.W.

At the stall of **Messrs. H. Tinsley & Co.** many pieces of measuring apparatus were on view, the most recent being, perhaps, the Willans Transformer Tester (see *E.W. & W.E.*, July, 1926), and a wavemeter of N.P.L. design from 500-6,000 metres.



Differential cell-testing voltmeter. Elliott Bros., Ltd.

Messrs. H. W. Sullivan & Co., Ltd., had a large display of laboratory apparatus including A.C. bridges and accessories, a standard multivibrator wavemeter (due to D. W. Dye of N.P.L.), precision heterodyne wavemeters, and wavemeters for very short wavelengths. There was also a display of various apparatus for the determination of effective resistance, inductance and capacity at radio frequencies.

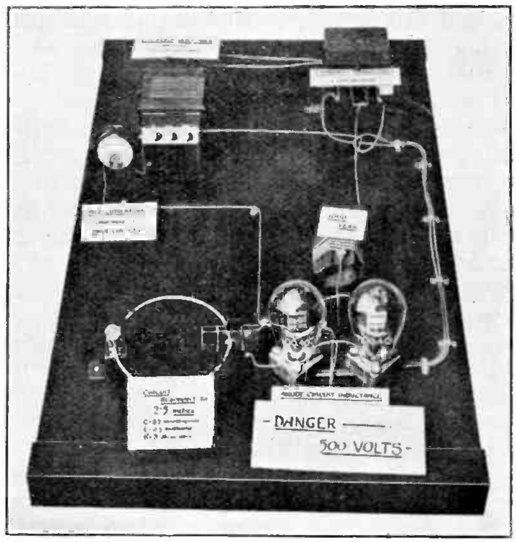
The Weston Electrical Instrument Co., Ltd., showed a large selection of the A.C. and D.C. instruments for which they are well known, an item of special wireless interest being a radio panel voltmeter of only 2 inches diameter for use on receiving sets.

The display of the **Zenith Electric Co.** was chiefly of resistances, including wire wound resistance units of high ohmic value, inductionless and of low capacity.

RESEARCH AND EXPERIMENTAL SECTION.

In Group A (some typical results of recent physical research) the **Admiralty Research Laboratory** showed a signal strength meter for use on waves over 6,000 metres. In the N.P.L. exhibit the only item of wireless interest was apparatus for obtaining standard telephonic frequencies from the seconds given by a clock pendulum. The pendulum maintains a 50-cycle fork, acting in conjunction with a multivibrator.

The Research Laboratories of the G.E.C. showed a model demonstrating the magnetron principle of the effect on space current of an external magnetic field, and skiagrams of water-cooled anode valves. The **Metropolitan Vickers Co.** had a display of short path valves, in the form of exhibits illustrative of the short path principle. The



A short-wave oscillator. Mullard Radio Valve Co.

B.T.-H. Co.'s Engineering Laboratories had an oscillating valve model in the form of a mechanical arrangement illustrating the principles involved in a triode oscillator. **Mr. J. N. Baird** had on view a model of the original television apparatus, as already exhibited at the Wireless Exhibition.

In Group B (Lecture Experiments in Physics) **Mr. G. G. Blake** had a triode valve model designed to illustrate the action of the three-electrode valve, demonstrating the effect of operating conditions and the reception of oscillations. Prof. G. B. Bryan also showed a valve characteristic model demonstrating the relationship between grid voltage and anode current.

In Group C (Famous Historical Experiments in Physics) were four exhibits lent by Prof. E. O. Appleton from the King's College (London) collection: 1. Coil used by Joseph Henry in his work on self-induction; 2. Resistance Box and Bridge used by Mr. Charles Wheatstone; 3. An A.B.C. Telegraph designed by Wheatstone in 1840; and 4. A mechanical model designed by Clerk Maxwell illustrating the induction of currents.

The Acoustic Problems of Microphones and Loud-Speakers.

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

THE monthly meeting of the Wireless Section, I.E.E., held on 5th January, was devoted to an informal discussion on "The Acoustic Problems of Microphones and Loud-Speakers."

The discussion was opened by **Mr. G. H. Nash, C.B.E.,** who said that instead of examining the subject from the standpoint of close detail of design—these subjects already being dealt with in numerous papers—he would rather lead the discussion on the lines of considering whether broadcasting was proceeding on the right lines and whether our ideas of what was needed were clear. He compared broadcast with personal attendance, say, at a concert or address—where eyes and other faculties were active. The transmitter and receiver should have a straight line of performance, and microphone and loud-speaker to be ideal should reproduce the complex sensations of the ear. The microphone offered fewer problems than the receiver. The condenser type was the most perfect in existence and had been adopted as an international standard.

He proposed to offer four heads of discussion: 1. To what extent were binaural transmission and reception advantageous? 2. What was the value of the extremes of the musical scale, *i.e.*, 30-60 cycles and 5,000 to 10,000 cycles? 3. Was it expedient to accept weakness in one part of the system and balance it by strengthening some other part? 4. How far could we expect efficiency and wide frequency response in the loud-speaker?

Dealing with the first point, he asked, was it necessary to have those transmitters and receivers so placed as to give the correct impression of the relative positions, movements of speakers, etc.? In the second point he showed that 30-60 cycles band was entirely absent in a wide range of music. In many loud-speakers the lower frequencies were not reproduced as such but were heard on harmonics. The upper end of 5 to 10kC was mostly present as overtones of other frequencies. If these extreme upper frequencies could be omitted the width of sideband would be smaller. Additionally, in estimating the need for their presence, it was very difficult to measure the loud-speaker output.

On the third head he showed a slide of the audio-frequency amplification at WJZ showing a magnified upper scale at the transmitter to compensate for loud-speaker defects. This necessitated increased load on the transmitter and at the receiver called for much greater anode voltages. On the fourth head he considered loud-speaker performance, pointing out that small diaphragms could not respond to low frequencies. Large volume needed larger power valves and increased high tension. The loud-speaker equipment of the future would probably be in the form of mains supply and much larger valves.

Continuing the discussion, **Mr. B. S. Cohen** expressed the opinion that binaural working might be of advantage in transmitting such matter as drama, but that experiment had shown it to be of little advantage for other purposes of reception. By international agreement, three standards of frequency range had been selected: 1. Ideal transmission of all speech, music, noise, etc., 30-10,000 cycles; 2. High quality speech and music, 100-5,000 cycles; 3. Commercial line telephony, 200-3,000 cycles. From tests of loud-speakers it was found that while many responded strongly at their resonant frequencies their outputs at 5kC were small. The difficulties of transmitting up to 10kC had been pointed out and he questioned the necessity of such band width. He then quoted efficiency figures for various types of apparatus, more especially microphones, and discussed possible lines of improvement as regards cavities, stretch of moving parts, etc.

Capt. P. P. Eckersley said that binaural transmission had not been given to the public because it necessitated two receivers. He agreed that it was legitimate to cut off extremes of sidebands, but considered that all frequencies should be transmitted in order to encourage the development of apparatus in response to them. He did not approve of sending up the transmitter amplification for the higher frequencies and the B.B.C. did not do it. The problem of the best type of microphone for broadcast purposes was considerable. It must have a flat response, negligible background of noise, and maintenance must be simple. He discussed some of the types that had been used and believed that the ideal of these requirements could be obtained.

The Chairman here suggested that the experiment might be tried of using Daventry and London simultaneously for binaural work. Mr. Eckersley replied that it had not been done so far although it was possible and had been considered.

Mr. C. F. Phillips agreed that the transmitter should endeavour to transmit both ends of the musical spectrum. The arguments against this were purely financial and should not govern the case. As regards increased power at the receiver for the wider scale, with the definite tendency towards operation from supply mains, this became unimportant. He had found that when they furnished proper reproduction the public did appreciate it.

Mr. R. P. G. Denman endorsed this view. As regards the lower frequencies, it was certainly necessary to go below 100. The extreme frequencies did produce a gain in results. In comparing a gramophone, with a mechanical cut off at 100, against an electrical system having a falling characteristic but not a cut off, the latter was distinctly better. The loud-speaker used was of the free-edge-cone pattern, coil driven. The interest and appreciation of the public were great, and many people had travelled considerable distances to witness a demonstration of this instrument.

Mr. A. C. Brown urged that consideration to articulation must be given in reproduction. Graham Bell, in his original work on the telephone, had aimed chiefly at this, and articulation must be considered as well as frequency.

Mr. Sandeman discussed the energy spectrum of the matter to be broadcast and that of noise. The lower frequencies carried more energy, so that if they were just sufficient to overcome noise the higher frequencies would not have sufficient energy. Hence arose the need for increased amplification of the higher frequencies. He then discussed the factors governing loud-speaker performance, regarding the loud-speaker in much the same way as an aerial and having a radiation resistance at its horn or diaphragm (in the case of cone types) and showed the difficulties of efficiency at the lower frequencies.

Mr. A. G. D. West agreed that efficiency and quality were antagonistic. The ordinary telephone receiver had a bad frequency characteristic and recently developed forms had better characteristics but were less efficient and necessitated more valves. It was still impossible to get a loud-speaker good below 100 cycles, and even the model mentioned by Mr. Denman distorted below this value. The increased transmitter amplification at the higher frequencies was chiefly to compensate for the inefficiency of the horn loud-speaker.

Mr. P. K. Turner said that binaural reception was a matter of phase, and that in broadcasting there was no guarantee of phase and therefore the arrangement was not applicable. As regards the extremes of frequency, he had tested two sets, one doing 50 per cent. at 30 and at 7,000 cycles, and the other working to 16 and 16,000 cycles. The better scale of the latter instrument gave a perceptible difference.

Mr. Hart discussed binaural reception and different points of acoustics, and the difficulty of estimating or measuring the amount of the sensation of hearing.

Mr. Nash briefly commented on several of the points raised in the discussion, more especially on the width of the band.

In concluding the meeting, the Chairman (**Prof. C. L. Fortescue**) said that the discussion had shown several questions to be settled. In America, thousand of observers had been used, and it was possible that we should have to refer to thousands of musicians in this country. Was a musical ear one that could distinguish everything, or did it produce a blend? The ultimate decision might be physiological or psychological rather than electrical.

Book Reviews.

RADIO FREQUENCY MEASUREMENTS: A HANDBOOK FOR THE LABORATORY AND A TEXT-BOOK FOR ADVANCED STUDENTS. By E. B. Moullin, M.A. Pp. 278 + xi., with 134 Figs. Griffin. 25/-

The subject of radio frequency measurements is one of wide interest which grows very rapidly. It is, on this account, a matter of considerable difficulty to choose and arrange the subject matter of a book on the subject which will not quickly lose its value by reason of new developments in the science of the practice and in the art of the methods of measurement at radio frequencies.

The present book is entitled *A Handbook for the Laboratory and a Text-Book for Advanced Students*. Within the compass of its two hundred and seventy pages, the book appears to fulfil its function fairly well; in particular, the book is very free from obsolete matter although naturally, it does not contain a large amount of novel matter.

The book is divided into nine chapters headed in order, (1) the valve oscillator, (2) measurement of potential difference and current, (3) measurement of frequency, (4) measurement of resistance, (5) measurement of capacity, (6) measurement of inductance, (7) measurement of antenna characteristics, (8) measurement of intensity of radiated fields and (9) miscellaneous measurements and notes.

At a first reading through, one misses a chapter on the general mathematics of circuits, but a closer reading shows that in each chapter the mathematics requisite to the section is quite sufficient as given in the section. Less repetition than might be expected occurs. A certain amount is inevitable since at radio frequencies we cannot separate the properties of circuit into water-tight compartments and say "this" is inductance and "that" is capacity. Resistance also must be very carefully defined as is well perceived and set out by the author.

Chapter I., dealing with the valve generator, is all too short. Too much emphasis cannot be laid upon the importance of the valve generator in radio-frequency measurements. It will be found in the great majority of cases that troubles and difficulties of measurements in which a valve generator is used, arise from irregularity and drifting of frequency and amplitude or insufficiency of its power. In this connection mention might have been made of the use of independently driven oscillators in which a small master valve produces the oscillations and energises the grid-filament circuit of a larger power valve.

The second chapter, dealing with potential difference and current, naturally gives prominence to the author's thermionic voltmeter, but the use of such an instrument to calibrate a thermo-junction heater of moderate resistance is open to question as it is probable that a considerable part of the differences in the ratio of readings of the two instruments as a function of frequency resides in the thermionic voltmeter rather than in the thermo-heater. The real advantage of the thermionic voltmeter resides in its extreme sensitivity rather than in its accuracy. In connection with the use of electrostatic voltmeters the author omits to mention the most serious drawback to the instrument, viz., the *change* in its capacity with reading. This change immediately causes a resonant circuit to become detuned when an attempt is made to tune the circuit with the voltmeter in parallel and renders it impossible to set the circuit to exact resonance with a source. The use of a thermionic voltmeter to measure small currents by observation of the P.D. across a condenser in series in the circuit concerned is open to serious objections. In the case quoted the reactance introduced by the condenser is 300 ohms. The compensation of this reactance by adjustments to the main condenser or inductance in the circuit is a very objectionable necessity of the method. The same current of 3mA can very readily be measured on a vacuum thermo-heater of 30 ohms resistance.

The suggestion at the end of the chapter to measure large currents by observing the secondary induced voltage in a mutual inductance, using a thermionic voltmeter, has the drawback that the calibration depends to the first order upon frequency. Large errors occur also due to the self-capacity of the secondary and to the capacity of the voltmeter. Harmonics would also produce enhanced voltages in the secondary.

The third chapter, on frequency measurement, is good from the point of view of fundamental or standard arrangements by which a basis of measurement may be established; the treatment is very full but more attention might have been given to the common resonance wavemeter and to the heterodyne wavemeter since these are indispensable in any laboratory and have now reached a considerably accurate stage of evolution. The cathode ray tube method developed by the reviewer has been omitted from the chapter, although it possesses advantages over the other cathode ray tube systems described, and was prior to them.

In the discussion on stationary waves on wires mention should have been made of the very excellent investigation of the velocity of waves along wires carried out by G. Laville (*Ann. d. Physique*, 1924).

The section on buzzer-excited oscillations is very complete. The treatment of the reinforcement of harmonics of the buzzer frequency is interesting but, in general, the frequency of the buzzer itself is so irregular that the effect of reinforcement of certain frequencies is difficult to obtain, although this property has been used in a similar manner to a multivibrator for purposes of frequency standardisation.

In the reviewer's experience a self-modulated valve oscillator is far more satisfactory than any buzzer wavemeter as a source of modulated radio frequency.

The chapter on the measurement of resistance is one of the best in the book in view of the difficulty of doing justice to the subject. The author shows that he has had considerable experience of resistance measurements on circuits of moderate or poor decrement (greater than 0.04). The real difficulties of resistance measurement commence when decrements less than 0.01 occur. Such decrements are by no means uncommon in present-day circuits, especially at frequencies above 1,000 kilocycles per sec. The cases for the resistance variation and the reactance variation methods are fairly compared. The reviewer has found the method of frequency variation very satisfactory in many cases, since a frequency difference can be easily set to an accurately known value by the aid of a tuning fork and a small heterodyne oscillator.

On circuits in which the total capacity is smaller than $500\mu\mu F$ and the decrement of the order 0.01, it is practically impossible to use the reactance variation method since changes of only $1\mu\mu F$ are required.

When a resonance curve has been obtained it is generally desirable to measure the breadth across the curve at a number of values of current and to re-plot the results in the form " width of peak " as ordinate to the expression

$$\frac{\sqrt{I^2_{res.}-I^2}}{I^2_{res.}}$$

as abscissa. A straight line should result, having a slope proportional to the log. dec. of the circuit. A valuable check is thereby obtained upon the accuracy of the measurements.

The chapter on capacity first describes various methods of measurement at low or telephonic frequencies. This is quite legitimate in a book on radio-frequency measurements since the foundations of capacity have to be laid in low or telephonic-frequency measurements using good air condensers to step up to radio frequencies. In this connection it is noted that the Carey Foster and the Schering bridges are not mentioned although these two are probably superior to all the others.

In connection with the radio-frequency tests a method, using mutual inductance, is described for measuring losses in a condenser, but it does not appear that the method has ever given satisfactory results. The fact that the mutual inductance must be equal to the self inductance in the oscillatory circuit requires a self inductance in the secondary circuit which is considerably greater than that in the primary. The self capacity of the secondary and losses associated therewith, will entirely invalidate the measurements when these are required to give the losses in an air condenser of good quality.

The presence of two coils each in the magnetic field of the other, such as must occur in any mutual inductance, will necessarily involve what may be termed a mutual resistance common to the two windings. It is very difficult to measure this resistance and it may have a value many times that under measurement, in the case of a good air condenser.

The measurement of dielectric losses has been dismissed in a short paragraph ; the subject is, however, one of considerable importance and merits a much fuller discussion.

The chapter on inductance is good, in particular the section dealing with the measurement of coil resistance and the theoretical excerpts from Butterworth's classical papers are noteworthy. It is noted that in the discussion of the separation of the self-capacity and effective geometrical inductance it is stated that the curve connecting λ^2 with " added capacity " is an accurate straight line. This, however, is only true if the wire of the coil is of such small cross section that the effect of eddy currents on the true inductance is negligible. It will be found with solid wire coils that the line has a curvature in a direction showing smaller inductance at smaller values of λ^2. In such a case the self-capacity cannot be defined from the experimental results. In those cases in which straight lines are obtained very accurate results may be obtained by the use of the formulæ of Hulbert and Breit, making use of the principle of least squares. The immersion method of measuring coil capacity has obvious limitations since it is often undesirable or impossible to immerse coils.

The chapter on antennæ is exceptionally clear and well written. The author has not shirked the difficulties of accurate conception of the true inductance, capacity and resistance of an antenna. The difficulty of visualising the birth of the waves has also been admitted.

With regard to actual analysis of the constants of antennæ the " tuning " of the antenna to certain wavelengths is, of course, frequently referred to. The precise meaning of this has not been defined and it would seem desirable that a clear statement should be made as to what is brought to a maximum under the influence of a constant impressed electromotive force. It is not clear that the second method (7) for determining the effective inductance and capacity of an aerial is superior to the direct method of plotting the line connecting λ^2 with added inductance ; it is virtually equivalent to obtaining two points on a line instead of a number of points.

Chapter VIII. is partly an extension of Chapter VII. The difficult subject of effective height of an antenna is dealt with shortly. The measurement of the electric field intensity occupies the next section of the chapter. In this specialised subject the relative values of the various methods used must be largely a matter of opinion and of the capabilities of the various workers in this subject. One important advantage of the use of coil reception systems over antenna methods for the measurement of field intensity is the possibility of measuring the components of the field in various azimuths and also of measuring the downcoming wave. Another advantage of loop or coil systems is that their constants are much more easily measured and are less variable than those of an antenna. Against the much smaller induced electromotive force in the coil may be offset the lower effective resistance in most cases.

In the section dealing with the production of known small electromotive forces for calibrating purposes in connection with field intensity measurement, the use of current transformers as developed by the reviewer has not been mentioned. This method answers nearly all the difficulties associated with such measurements, except at very high radio frequencies. The current transformer is a form of mutual inductance which is nearly ideal.

The final chapter deals with miscellaneous measurements and notes ; these are necessarily somewhat disjointed as they fall outside the general plan of classification of the book. The chapter includes notes on the following subjects: Measurement of harmonics, amplification of amplifiers, equations of a transformer, rectification with a heterodyne, analysis of resonance built up by impulses (multivibrator for example), and finally the resonance frequency of compound circuits. Obviously these matters can only be dealt with sketchily in the twenty pages forming this chapter.

Taken altogether the book may be said to be very readable and all the matter contained in it is interesting. The choice of matter for such a book is one of considerable difficulty, and in this book it is too much to expect that it will meet with universal approval, since many will desire a more detailed description of the procedure in carrying out measurements and in the choice and set up of apparatus which is required, than will be found in the book.

The book is very free from errors, the only errors noted are of small importance: on p. 5, A should be a, and on p. 165 the expression on line 7, $h=E \sin pt$, should be $h=H \sin pt$. D. DYE.

DAS ELEKTRISCHE FERNSCHEN UND DAS TELEHÖR (Television). By Dénes von Mihály. Pp. 196, with 112 Figs. M. Krayn, Berlin.

This is the second enlarged edition of a book first published in 1923. Since 1923 the subject of Television has been worked at with considerable success, especially in this country by Baird, whose success has centred attention on the subject. Mihály of Budapest has devoted much attention to the subject, and in this book goes into the matter very fully. After stating the problem and pointing out the difficulties, he gives a historical review of the methods which have been suggested and tried, including some of his own. A short section towards the end is devoted to the transmission of pictures and writing, a very different proposition but one which has many points in common with Television.
G.W.O.H.

LES FILTRES ELECTRIQUES: Theory, Construction, Applications. By Pierre David, with a Preface by Général Ferrié. Pp. 130, with 76 Figs. Gauthier-Villars, Paris. 25 fr.

Electric filters are combinations of circuits allowing complex currents to be analysed according to their frequency, those of desired frequencies being allowed to pass, those of undesired frequencies being cut out. A great amount of research has been done on this subject in recent years, especially in America. The present book recapitulates and presents this work in a complete homogeneous form; in addition to the theory it gives practical rules for the construction of filters to meet given specifications, together with tables and curves. Practical examples are given showing how nearly experimental results agree with the calculations.

The book concludes with a very useful classified bibliography giving 67 references. G.W.O.H.

DER BAU VON WIDERSTANDS-VERSTÄRKERN (Construction of Resistance-coupled Amplifiers). By Manfred von Ardenne. Pp. 142 with 85 Figs. R. C. Schmidt & Co., Berlin. 3.60 marks.

No one has devoted more attention to the possibilities and limitations of resistance-coupled amplifiers than von Ardenne. His work is well known, especially that in conjunction with Dr. Loewe—who has written a foreword to this book—whereby they have developed the multiple valve with the components of three valves and the coupling resistances and condensers all assembled in a single bulb not much larger than an ordinary valve. This second edition of von Ardenne's book deals very fully with the theory and design of resistance-coupled amplifiers, every point is discussed and very fully and clearly illustrated by means of practical examples. We do not agree with every statement made, but we unreservedly recommend the book to all those interested in the subject, who have the necessary knowledge of German.

G.W.O.H.

ALTERNATING CURRENT RECTIFICATION. By L. B. W. Jolley, M.A. Pp. xxii. + 472, with 340 Figs. Messrs. Chapman & Hall. 30s.

The first edition of this book was published in 1924 and that a second edition is called for so soon indicates the widespread interest in this subject. The book is divided into seven parts, of which the first is purely mathematical; succeeding parts deal with mechanical rectifiers, gaseous rectifiers, electrolytic rectifiers, wireless rectifiers, inverters, applications of rectification to measurements, etc. The impression gained from a perusal of the book is that the author is a mathematician rather than an electrical engineer. When he is dealing with the mathematical analysis of any process of rectification he is on safe ground but his descriptions of the mode of operation are sometimes anything but convincing. As an example we would give the description of the motor-convertor on page 80 with such statements as "the driving unit is an induction motor which is quite separate from the convertor," a mis-statement which is somewhat supported by the very misleading diagrammatic sketch on page 81. Another example occurs on the following page, where a diagram is supposed to represent a two-part commutator; unfortunately the draughtsman appears to have made a mistake in putting brushes where there should have been fixed connections, but even more unfortunately the author has followed the draughtsman in his description of the operation of the commutator and thus leaves the production of unidirectional current by this simplest of all devices a profound mystery. We regret that the author did not confine himself to the mathematics of rectification and leave these more practical matters to a suitable collaborator.

G.W.O.H.

H.T. and L.T. from a 250-volt D.C. Supply.

By A. Robertson.

MANY systems for utilising the electric light mains for anode current supply in wireless receivers have been described recently in the Press.

Few of these have embodied satisfactory smoothing arrangements, and would therefore be incapable of dealing with town main current in which a commutator ripple was present.

The arrangements about to be described have all been tried out and proved successful on a 250-volt D.C. supply, obtained from 25-cycle, 6-phase rotary convertors.

This supply required a considerable amount of smoothing out in order to get rid of the hum from the converting plant in the sub-station.

The smoothing was not deemed satisfactory until it became impossible to tell, by listening on the headphones, whether the set was running from a battery or from the town main supply.

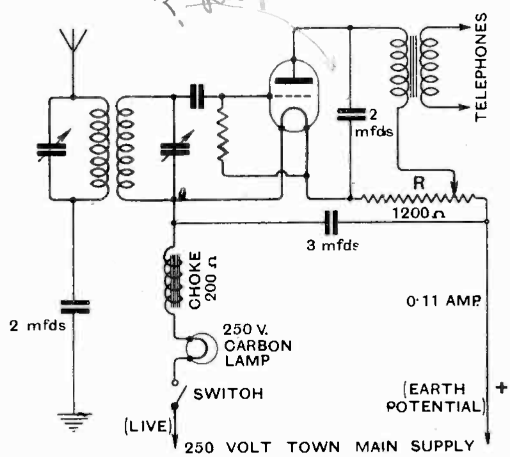


Fig. 1.

All the tests were made on a supply taken from the "negative" side of a 3-wire D.C. system.

Fig. 1 shows a simple one-valve receiver in which both the L.T. and H.T. supplies are taken from the electric light mains.

As this supply is taken from the "negative" side of a 3-wire D.C. system, the + terminal is at earth potential and the — terminal 250 volts below earth. The earth lead should therefore be connected to the receiver through a condenser capable of withstanding

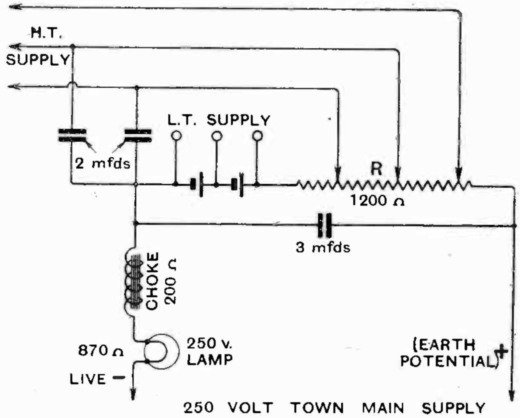


Fig. 2.

the full town main voltage. It was experimentally determined that the best position for the choke coil was at the "live" town main terminal. Results obtained from choke coils connected at "earthed" town main terminal and also in anode circuit, did not justify their inclusion in the circuit. A $3\mu F$ condenser was connected between the receiver side of choke coil and + town main terminal, to by-pass any ripple which succeeded in passing through the choke coil. The condensers in anode circuit function as reservoirs and contribute little or nothing towards smoothing of ripple.

A choke coil connected in the wrong place may defeat its object. For example: a choke coil inserted between the + L.T. battery terminal and resistance *R* (Fig. 2) will cause the hum to reappear. This result, though not unexpected, indicates that the resistance *R* should be of a non-inductive type.

This resistance consists of a bank of twelve low voltage carbon lamps having a total resistance of about 1,200 ohms. The resistance of the choke coil is 200 ohms, making the total resistance of circuit connected to town mains about 2,270 ohms, which allows a current of .11 amp to be drawn from supply. This represents 27.5 watts and costs one penny per week of 36 hours, with electricity at one penny per unit. Provision was made for obtaining the requisite H.T. voltages for each valve by taking a tapping from each lamp, in resistance *R*, to a wander plug socket. A voltage range up to 130 volts was thus available in twelve steps of approximately 11 volts each.

Carbon lamps were used in preference to a wire wound resistance in order to prevent the sudden rush of current through valve filament, which would otherwise occur when set is switched on.

The space occupied by the resistance, chokes and condensers is less than that required for a H.T. battery for a similar voltage.

A two-valve (H.F. and Det.) receiver with both valves in parallel, was run entirely from town main supply and proved entirely satisfactory whether receiving local or Continental stations.

Fig. 2 shows an arrangement which the writer has used for some time in connection with a three-valve receiver. The L.T. battery has been retained in this case for reasons of flexibility, as valves having very different filament requirements are used on this set.

The L.T. battery is connected in series with the resistance *R* in the town main supply circuit. It consists of a 6-volt alkaline accumulator divided into two units of 3 volts each, fitted with sockets, so that the filament circuit can be connected to either unit by means of a two-pin plug. This plug is changed over on alternate weeks, an arrangement which permits one unit to be charged up while the set is in operation, while the other unit either remains floating or slightly discharging, according to filament requirements.

Experience proved that the current of .11 amp. taken from town mains, while receiver was in operation, was sufficient to maintain the L.T. battery without any additional charge.

The present installation has been in use for nearly a year, during which period the battery has required no attention, apart from an occasional "topping up" with water. There has been no failure of any kind since it was put into operation.

There is little or no risk of damaging valve filaments through accidental contact with H.T. supply, as the current from this supply is limited to .11 amp which is not sufficient to do any harm.

Telephone transformers provide adequate protection against shock. The writer has employed and obtained excellent results from a type of transformer which, so far as he is aware, is quite new. Its operation can best be explained by the following experiment. A small power valve is connected up as shown in Fig. 3, an ammeter is connected to the + and — filament terminals and also in the anode circuit.

With a filament current of, say, .11 amp and the H.T. wander plug disconnected from battery, both filament ammeters will read alike (*i.e.*, .11 amp each).

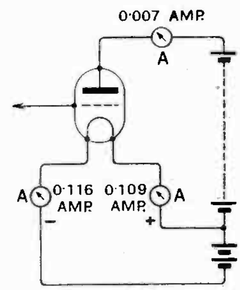


Fig. 3.

When the H.T. wander plug is connected to a suitable supply and a current of, say, .007 amp taken by anode, the two ammeters in filament circuit no longer show a like reading. The + ammeter reading will now have decreased by about .001 amp and the negative ammeter increased by about .006 amp. (With the L.T. battery reversed these readings would become .002 and .005 respectively.) A perceptible diminution in the light from valve filament would be noticed when anode current was switched on.

As a result of the above experiment, the writer obtained a three-winding transformer having a resistance of 25 ohms per winding, and connected up in the filament circuit in such a manner that the filament current passed up one leg of transformer and returned through the other leg in a direction such as to neutralise the magnetic flux due to the steady filament current (Fig. 4).

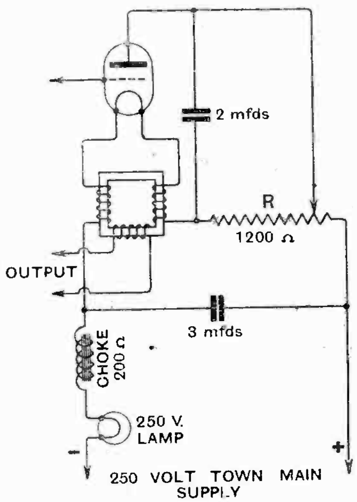


Fig. 4.

A variation in the anode current due to reception of wireless signals caused a reduction of flux in one leg of transformer and an increase in the other leg. A voltage was thus induced in the third winding which could either be used as a telephone transformer or an intervalve transformer or, if desired, the third winding could be connected between grid and filament of its own valve, in which case a very effective L.F. oscillator would be obtained.

The extra resistance which such a transformer introduced into filament circuit proved to be of no disadvantage when used in conjunction with the town main L.T. supply.

The data given are suitable for a three-valve receiver with the following average running conditions :—

About 4 hours per night with 2 valves on local station.

About 1 hour per night with 3 valves on distant station.

And an occasional whole evening's programme with 3 valves on distant station.

It is assumed that loud-speaker reception is desired in each case and that the valves used are as follows :—

One power valve taking .12 amp, together with detector and H.F. valves taking .06 amp each.

If all three valves are of the .06 amp type, the battery will be overcharged as the input to batteries would always be in excess of the output whether all three valves were always in operation or not.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPAGADO DE ONDOJ.

Amatora Long-Distanca Laborado.—H. N. Ryan.

La perioda kontribuaĵo pri ĉi tiu temo pritraktas lastatempajn rezultojn ĉe malfortaj sendiloj.

PROPRECOJ DE CIRKVITOJ.

Kvarcaj Kristaloj kaj Ilia Praktika Aplikado al Senfadenaj Cirkvitoj.—Prelego legita antaŭ la Radio-Societo de Granda Britujo, je 24a Novembro, 1926a, de S-ro. A. Hinderlich, M.A.

Post mallonga historia enkonduko, la proprecoj de kvarcaj kristaloj estas diskutitaj kaj detaloj donitaj pri la manipulado, muntado, k.t.p. La uzado de la kristalo kiel resonatoro kaj oscilatoro estas poste priskribita, kun ilustraĵoj de diversaj konektaj aranĝoj por la lasta celo.

Sekvas rimarkigoj pri funkciado kaj provado de la kristaloj, kaj sekcioj pri elementaj kaj altgradaj aplikoj, enhavante la uzadon de kvarcaj oscilatoroj kiel frekvencaj normoj, sendila kontrolado, k.t.p.

La diskutado, kiu sekvis la legadon de la prelego, estas ankaŭ presita.

La Desegnado de Alternkurentaj Ondformoj.—H. A. Thomas.

Enkonduka Sekcio pritraktas la neceson por kono pri enmetaj-elmetaj ondformoj de amplifikatora aŭ sendila sistemo. Por frekvencoj ĝis ĉirkaŭ 300 cikloj estas priskribita kaj ilustrita la uzado de Einthoven'a Galvanometro, kune kun rapidega fotografilo (Tipo de *Bureau of Standards* Usona Oficejo de Normoj), kaj tipaj fotografaĵoj montritaj. Por plialtaj frekvencoj, la uzado de Katod-Radia Oscilografo (Tipo de *Western Electric*) estas priskribita kaj ilustrita. La uzo de la ekscitiga fonto por provizi tempan skalon al la oscilografo estas unue montrita. La metodo por interpreti la rezultantan Lissajous'an figuron estas diskutita. Linia tipo de tempo-bazo, ŝuldata al Appleton, Watt, kaj Herd, estas poste priskribita kaj la speco de figuraĵo obtenita estas montrita. La tuta ekipaĵo uzanta ĉi tiun bazon estas tiam priskribita kaj ilustrita fotografe.

SENDADO.

Kelkaj Notoj pri Desegnaj Detaloj de Altpotenca Radio-Telegrafa Sendilo Uzanta Termionajn Valvojn.—Resumo de Prelego legita de D-ro. R. V. Hansford kaj S-ro. H. Faulkner, B.Sc., antaŭ la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj, Londono, je la Decembro, 1926a.

La prelego pritraktas diversajn difinitajn punktojn pri desegnado, precipe de la Rugby'a Stacio. Oni dividis la temon je 6 sekcioj :—

I. Plej taŭga antena cirkvito laŭ vidpunkto de elimino de harmonikoj ;

II. La desegno de la elektraj proporcioj de la antena cirkvito ;

III. La induktancaj bobenoj por la antena cirkvito ;

IV. Kelkaj notoj pri desegnado de valvaj cirkvitoj, kaj la kondiĉoj de valva funkciado ;

V. Klavado kaj formo de signaloj ;

VI. Lastatempaj rezultoj ĉe Rugby.

Presita ankaŭ estas raporto pri la diskutado, kiu sekvis la legadon de la prelego.

Telefon-Sendila Modulado Mezurita ĉe la Riceva Stacio.—L. B. Turner.

La metodo priskribita estas simpla metodo, facile aplikebla al ekzistantaj riceviloj, kaj ne postulas konon pri la valvaj konstantoj. En la okazo pritraktita, la metodo estas aplikita al krada rektifikatoro sekvanta unu ŝtupon de altfrekvenca amplifado. La metodo konsistas je la momenta mezuro, pere de Moullin-tipa termiona voltmetro, de la voltkvanto transe de la malaltfrekvenca ŝokbobeno dum iu elektita brodkasta programero. La modulo tiam ekzistanta estas esprimita per terminoj de konataj rezistancoj enmetitaj en la anodan cirkviton. La aparato kaj procedo estas priskribitaj, kaj la derivo de la formulo sekvita, kaj ekzemploj de mezurado estas donitaj, montrantaj modulajn proporciojn variantajn de 15 ĝis 61 procento.

En redaktora artikolo oni faras kritikon pri la formulo derivita kaj sugestas plisimplan formulon, kun tabela komparo de la modula proporcio, kalkulita per la du formuloj.

RICEVADO.

Kvin-Valva Ricevilo Kun 2 Altfrekvencaj Ŝtupoj por 900-3,000 Metroj. —W. James.

La aparato priskribita uzas agorditan enmeton, du ŝtupojn de altfrekvenca amplifado, detektoron, kaj 2 malaltfrekvencajn ŝtupojn. La altfrekvencaj ŝtupoj estas kuplitaj transformatore, kun la sekundarioj agorditaj. Oni diskutas la elekton de la valvoj, altfrekvencan kuplon, kaj atingon de stabileco. La konstruo de la altfrekvenca transformatoro estas priskribita, kaj la altfrekvencaj kaj malaltfrekvencaj amplifikatoraj sekcioj diskutitaj detale. Dimensia aranĝo kaj la fina aspekto estas ilustritaj, kaj fina sekcio priskribas la funkciigon de l'aparato.

DIVERSAĴOJ.

Resumoj kaj Aludoj.

Kompilita de la *Radio Research Board* (Radio-Esplorada Komitato) kaj publikigita laŭ aranĝo kun la Brita Registara Fako de Scienca kaj Industria Esplorado.

Venontaj Lekcioj.

Oni anoncas ke serio de ses lekcioj pri " Mallongaj Elektraj Ondoj traktitaj Eksperimente," de S-ro. J. H. Morrell, M.A., estos donita ĉe la Orienta Londona Kolegio, Mile End Road, Londono, E., je 6a horo p.t.m., je lundo, 7a Februaro, kaj sekvantaj lundoj.

Matematiko por Senfadenaj Amatoroj.—F. M. Colebrook.

La serio estas daŭrigita el antaŭaj numeroj. La nuna parto traktas pri solvo de ekvacioj kaj kompleksaj numeroj, montrante la signifon de simbolo " i," la adicion, la multiplikon, k.t.p. de kompleksaj numeroj, kaj la apliko al la ĝenerala ekvacio de la *n*a grado.

Abstracts and References.

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

PROPAGATION OF WAVES.

ON WIRELESS INTERFERENCE PHENOMENA BETWEEN GROUND WAVES AND WAVES DEVIATED BY THE UPPER ATMOSPHERE.—E. V. Appleton and M. Barnett. (*Proc. Royal Society*, 113, A764, pp. 450-458.)

A paper dealing with the problem of the cause of the natural succession of interference effects, which constitutes fading at moderate distances and takes place continuously throughout the night-time, summarised as follows :—

1. Photographic records of interference "fringes" with waves of 350 to 400 metres have been obtained. Such interference is produced between waves travelling along the ground and those deviated by the ionised layer in the upper atmosphere. From the records the relative magnitudes of the effects of the atmospheric and ground waves and the resolving power of the equivalent optical system can be simply deduced.

2. The variations in resolving power throughout the night and daybreak periods have been studied and interpreted in terms of the variations of the equivalent height of the layer. The observations show that the equivalent height gradually increases throughout the night, but that about half an hour before sunrise its value falls rapidly. At about the same time the secondary maxima and minima on the main interference fringes disappear. As the morning proceeds, the atmospheric ray is gradually reduced in intensity and finally vanishes.

ÜBER DIE IONISATION DER ATMOSPHÄRE UND IHREN EINFLUSS AUF DIE AUSBREITUNG DER KURZEN ELEKTRISCHEN WELLEN DER DRAHTLOSEN TELEGRAPHIE (On the ionisation of the atmosphere and its influence on the propagation of the short electric waves of wireless telegraphy).—H. Lassen. (*Zeitschr. f. Hochfrequenz*, 28, 4, October, 1926, pp. 109-113; 28, 5, November, 1926, pp. 139-147.)

On the foundation of our present-day knowledge of the composition of the upper layers of the atmosphere and the ionisation of gases by ultra-violet light, attempt is made to describe the state of ionisation of the atmosphere, in so far as it is of significance for the propagation of the short waves of wireless telegraphy (less than 100 m.). A layer where ionisation is particularly marked is found to exist between 95 and 130 kilometres. This layer has no sharp boundary in the downwards direction—within the layer ionisation upwards at first increases and then decreases again. The propagation of short waves to great distances takes place for the most part in this layer, the effect of the ionic content expressing itself by a refraction of the wave, there being no substantial reflection. Damping is small. The ionised layer also remains in existence through the night, owing to the great rarefaction of the atmosphere at those altitudes, but the ionic concentration fluctuates with the twenty-four hours, accounting for the differences between day and night transmission. The remaining phenomena of short-wave transmission, skip distance, fading, etc., are also explained.

Further elucidation of the state of ionisation of the upper layers of the atmosphere is to be expected principally from practical measurements with waves of a few hundred metres (broadcast length), where it must be admitted, the relations are no longer quite so simple from the physical standpoint as with short waves.

LA LUNE INFLUENCE-T-ELLE LES TRANSMISSIONS RADIOÉLECTRIQUES ? (Does the moon affect radio transmission ?).—P. Vincent. (*L'Onde Electrique*, 5, 58, October, 1926, pp. 544-547.)

The author confirms the fact, that the movements and phases of the moon are not entirely unconnected with the variations in intensity of radio reception, from an examination of the graphs of the field produced at Meudon by the station Lafayette He finds that maximum intensity mostly occurs on days immediately following new phases of the moon, and seldom during the two or three days that precede them.

No attempt is made to discuss the different theories that might be put forward to explain this, *e.g.*, a disturbing influence of the moon on solar radiation ; or a direct influence of radiation emitted by the moon or reflected from it ; or an effect connected with the tides, themselves linked up with the movements of the moon.

COMMUNICATION TEST ON SHORT WAVES ACROSS THE PACIFIC.—T. Nakagami and T. Kawahara. (*Journ. Inst. Elect. Engineers Japan*, 460, November, 1926, pp. 1251-1264.)

The tests were made last spring between stations in Japan working on 21.5, 40.5, 43 and 115 metres respectively, and a ship travelling between Yokohama and San Francisco carrying a 500-watt transmitter working on 30 metres. The results showed :—

1. That a 40.5 m. wave may be used fairly satisfactorily for the whole range up to 8,400 km. at night.

2. That a 21.5 m. wave is much better than 40.5 for daytime transmission.

3. Skip distance phenomena are well exhibited by the audibility curves, and

(*a*) the shorter the wave the greater the skip distance ;

(*b*) the shorter wave skips farther at night than by day.

4. For a certain distance there is one wave that gives the same signal strength both by night and

by day. From the curves one obtains 21.5 m. for 3,100 km., 30 m. for 1,500 km., and 40.5 m. for 520 km. These data yield a curve showing the relation between distance and wavelength and thus the right wavelength to choose for a given distance—at this season of the year: in summer this wave would be shorter and in winter longer.

ELECTRIC WAVES AND THEIR PROPAGATION.—E. Rutherford. (*Nature*, 118, 4th December, 1926, pp. 809-811.)

Extract from the anniversary address delivered before the Royal Society on 30th November: a survey of the progress of our knowledge of the subject.

DIE WISSENSCHAFTLICHEN PROBLEME DES RUNDFUNKS (Scientific problems of broadcasting). —K. Wagner. (*Teleg. u. Fernspr. Techn.*, 15, pp. 76-78.)

Three principal problems are said to be awaiting solution: the determination of the laws of propagation of electromagnetic waves of different lengths, the measurement of atmospheric disturbances and their variation with place and time, and the investigation of the fluctuations of received signal strength.

INTEGRALS OF THE EQUATIONS OF ELECTRODYNAMICS, WITH AN APPLICATION TO THE ELECTRIC CONSTANTS OF A TRANSPARENT MEDIUM.—H. M. Macdonald. (*Proc. Royal Society*, 113, A764, pp. 237-253.)

EINIGE FOLGERUNGEN AUS DEN FELDGLEICHUNGEN DES SCHWINGENDEN DIPOLS (Some consequences of the field equations of the oscillating dipole).—F. Pollaczck. (*Elek. Nachr. Technik*, 3, 11, pp. 433-438.)

A mathematical discussion.

ELEKTROMAGNETISCHE SCHWINGUNGEN UND WELLEN IN FARADAYSCHER BETRACHTUNGSWEISE (Electromagnetic oscillations and waves from Faraday's view-point).—F. Kiebitz. (*Telefunken Zeitung*, 8, 43, October, 1926, pp. 19-24.)

A discussion of the phenomena on which wireless telegraphy is based showing that a representation of the phenomena in the dielectric can have advantages. The radiation of electromagnetic forces, electric oscillations and their damping are described without employing the notions of current, tension or resistance, whereby the way to the analytic treatment of these phenomena follows directly from Maxwell's laws. The propagation of electromagnetic waves appears as a most simple natural phenomenon. The oscillation in a conductor is represented as a disturbed electrodynamic phenomenon, the radiation being an imperfection of this disturbance. The damping in an oscillatory circuit is described by means of time values that are easily pictured.

MAGNETIC STORMS AND WIRELESS COMMUNICATION. —T. L. Eckersley. (*Nature*, 118, 4th December, 1926, pp. 803-804.)

In *Nature* of 6th November, p. 662, Sir Joseph Larmor suggests that the attenuation of the Canadian beam signals during magnetic storms is due to an incursion of electrons twisting the ray-paths out of regularity. Mr. T. L. Eckersley here states that the explanation that appeals to him is that ionic refraction is not the only factor determining long distance short-wave transmission, but that there is also the effect of energy absorption by collisions of electrons with molecules. The fact that the range of a station in summer and in low latitudes is less than that in winter and high altitudes, is part of a considerable body of evidence that absorption plays an important part in long distance short-wave transmission. It is shown why on theoretical grounds absorption would be expected to have an appreciable effect in transmission over distances greater than about 1,000 km.

At short distances the effect of increased bending, due to increased ionic density, is most apparent. The strength of local stations received in England was considerably augmented at times during the magnetic disturbances.

ATMOSPHERICS.

GLEICHZEITIGE LUFTSTÖRUNGEN IN DER DRAHTLOSEN TELEGRAPHIE (Simultaneous atmospherics in wireless telegraphy).—M. Bäumler. (*Elek. Nachr. Technik*, 3, 11, pp. 429-433.)

The author has already shown (*Jahrb. drahtl. Tel.*, 19, 2; 20, 6; 23, 1) that the range of atmospherics can be very great, disturbances having been simultaneously recorded at stations as far apart as Berlin and Rocky Point, 6,400 km. from one another. In this paper he describes his continued investigation of the subject with the co-operation of the Radio Corporation of America, employing the receiving stations at Koko Head (Oahu, Hawaii) and Marshall (California). A large number of corresponding disturbances were recorded at these stations, which are 3,900 km. apart, and isolated disturbances were found to occur simultaneously at distances of 10,000 to 12,000 km. The author applies the general propagation phenomena of electromagnetic waves to the propagation of atmospherics to explain the frequency of the occurrence of simultaneous disturbances, *i.e.*, atmospherics would be expected to travel better by night than by day, over sea than over land, and also to be considerably attenuated on passing from darkness to daylight or *vice versa*. The close correspondence between the atmospherics recorded at Koko Head and Marshall is attributed to both stations being in darkness at the time of the tests.

Specimens of recording strips at Koko Head, Marshall and Berlin are reproduced, showing the simultaneous occurrence of atmospherics at these places.

The causes of the disturbances are considered to be changes in the state of the electric field of the atmosphere or of the magnetic field of the earth, rearrangements in the earth's interior or phenomena of electrical equilibrium in the cosmos. Lightning discharges belong to changes in the state of the earth's electric field and the intense discharges in the tropics are regarded as a principal source of atmospherics.

LES PERTURBATIONS ORAGEUSES DU CHAMP ELECTRIQUE ET LEUR PROPAGATION À GRANDE DISTANCE.—P. Lejay. (*L'Onde Electrique*, 5, 59, November, 1926, pp. 557-576.)

The last three chapters of a paper read before the S.A.T.S.F., summarised in the preceding issue of these abstracts (*E.W. & W.E.*, p. 50, January, 1927).

PROPERTIES OF CIRCUITS.

OPERATION OF THERMIONIC VACUUM-TUBE CIRCUITS.—F. Llewellyn. (*Reprint B-*208, Bell Telephone Laboratories, Inc.)

General exact equations are derived for the output current when the valve is connected in circuits of any impedance and excited by any variable voltage. The method of derivation is illustrated in the special case where resistances only are considered, and the adaptation of complex impedance to use in non-linear equations is shown. Approximations that are allowable in various practical applications are indicated, and the equations are applied in some detail to grid-leak detectors, and in brief to other types of detectors, modulators, amplifiers and oscillators.

LES ANTENNES-FILTRES.—J. Plebauski. (*L'Onde Electrique*, 5, 58, October, 1926, pp. 532-544.)

It is shown that several antennæ can be combined by mutual coupling so that their energies add together for certain frequencies and subtract for others. They thus behave like the elements of a filter and furnish resonance curves that are almost rectangular with high efficiencies.

ÜBER DIE VERSTÄRKUNG VON IM HÖRBEREICH LIEGENDEN SCHWINGUNGEN MIT WIDERSTANDSVERSTÄRKERN (On the amplification of oscillations in the audible range with resistance amplifiers). — A. Forstmann. (*Zeitschr. f. Hochfrequenz*, 28, 5, pp. 156-161.)

Deduction and discussion of the relations for an amplifier with resistance capacity coupling whose distortion in a prescribed range of audible frequency does not exceed a given amount.

TRANSMISSION.

SOME NOTES ON DESIGN DETAILS OF A HIGH POWER RADIO TELEGRAPHIC TRANSMITTER USING THERMIONIC VALVES.—R. Hansford and H. Faulkner. (*E.W. & W.E.*, January, 1926, pp. 42-48.)

Abstract of a Paper read before the Wireless Section of the Institution of Electrical Engineers, on 1st December, 1926.

QUARTZ CRYSTALS AND THEIR PRACTICAL APPLICATION TO WIRELESS CIRCUITS.—A. Hinderlich. (*E.W. & W.E.*, January, 1927, pp. 29-41.)

A Paper read before the Radio Society of Great Britain, 24th November, 1926.

The phenomena of piezo-electric quartz are considered with special reference to radio transmitting stations.

ROHRENSENDER-SCHALTUNGEN, INSBESONDERE FÜR KURZE WELLEN (Valve transmitter circuit arrangements, especially for short waves).—W. Kummerer. (*Elek. Nachr. Technik*, 3, 11, pp. 408-414.)

A lecture given at the Düsseldorf meeting last September, dealing with the reaction that occurs between principal and modulating circuits in the case of externally modulated valve transmitters, and discussing various methods for eliminating it.

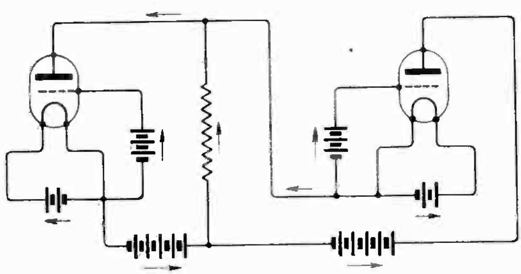
UN PROCÉDÉ SIMPLE DE MODULATION (A simple method of modulation).—G. Veyre. (*L'Onde Electrique*, 5, 58, October, 1926, pp. 547-553.)

A new method of modulation is given in which the oscillator and modulator have their plates in parallel, as in the continuous current system, but dispensing with the choke coil of that system by altering the connection of the two plates. The author describes the modulation as excellent and economical and gives some particulars of his station at Casablanca with the results obtained.

RECEPTION.

ALIMENTATION DES RÉCEPTEURS RADIOTÉLÉPHONIQUES PAR COURANT ALTERNATIF (Supplying radio-telephone receivers with alternating current).—H Niogret. (*L'Onde Electrique*, 5, 59, November, 1926, pp. 602-610.)

The special circuit arrangement considered consists essentially of two triodes with the spaces between filament and plate placed in series as shown in the figure below



This combination can be substituted for the triode in all its ordinary applications. It allows the employment of H.T. generators with varying voltage and, in certain cases, filament supply with alternating current.

COMPARISON DE LA DÉTECTION PAR LAMPE ET PAR GALÈNE (Comparison between valve and crystal detection).—Bertrand, Cayrel and Masselin. (*L'Onde Electrique*, 5, 59, November, 1926, pp. 593-601.)

The sensitivity of the valve is found to be very superior to that of galena for loud reception, appreciably superior for normal reception and practically equal for reception corresponding to the limit of audibility. The valve offers the further advantage of being able to supply several headpieces connected in parallel without perceptible reduction of the sound strength. This double superiority of the valve is explained.

DISTORTION IN BROADCAST RECEIVERS. (*Electrical Review*, 24th December, 1926, pp. 1049-1050.)

Abstract of a paper read by Mr. J. A. Cooper before the Wireless Section of the South-Midland Centre of the Institution of Electrical Engineers on 6th December.

A FLOATING BEAT NOTE.—F. Anderson. (*Q.S.T.*, 10, 12, December, 1926, p. 18.

A circuit arrangement is given providing an automatic frequency change for superheterodynes, doing away at the same time with the troublesome double beat.

DEVISING A SHIELDED RECEIVER KIT.—M. Silver and K. Clough. (*Q.S.T.*, 10, 12, December, 1926, pp. 27-31.)

STATIONS : DESIGN AND OPERATION.

HAUPTFUNKSTELLE FÜR UNGARN IN SZÉKESFEHÉRVAR (High power station for Hungary at Stuhlweissenburg.) (*Telefunken Zeitung*, 8, pp. 57-63.)

Illustrated description of this station, about 60 km. to the south of Budapest, the transmitting equipment including an alternator of 50kW antenna output and a 10kW externally modulated valve oscillator. Reception takes place at Tarnok, about 20 km. from Budapest—where the central office is situated. Stations principally communicated with are Berlin, Paris, Pisa, Northolt, Cracow, Sofia, Barcelona and Fiume.

AERIALS AND RECEIVING APPARATUS AT THE NEW ST. ALBANS STATION.—L. Jones. (*Wireless World*, 8th December, 1926, pp. 761-764.)

DIRECTIONAL WIRELESS.

THE CHARACTERISTICS OF BEAM TRANSMITTING AERIALS.—J. Catterson-Smith. (*Journal of the Indian Institute of Science*, 9B, 2, pp. 9-19.)

The phases of the components of the radiated field of multiple aerial systems are considered and polar distribution diagrams plotted. The production of a single beam with minor secondary rays is dealt with by means of examples. Cylindrical parabolic and plane reflectors of the double grid type are contrasted and methods are considered of reducing dispersion in both vertical and horizontal planes.

STATIONARY AND ROTATING EQUISIGNAL BEACON. —W. Murphy and L. Wolfe. (*Soc. Auto. Engrs. Journal*, September, 1926, pp. 209-220.)

The equisignal method of airplane signalling consists in receiving signals, sent out by one or more transmitting stations, alternately on two loops, the planes of which differ by a certain angle. If the signals obtained on the two loops are equal in intensity, the bisector of the angle between the loops will correspond to the line of wave propagation.

In the development of the apparatus described in this paper use is made of the Bellini-Tosi antenna system and Kiebitz's idea of employing two directional antennæ, the planes, and therefore the directional effects, of which differ from one another by a certain angle and sending out the letter *n* (- .) in Morse code on one antenna and the letter *a* (. -) on the other (*Jahrb. drahtl. Tel.*, 15, 1920, p. 299). The paper shows how these two systems are combined to produce either rotating equisignals or fixed equisignals in any desired direction and is illustrated with charts, diagrams and photographs. Two practical examples of flights are given.

PROCÉDÉ ET APPAREIL POUR CALCULER RAPIDEMENT LE POINT EN RADIOGONIOMÉTRIE.—C. Ledoux. (*Comptes Rendus*, 183, 22, 29th November, 1926, pp. 1029-1030.)

On account of the small space, vibration, and quickness required, direction-finding in an aeroplane debars in practice methods with large maps, geometrical instructions, cumbersome abaci or numerical calculations. An instrument dispensing with these is described, giving results sufficiently accurate for aerial navigation.

RADIOGONIOMÈTRES ET RADIOPHARES À MAXIMUM ACCENTUÉ. — L. Bouthillon. (*Comptes Rendus*, 183, 21, 22nd November, 1926, pp. 955-957.)

A mathematical examination of the radiogoniometer problem considered identical with that of the rotating radio beacon.

NOTE SUR LE CALCUL DE LA COURBE DE DÉVIATION D'UN RADIOGONIOMÈTRE DE BORD SUR LES NAVIRES DE COMMERCE (Note on the calculation of the error curve of a radiogoniometer on mercantile ships). — M. Gouinet. (*L'Onde Electrique*, 5, 58, October, 1926, pp. 553-555.)

The author points out a small correction to be made in Mesny's formula for it to apply better to the radiogoniometer on large modern packet-boats.

VALVE DESIGN AND THERMIONICS.

ÜBER DIE VERWENDUNG DER ELEKTRONENRÖHRE ALS HOCHFREQUENZGENERATOR BEI ABWESENHEIT FREMDER HILFSSTROMQUELLEN (On the employment of the valve as high-frequency generator in the absence of outside sources of auxiliary current).—F. Müller. (*Arch. f. Elektrot.*, 17, 2, pp. 143-152.)

If in the working of an ordinary valve, the external electromotive forces in the form of heating and anode batteries are eliminated, there still remain the inner forces between hot filament on the one hand, and anode and grid on the other—due chiefly to the emission of thermo-electrons from the filament, which may be determined from the different electronic velocities.

In this article experiments are described which leave no doubt that the inner electromotive forces of a valve can serve for the generation of undamped oscillations. External electromotive forces are eliminated by using interrupted direct current instead of the usual sources of heating current. By means of a special rotating interrupter the filament is periodically heated and then connected to the anode with the source of current disconnected.

A current is thus produced in the anode (or grid) circuit due to the inner electromotive forces. These latter can assume values from one up to several volts with an internal resistance of some thousand ohms. If such an arrangement be completed with oscillatory circuits, oscillations will be generated whose maintenance is to be traced to the action of the electrons with the greatest heat velocities.

A thorough treatment of the problem could only be carried out with an extraneous source of heat of a non-electric nature, but the difficulties of such an experiment are very great owing to the simultaneous attainment of high temperatures and high vacua involving experimental conditions that are almost mutually exclusive.

MESSUNG GROSSER EMISSIONSSTRÖME AN SENDERÖHREN UND GLEICHRICHTERN (Measurement of large emission currents in transmitting valves and rectifiers.)—G. Jobst and K. Matthies. (*Telefunken Zeitung*, 8, 43, October, 1926, pp. 39-42.)

Two methods of measurement are described differing from the usual methods, in which grid is joined to anode and the anode connected to a positive direct tension, in that only short discharge impacts are employed. In the first method this is achieved by means of condenser discharges, and in the second method by means of alternating tension with or without an applied negative tension.

POSITIVE RAYS PRODUCED IN THERMIONIC VACUUM TUBES CONTAINING ALKALI-METAL VAPOURS. —H. Ives. (*Journ. Franklin Institute*, January, 1926, pp. 47-69.)

Description of experiments establishing the fact that it is possible to produce positive ions of the alkali metals—sodium, potassium, rubidium, and caesium—by allowing the alkali metal vapours to come in contact with a heated tungsten filament, and that the range of filament temperatures through which this phenomenon occurs is limited. The lower limit of temperature is set by the coating of the filament with a layer of alkali metal, and the upper limit (in so far as the production of positive ions *alone* is concerned) by the occurrence of the electron emission of the tungsten filament itself.

MEASUREMENTS AND STANDARDS.

RADIO FIELD-STRENGTH MEASURING SYSTEM.—H. Friis and E. Bruce. (*Reprint B*-209, Bell Telephone Laboratories.)

A paper dealing with a new system of measurement which has been used successfully at a frequency as high as 40 megacycles. The apparatus is a double-detector receiving set which is equipped with a calibrated intermediate frequency attenuator and a local signal comparison oscillator. The local signal is measured by means of the intermediate frequency detector, which is calibrated as a valve voltmeter.

THE PIEZO-ELECTRIC QUARTZ RESONATOR AND ITS EQUIVALENT ELECTRICAL CIRCUIT.—D. W. Dye. (*Proc. Physical Society, London*, 38, 5, pp. 399-458.)

The quartz piezo-electric resonator is examined experimentally and theoretically with special regard to an equivalent electrical system which can represent it.

It is shown that, as theoretically predicted by Butterworth, such a resonator can be represented by an inductance, a resistance and a capacity all in series. These are pictured as in parallel with another small condenser and the whole is in series with a third condenser, the additional condensers representing air-gaps. The equations for the current in an oscillating circuit, to which the resonator is attached, are developed and it is found that almost perfect agreement exists between the forms of current curve obtained theoretically and experimentally. This agreement is found to hold for longitudinal resonators of as low a frequency as 44,000 and for transverse resonators of as high a frequency as 15,000,000 periods per second.

It is next shown how the logarithmic decrement of the resonator may be obtained from a rectified line plotted from observations on the current in the oscillatory circuit as a function of frequency width across the crevasse which pierces the summit of the resonance curve.

The methods of analysis of the equivalent mesh into its components are next developed and it is shown that this analysis can be effected by carrying out a series of observations of the current at resonance when the air-gaps are varied by known amounts, or when the effective resistance of the oscillatory electrical circuit is given different known values.

The effects on frequency of response of variation of air-gap are studied and the difference between prediction and observation is discussed.

The temperature coefficient of frequency of a considerable variety of resonators is examined over a range of temperatures up to 40°C. It is found that very diverse results are obtained and probable explanations are offered.

The current taken by the quartz mesh is examined in some detail theoretically, and one or two experimental curves are given, together with a graphical method of deducing the curve of current from the constants of the quartz.

ÜBER PIEZO-ELEKTRISCHE KRISTALLE BEI HOCHFREQUENZ (On piezo-electric crystals at high-frequency). — A. Meissner. (*Elek. Nachr. Technik*, 3, 11, pp. 401-408.)

Lecture given to the Heinrich Hertz Society at the Düsseldorf meeting of German scientists, September, 1926: a general survey of the subject.

THE RESISTANCE OF HIGH-FREQUENCY CIRCUITS. —R. Ramsey. (*Phil. Mag.*, 2, 12, December, 1926, pp. 1213-1218.)

Although the resistance of a high-frequency circuit is apparently easy to determine, the separation of the resistance of the coil from that of the condenser is a difficult matter. It has been customary to consider the resistance of the condenser small enough to be neglected, so that the entire resistance of the circuit is ascribed to the coil.

The first attempt to measure the resistance of a condenser at high frequency was made by Weyl and Harris (*Proc. Inst. Radio Eng.*, 13, February, 1925, p. 109), and another method has been employed by Callis (*Phil. Mag.*, 1, February, 1926, p. 428). The results obtained in both cases are much larger than usually assumed, the resistance of a good variable condenser being found to vary from near one ohm at full capacity to fifteen or more at small capacity.

The writer tried to verify these results and describes his experiments here in detail. He found, however, that the resistance of a good radio condenser is not excessive and that the results of Weyl and Harris, and Callis are entirely too large. He shows that the probable explanation of their results is that an appreciable amount of energy is radiated from an ordinary circuit, *i.e.*, there is a certain amount of resistance in the circuit which cannot be ascribed to either the condenser or the coil.

Telephone Transmitter Modulation Measured at the Receiving Station.—L. B. Turner. (*E.W. & W.E.*, January, 1927, pp. 3-5.)

A New Form of Frequency Meter.—S. Chiba. (*Journ. Inst. Elect. Eng. of Japan*, No. 459, October, 1926, pp. 1121-1126.)

Description of a new form of frequency meter for the accurate measurement of acoustic frequencies. Circuit diagrams are shown, the frequencies being given by the approximate formulæ:

$$f = \frac{1}{2\pi\sqrt{nCM}} \text{ and } f = \frac{\sqrt{n}}{2\pi\sqrt{CM}}$$

where n is a constant.

By suitably choosing C, M, and the high resistance, the error can be reduced to less than 1 per cent. over the entire range of the frequency to be measured.

Berechnung der Induktivität von Spulen (Calculation of the inductance of coils).—K. Müller. (*Arch. f. Elektrot.*, 17, 3, pp. 336-353.)

A mathematical article in which, among other deductions, the correct formula is found for the mutual inductance of two cylindrical, single-layer, co-axial coils, differing from that of Kirchhoff, also there is given in closed form the radial and axial components of the magnetic field strength of a circular current, or a single-layer cylindrical coil, for a given point in space.

Ein Nomogramm zur Berechnung von Zylinderspulen (A nomogram for the calculation of cylindrical coils).—E. Klotz. (*Telefunken Zeitung*, 8, pp. 42-44.)

The Relative Importance of Losses in Radio Receiving Systems. — W. Harper. (*Q.S.T.*, 10, 12, December, 1926, pp. 21-24.)

A discussion of the subject of inductance standardisation.

Messungen an der Bergantenne am Herzogstand. (Measurements on the Herzogstand mountain antenna.)—O. Scheller. (*Elekt. Nachr. Technik*, 3, 11, pp. 423-425.)

The construction of this unique antenna has been described in *E.N.T.*, 3, 7, pp. 241-255. The present article gives details of the aerial and earth tests that were made when the antenna was under erection, the results of which determined the line that further construction should take. The first radiation measurements were made in 1920-1921 by Dr. Gerth, who describes them in the following article—*E.N.T.*, 3, 7, pp. 425-428.

Loud-Speaker Characteristics. — H. Krönke (*Wireless World*, 15th December, 1926, pp. 805-807.)

Description of a new method of measurement developed by Dr. Erwin Meyer.

The Delineation of Alternating Current Wave Forms.—H. A. Thomas. (*E.W. & W.E.*, January, 1927, pp. 15-23.)

SUBSIDIARY EQUIPMENT AND MATERIALS.

The History and Development of the Telephone.—Sir Oliver Lodge. (*Journ. Inst. Elect. Engrs.*, 64, pp. 1098-1114.)

Lecture delivered before the Institution, 24th June, 1926, on the occasion of the jubilee of the telephone, including a section on wireless telephony.

Aufnahme-Mikrophone für den Rundfunk (Microphones for broadcast transmission).—F. Weichart. (*Zeitschrift f. Hochfrequenz*, 28, 4, pp. 120-128.)

A discussion of microphones divided into the following six groups:—

Contact microphones.
Capacitative microphones.
Electromagnetic and electrodynamic microphones.
Gas microphones.
Thermo-microphones.
Crystal microphones.

On the Condenser-Telephone.—B. Cohen. (*Phil. Mag.*, 2, 12, December, 1926, pp. 1271-1272.)

A letter referring to Dr. Green's paper (*Phil. Mag.*, 2, 9, September, 1926), in which the results at first sight are somewhat perplexing, and pointing out that the paper really deals with the operation of a condenser-telephone with a special and very unsuitable form of coupling so far as low capacity types of instrument are concerned.

A Break-In Relay.—M. Brainard. (*Q.S.T.*, 10, 12, December, 1926, pp. 34-36.)

A Revolutionary Development in Mica Insulation.—L. Barringer. (*General Electric Review*, 29, 11, November, 1926, pp. 757-762.)

Account of a new resin " Glyptal " which is very superior to shellac for mica insulation.

GENERAL PHYSICAL ARTICLES.

Optique et Radio Electricité (Optics and Wireless).—L. Bouthillon. (*L'Onde Electrique*, 5, 59, November, 1926, pp. 577-592.)

In a first part of the article (*L'Onde Electrique*, July, 1925) radio problems are shown to have their optical analogues: directional frames are compared with Fresnel's mirrors, curtain antennæ with illuminated slits, and Zenneck's wave with that of Brewster.

In this second part, the author investigates the wireless equivalents of elliptical, parabolic and circular mirrors, and some simple optical systems.

SUR LES VARIATIONS DES PROPRIÉTÉS OPTIQUES DU QUARTZ PIÉZO-ELECTRIQUE SOUMIS À DES COURANTS DE HAUTE FRÉQUENCE (On the variations of the optical properties of piezo-electric quartz subjected to high-frequency currents).—E. Taivil. (*Comptes Rendus*, 183, 6th December, 1926, pp. 1099-1101.)

Preliminary account of an optical phenomenon which may be of service for oscillographs and light modulators for phototelegraphy and television.

A CRITICAL RÉSUMÉ OF RECENT WORK ON DIELECTRICS. (*Journ. Inst. Elect. Engineers*, 64, November, 1926, pp. 1152-1190.)

Report prepared by Mr. Hartshorn at the National Physical Laboratory and received from the British Electrical and Allied Industries Research Association: a critical review of modern work and theories upon the subject of dielectric phenomena, extending over the past ten years.

PHASE DIFFERENCE IN DIELECTRICS.—J. Whitehead. (*Journ. Amer. Inst. Elect. Engineers*, 45, 12, December, 1926, pp. 1225-1228.)

A brief description of the origins and causes of phase difference in dielectrics.

A THERMIONIC THEORY OF THE ELECTRICAL CONDUCTIVITY OF DIELECTRICS.—H. Saegusa. (*Journ. Inst. Elect. Inst. Japan*, No. 460, November, 1926, pp. 1284-1291.)

An expression is obtained for electrical conductivity as a function of temperature and material constants. The natural frequencies of quartz plates are also deduced, the values falling within the range of those actually observed.

HIGH FREQUENCY RAYS OF COSMIC ORIGIN III. MEASUREMENTS IN SNOW-FED LAKES AT HIGH ALTITUDES.—R. Millikan and G. Cameron. (*Physical Review*, 28, 5, November, 1926, pp. 851-868.)

Experiments are described which provide new evidence for the existence of very hard etherial rays of cosmic origin entering the earth uniformly from all directions. The evidence points to the spectral distribution of these rays, the lower end of the absorption curve requiring a coefficient of .18 per metre of water and the upper end a coefficient of .30 per metre of water. These coefficients correspond to frequencies fifty times those of ordinary gamma rays. With regard to the origin of cosmic rays, it is concluded that these rays do not result from the union of protons with negative electrons, but that they are due to nuclear changes of about one-thirtieth the energy corresponding to such union taking place throughout the depths of the universe.

RECENT DEVELOPMENTS OF COSMICAL PHYSICS.—J. H. Jeans. (*Supplement to Nature*, 118, 4th December, 1926, pp. 29-40.)

A lecture delivered at University College, London, on 9th November, 1926.

In the section on highly-penetrating radiation Dr. Jeans shows that "we should expect the atmospheres of the stars, sun, and earth, and even the solid body of the earth, to be under continual bombardment by highly-penetrating radiation of nebular origin."

PROPERTIES OF HIGH FREQUENCY RADIATIONS.—J. Gray. (*Nature*, 118, 4th December, 1926, pp. 801-802.)

Statements are made tending to show that no conclusive evidence has been found for the view that the radiation causing the ionisation in closed vessels is a cosmic radiation of high frequency.

LUMINESCENCE FROM SOLID NITROGEN, AND THE AURORAL SPECTRUM.—L. Vegard. (*Nature*, 118, 4th December, 1926, p. 801.)

A letter in reply to statements by Prof. McLennan and his collaborators regarding the origin of the auroral spectrum, published in *Nature* of 18th and 25th September.

The writer states that the identification of the auroral line with an oxygen line, observed by McLennan, seems to be in contradiction with facts and maintains that his continued experiments with solid nitrogen show that solid nitrogen gives the whole typical auroral spectrum from red to ultraviolet.

THE AURORA BOREALIS AS OBSERVED FROM NORWAY. (*Nature*, 118, 4th December, 1926, pp. 797-799.)

A review by Prof. S. Chapman of Prof. Størmer's work giving the results of measurements obtained from photographs of auroræ occurring in Norway between 1911 and 1922.

POWER OF FUNDAMENTAL SPEECH SOUNDS.—C. Sacia and C. Beck. (*Reprint B*-206, Bell Telephone Laboratories.)

Description of a continuation of the work on speech power by means of oscillographic studies of vowels, semi-vowels and consonants. A previous paper considered the characteristics of a few individual sounds from the power standpoint, but the principal emphasis was placed upon speech as a whole. In this later analysis sounds are considered individually on the basis of instantaneous and mean power. A practical application of the results is suggested.

A POSSIBLE CONNECTION BETWEEN THE WAVE-THEORY OF MATTER AND ELECTRO-MAGNETISM.—H. Bateman. (*Nature*, 118, 11th December, 1926, pp. 839-840.)

THEORIES OF A NEW SOLID JUNCTION RECTIFIER.—L. Grondahl. (*Science*, 64, pp. 306-308.)

Preliminary announcement of a new type of rectifier, consisting of a disc of copper with a coating of oxide formed on its surface. Under suitable conditions, current flows more readily from the oxide to the copper than in the reverse direction. Explanations of contact rectification usually given, such as electrolysis and thermo-electricity, are shown to be untenable for this new electronic solid-junction rectifier. The seat of rectification is apparently restricted to the layer near the junction between the copper and the compound formed on it.

THE IONISATION OF ATOMS BY ELECTRON IMPACT.—E. Lawrence. (*Physical Review*, 28, 5, November, 1926, pp. 947-961.)

Precision in critical potential measurements in the past has been seriously limited by the lack of homogeneity in velocities of the electrons. This source of error has been eliminated by separating out magnetically electrons of definite velocities. The electron beams used in the present experiments were not characterised by great homogeneity in velocities but by sharp upper limits to their velocity distributions. Critical potentials were measured as the differences between two retarding potentials —the smallest retarding potential preventing the entrance of the electrons into the Faraday cylinder type of ionisation chamber and the largest retarding potential for which the effect under investigation is observed—thereby eliminating errors due to contact electromotive forces.

ON THE EXCITATION OF POLARISED LIGHT BY ELECTRON IMPACT.—H. Skinner. (*Proc. Roy. Soc.*, 112, A762, pp. 642-660.)

An electron tube producing an intense unidirectional stream of electrons of slow speed is used for the excitation of the mercury spectrum, and polarisation measurements are made on the light emitted from the tube in a direction at right angles to the direction of the stream. It is found that with an electron speed corresponding to 20 volts many of the mercury lines are partially plane-polarised, most with direction of the maximum electric vector parallel to the stream, but some in the perpendicular direction.

ON THE TOTAL PHOTO-ELECTRIC EMISSION OF ELECTRONS FROM METALS AS A FUNCTION OF TEMPERATURE OF THE EXCITING RADIATION.—S. Roy. (*Proc. Roy. Soc.*, 112, A762, pp. 599-630.)

MISCELLANEOUS.

TRANSATLANTIC WIRELESS. (*Electrician*, 97, 17th December, 1926, p. 696.)

Mr. Marconi describes his experiences 25 years ago, when on 12th December, 1901, he succeeded in establishing wireless communication between Poldhu, Cornwall, and St. John's, Newfoundland, showing photographs of the original plant and equipment. With regard to the next 25 years, Mr. Marconi says there will probably be almost as great a development in means of obtaining directional wireless transmission and reception as there has been in other directions during the last 25 years, also that there is a possibility that the transmission of power over moderate distances may be developed and that television will become an actuality.

CARRIER CURRENT COMMUNICATION OVER TRANSMISSION LINES.—E. Carter. (*General Electric Review*, 29, 12, December, 1926, pp. 833-845.)

An article dealing with the requirements to be fulfilled, single-frequency duplex equipment, inter-system communication, amount of carrier energy required, and operation.

BILDTELEGRAPHIE UND SCHNELLTELEGRAPHIE MIT DER KAROLUS-ZELLE (Picture and high-speed telegraphy with the Karolus cell).—F. Schröter. (*Telefunken Zeitung*, 8, 43, October, 1926, pp. 7-13.)

RADIO STATISTICS. (*Scientific American*, December, 1926, p. 458.)

The data collected from a two-year survey of broadcasting in the United States revealed the fact that of the 1,424 stations licensed by the Government since November, 1920, 878, or 62 per cent., have ceased to function. The two principal reasons for the discontinuance of broadcasting are inability to finance, 45 per cent., and service unsatisfactory as compared with the larger competing stations, 17 per cent.

THE B.E.S.A. GLOSSARY.—G. W. O. Howe. (*Electrical Review*, 10th December, 1926, p. 979.)

A letter in answer to those of Mr. Fawcett and Prof. Fortescue appearing in the *Review* of 12th and 19th November respectively. Referring to the former, Prof. Howe explains that "electromotive force" and "magnetomotive force" are misnomers and not forces at all; and replying to the latter letter, he distinguishes between B and H and goes on to show that H has real existence. In the *Review* of 24th December Prof. Fortescue writes that this does not answer his question, his inquiry as to the objective difference between a field strength and a flux density applying to either the electric or the magnetic field.

Correspondence.

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

Effective Resistance of Inductance Coils.

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

SIR,—In connection with the masterly series of articles on the Effective Resistance of Inductance Coils at Radio Frequency in *E.W. & W.E.* and the applications of the same principles to low loss coil design given in the *Wireless World*, the following may be of interest to some of the many readers, who, like the present writer, must have been impressed and highly appreciative of the brilliant manner in which Mr. Butterworth handled an extremely complex subject.

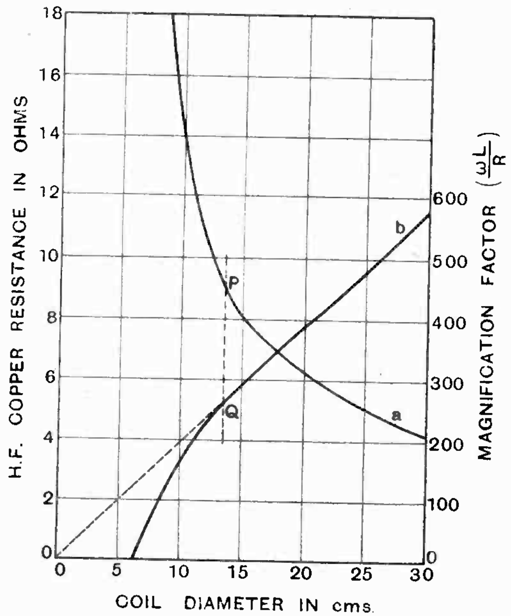


Fig. 1.

Mr. Butterworth, very practically, concerns himself chiefly with coils of quite small dimensions, and while these coils are all that can be desired for valve apparatus, particularly where appreciable reaction is used, it seems that many people would not be concerned with any reasonable increase of size or cost to obtain a very efficient coil for, say, the reception of Daventry with a crystal set. With the limitation of size he imposes, Mr. Butterworth advises the use of a multilayer coil for this wavelength as it can be made more efficient than a single layer coil, but if the size is not limited, the single layer coil with a winding length equal to its radius is, according to his tables, undoubtedly the best shape.

The following are particulars of a series of coils for this wavelength, *i.e.*, having an inductance of 2,000 microhenries, which are single layer and have the ratio of length to diameter 0.5.

The diameter is progressively increased up to 30 cms., and the number of turns and the wire diameter are adjusted for best efficiency in each case.

TABLE I.

SOLID WIRE COILS.

Dia. (cms.).	No. of turns.	Wire.	R_c (ohms).	$M=\frac{\omega L}{R_c}$
7.5	161	38 D.S.C.	34.55	68*
10.5	139	32 D.S.C.	13.92	169*
12.5	125	28 D.S.C.	9.85	239*
15.0	114	23 D.S.C.	7.96	295
17.5	105	22 D.S.C.	7.05	333
20.0	98	21 D.S.C.	6.15	382
22.5	93	20 D.C.C.	5.45	432
25.0	88	19 D.C.C.	5.00	470
27.5	84	18 D.C.C.	4.54	518
30.0	80	17 D.C.C.	4.11	572
			(*a*)	(*b*)

* Best wire diameter not possible, but nearest used.

The results are also plotted in Fig. 1.

It is seen that the last coil has a magnification factor about three times greater than the average good commercial coil of this inductance.

It is interesting to notice how sharply the resistance curve rises as soon as it is not possible to use the optimum wire diameter.

The values, of course, neglect other losses in the coil, but as Mr. Butterworth points out, these are practically negligible with reasonable design.

Another interesting point in the graph is that Curve *b* (magnification factors) is a straight line passing through the origin (the dotted portion showing continuation of curve if it were possible to use optimum wire diameter in each case), thus *showing that the best resistance is inversely proportional to the diameter*, as Mr. Butterworth states would be so for high frequency.

The resistances of coils were also calculated using stranded wire, this being only possible in the case of the last five coils.

The particulars are given in Table II.

TABLE II.

$L=2{,}000\mu H$. $b/D=0.5$.

STRANDED WIRE COILS.

Dia. (cms.).	No. of turns.	Wire.	R_c (ohms).	$M=\frac{\omega L}{R_c}$
20.0	98	9/34	4.23	555
22.5	93	9/34	4.20	560
25.0	88	9/34	4.19	565
27.5	84	27/36	2.58	910
30.0	80	27/36	2.50	940

The D.C. resistances were calculated from tables neglecting twist, so will be slightly larger.

It will be seen that the extremely low figure of 1.25 ohms per millihenry is obtainable in the last case.

The writer hopes to verify these resistances experimentally and to see whether results in the case of crystal reception of Daventry justify the large space occupied by these coils.

JOHN L. SMITH.

Mathematics for Wireless Amateurs.

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

SIR,—As a reader of above since its commencement as a periodical, may I offer my thanks for the excellent articles on Mathematics contained therein. As an enthusiastic, albeit a humble, student, of physical science, and particularly "Radiations," I find Mr. Colebrook's articles particularly useful as a "refresher course," and I trust that he will be allowed to take us through the "Calculus." His treatment, judging from the present instalments, would promise a treat to which I am looking forward.

Note.—I do not find answers to given examples in previous numbers. Is it intended to give these? I am also glad to note the inclusion of notes on experiments such as the introduction of sodium and potassium into discharge tubes. To emulate this is going to give me many hours' pleasure. Let's have some more of this, please! In conclusion may I express the hope of some articles on the "Physics" of radiations as distinct from engineering.

I realise that perhaps I am but one voice in thousands.

J. G. CLAYTON.

Plate-current, Plate-voltage, Characteristics.

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

SIR,—I have been much interested in the controversy following my original letter on the above subject and Mr. Green's reply, with which I agree entirely. Of course, I only quoted the Krönke article on resistance coupling as a case in which existing views had been shown to be erroneous and not as a case of transformer coupling!

I noted his remarks on Mr. P. W. Willans' paper, but must comment that this deals with practical examples where, as I remarked, intercapacities and leakages come in and upset one's theory. Also, as Mr. Willans implies, he sacrifices the most "freaky," and therefore greatest response, curve for a flat-topped curve much better for music reproduction. (See in this connection Mr. Kirke's paper, June issue, p. 358.)

Mr. Fowler Clark takes exception to two of my statements in his letter but takes them out of their context, thereby altering their import considerably, though they are still true even when so ill-used!

To meet him on his own ground, I must first point out that R and X are not necessarily connected by any such law of equal variation; in fact, they can be almost independent variables. Taking any particular values of R and X, it is undoubtedly true that

$$I^2R,\quad I^2\frac{1}{\sqrt{R^2+X^2}}\quad\text{and}\quad I^2X$$

all reach maximum values together but it is a colossal howler to say that this happens when $\sqrt{R^2+X^2}=\rho$ (valve A.C. resistance). Keeping R and X constant I can always be increased by reducing ρ the internal A.C. resistance (*e.g.*, by turning the valve filament up and I tends to its maximum as $\sqrt{R^2+X^2}/\rho$ tends to infinity.

I must point out that there are two points on *every* transformer curve at which its impedance is matched to any valve, but that in all cases the "response" curve, *i.e.*, curve of overall amplification of valve and transformer is nearly at its minima at these; the highest amplifications are at points where the transformer impedance is ten or a hundred times as great as the valve A.C. resistance.

As Mr. Fowler Clark most truly remarks, there is a very cogent reason to have one of these points low in the audio scale—no one would buy a transformer which was matched on, say, the middle G, because its overall performance would be so poor—some of the early cheap transformers came near to this.

Anyone knows that to reduce amplification one turns a valve filament down—*i.e.*, raises its A.C. resistance more nearly to the impedance of the associated transformer. I fear that Mr. Fowler Clark rushed into the fray guided by his preconceptions and is trying to fit arguments to them without going to facts sufficiently.

If, however, the standard expression for overall amplification is taken

$$\left(\mu\sigma\sqrt{\frac{X^2}{X^2+(R+\rho)^2}}\right)$$

where μ, σ, X and R have their usual significance and $\rho=$ internal A.C. resistance of the valve the following facts are evident:—

1. The smaller R and/or ρ are in proportion to X the nearer the expression is to its maximum.

2. Taking $\left\{\frac{\sqrt{X^2+R^2}}{\rho}\right\}$ as the independent variable the overall amplification becomes a maximum as $\frac{\rho}{\sqrt{X^2+R^2}}$ tends to 0.

I must therefore reiterate my original point that *theoretically* one must increase the ratio of the transformer impedance to the valve internal A.C. resistance as much as possible.

How does practice modify this? Mr. Willans shows us in the July issue.

We want not only large amplification, but a nice flat-topped curve. This is gained by picking a σ to suit the valve and although ultimately the impedance ratio must yield partially to space considerations, intercapacities and other practical points—still it is right to say that the main law holds good that the transformer should be of the utmost possible impedance and not of matched impedance except in the one case of power output to a loud-speaker. One big firm quoted by Mr. Fowler certainly agrees with me.

Messrs. C. Holt Smith and Albert Hall gave different angles to the discussion and Mr. Albert Hall in particular gave some valuable practical measurements in support of my views and quotes Mr. Dye's paper very appositely. He has, in fact, stated my case far better than I did myself.

I should like to thank both critics and apologists for some extremely interesting views.

I. A. J. DUFF, B.A., A.M.Inst.C.E.

Manchester.

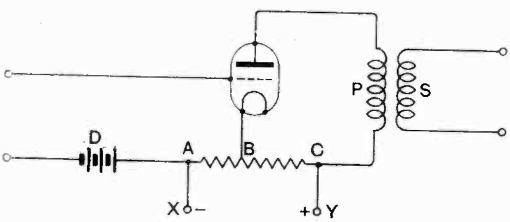
Some Recent Patents.

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.

VALVE CIRCUITS SUPPLIED FROM MAINS.

(*Application date, 15th August, 1925. No.* 261,110.)

Many circuits have been devised for smoothing mains supply for use with valve circuits, but the accompanying invention, due to G. M. Wright, gives details of a circuital arrangement wherein any fluctuations which may arise are substantially balanced out. The specification gives one or two examples of the arrangement for various methods of valve coupling. The circuit is comparable with an arrangement which is used for determining the amplification factor of a valve, and, in fact, is somewhat similar. The invention consists in shunting the anode supply with a fixed resistance,

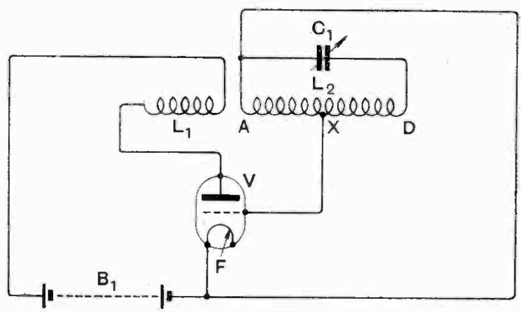


the filament connection of the valve system being made to a tapping on the resistance. The tapping point is so arranged that any variation of potentials in the grid circuit are balanced by proportionately opposite variation of potential in the anode circuit, thereby maintaining a substantially constant output. The accompanying diagram illustrates the invention as applied to a transformer-coupled valve. The anode circuit of the valve V contains the primary winding P of a transformer PS. The high tension supply XY is shunted by a resistance ABC. The grid circuit or input circuit of the valve is connected, not between the grid and filament, as is usual, but between the grid and the negative high tension terminal, *i.e.*, the end A of the resistance ABC, the filament connection being taken at B. Any variation in anode voltage supply will cause a fall of potential along the resistance ABC. A certain voltage will then be set up across the resistance AB, which will be communicated to the grid circuit of the valve, causing a corresponding magnified voltage to be produced in the anode circuit of the valve. Similarly, however, a voltage will be set up across the resistance BC which will be introduced into the anode circuit, since the resistance BC comprises part of the anode circuit. This voltage, however, will be opposite in sense to that produced by the magnified voltage across the resistance AB. Hence it follows that if the resistance BC is equal to the resistance AB multiplied by the amplification factor of the valve, the two voltages introduced into the anode circuit will be opposite and equal. The resistance AB BC is arranged in this proportion. A bias battery is shown at D for the purpose of balancing the steady potential drop across the resistance AB. The specification also describes the invention as applied to resistance-coupled valves, and indicates the manner in which the proportions of the resistance are determined.

FREQUENCY STABILISATION.

(*Application date, 13th November, 1925. No.* 261,905.)

It is essential that the constants of a wavemeter shall not vary, but this is liable to occur if the valve with which the instrument has been originally calibrated is substituted by another. Although valves of the same type have substantially similar characteristics one cannot really depend upon the input capacity, for example, remaining the same for all valves of the same type. A wavemeter circuit which overcomes this difficulty is described by Lt.-Col. K. E. Edgeworth, D.S.O., M.C., in the

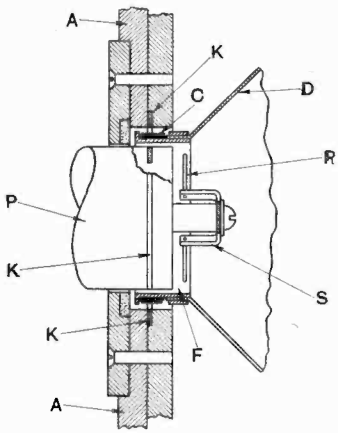


above British Patent. One arrangement, utilising a tuned grid circuit, is shown in the accompanying illustration. A valve V is provided with a reaction coil L_1 and the usual anode battery B_1. This is coupled to an inductance L_2 tuned by a variable capacity C_1. One end A of the inductance L_2 is connected to the filament F, this end being nearest to the reaction coil L_1. Instead of connecting the free end D of the tuned circuit directly to the grid, the grid connection is taken to a tapping X along the inductance L_2 so that only a few turns are connected between the grid and the filament. Variation of inter-electrode valve capacity under these conditions does not affect the frequency of the tuned circuit L_2 C_1 to such an extent as it would if the grid connection were taken at D. The reason for this should be obvious, of course, and is due to the fact that if any valve having a self-capacity higher than that of the original valve is used, the increased grid-filament capacity will only be in shunt to a few turns of the inductance L_2, and, accordingly, the frequency of the circuit $L_2\ C_1$ will only be lowered by an almost imperceptible amount, depending, of course, upon the ratio of the turns in circuit to the total turns of the inductance.

A MODIFIED COIL DRIVE.

(Convention date (U.S.A.), 20th April, 1925. No. 250,931.)

Readers are no doubt familiar with the patent specifications relating to the Rice-Kellogg type of loud-speaker. A modified form of coil drive is described by C. W. Rice in the above British Patent.

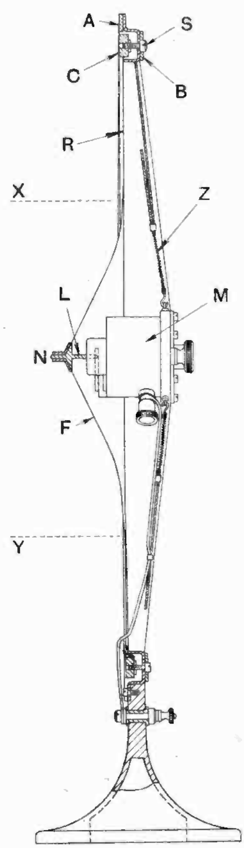


The type of loud-speaker referred to, of course, is that comprising a diaphragm attached to a light, rigid. moving coil, which is in an annular gap of a very powerful magnetic system. The speech currents are applied to the moving coil in which they create a field, cutting that due to the electro-magnet. Since the electro-magnet is fixed the force between the two fields causes the moving coil to be displaced, thereby energising the diaphragm. The specification states that the impedance of the moving coil is determined partly by its ohmic resistance, and partly by its reactance. At very low frequencies the impedance is due almost entirely to the ohmic resistance, whereas at higher frequencies the reactive component may predominate. This may, however, give rise to unequal response over the frequency range, and the object of the invention is to flatten out the response curve, which is accomplished by associating the moving coil with short-circuited turns or rings of copper of considerable dimensions located in the pole pieces, these copper rings acting somewhat in the manner of a short-circuited secondary winding of a transformer with reference to the moving coil. The accompanying illustration shows one method of arranging the invention, where a diaphragm *D*, the edge of which is not shown, is fixed to a light coil *C* wound on a cylindrical former *F* joined to the truncated portion of the conical diaphragm *D*. The moving coil *C* is in the air gap between the pole pieces comprising a cylindrical pole *P* and an annular pole *A*. The remaining portion of the magnetic system is not shown for the sake of clearness. The coil *C* is prevented from touching the central pole piece *P* by means of supports in the form of light rods *R* fixed to a spider *S* screwed to the end of the pole piece *P*. The free edge of the conical diaphragm *D* is also supported by thin leather, rubber, silk, or other suitable material. Two copper rings *K* are respectively embedded in the two pole pieces, that is, the central pole piece *P* and the annular built-up pole piece *A*. It will be obvious that lines of force from the coil *C* will cut the two rings *K*, which since they are closed circuits, will act as short-circuited secondary windings, thereby considerably lowering the impedance of the coil, which will not tend to increase so rapidly as the frequency of the applied voltage is raised. In this manner a more even response is obtained.

A CONE TYPE DIAPHRAGM.

(Application dates, 30th April, and 22nd June, 1925. No. 257,317.)

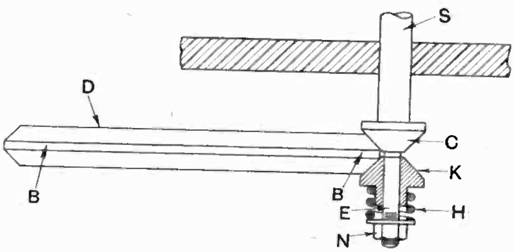
Another form of cone type diaphragm is described in the above British Patent Specification by N. W. McLachlan. Essentially the diaphragm comprises a combination of a cone and a ring, the two being integral and made of one piece of fabric, which is stiffened by treating with "dope" or celluloid varnish. The varnish is applied first on one side and allowed to dry, and then on the other, the process being repeated until sufficient strength is obtained. The edge of the diaphragm is held in a channel section, consisting of two rings *A* and *B*, variation of tension being obtained by means of another ring *C*, which is adjusted through the back of the channel section by means of screws *S* arranged round the periphery. The apex of the cone *N* is driven by a link *L* attached to a magnetic system *M*. This is supported by means of springs *Z*, which are attached to the metal ring supporting the diaphragm. The specification mentions that other material may be used for the supporting rings, and may have effect upon the tonal qualities of the loud speaker.



AN INGENIOUS DRIVE.

(*Application date, 19th August, 1925. No. 261,476.*)

In order to overcome the necessity for accurate assembly of a driving mechanism, such as a slow motion device for a variable condenser, a rather ingenious form of drive is described by H. J. Gowring and the Western Electric Company, Limited, in the above British Patent. One arrangement of the invention is shown in the accompanying illustration, where a disc D, mounted on a shaft, not shown, has to be driven from a shaft S. The edge of the disc is bevelled as shown at B. The shaft S is provided with a cone-shaped member C, while an extension of the shaft S is screwed and carries a nut N and a helical spring H. The helical spring H engages another cone K, shown in cross section, which is free to move on the extension E of the shaft S. The spring H exerts sufficient force upon the movable cone K to grip the bevelled edge of the disc firmly between the two cones C and K. Rotation of the shaft causes the two surfaces of the cones C and K to co-operate with the bevelled

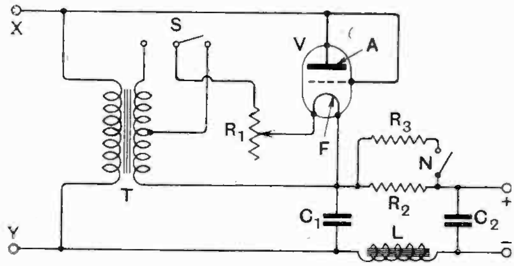


edge of the disc, thereby enabling the cone C to drive the disc. It will be obvious that owing to the nature of the drive a certain amount of flexibility is imparted to the system, thus obviating the necessity of the accurate alignment and disposition of the shaft S with respect to the disc D.

ANOTHER MAINS UNIT.

(*Application date, 7th September, 1925. No. 262,190.*)

The construction of the mains unit which embodies a particular form of smoothing circuit and special arrangement for the rectifying valve is described in the above British Patent by S. G. Thaine. The circuit which is employed is shown in the accompanying illustration. The alternating current supply is shown at X and Y, where it is taken direct to the anode A of the rectifying valve. This is shown as a three-electrode valve with the grid joined to the anode. A transformer T provides the heating current for the filament F of the valve V, while a variable resistance R_1 controls the filament current. The transformer is provided with a two-way switch S which connects the filament to either of two tappings. This enables the device to be used with small receiving valves having either bright or dull emitting filaments. The smoothing circuit is rather unusual, and comprises two condensers C_1 and C_2 on either side of a combination of resistances and a choke. The negative wire contains a choke L between the two condensers C_1 and C_2, while the positive lead contains resistances R_2 and R_3, the switch N being

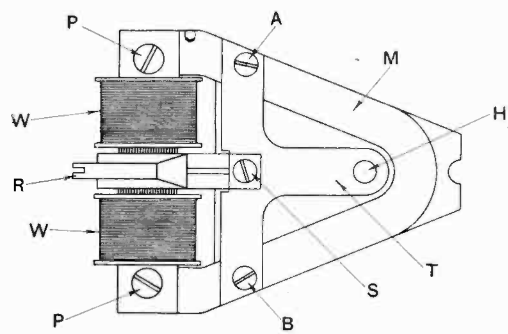


provided for connecting the resistances in parallel. The specification states that the choke may be of the order of 51 henries, and the resistance R_3 may be about 100,000 ohms, and the resistance R_2 about 9,000 ohms.

REED MOUNTING.

(*Application date, 19th September, 1925. No. 261,506.*)

A method of mounting a reed for the purpose of driving the diaphragm of a loud-speaker is described by S. G. Brown in the above British patent. The magnetic system of the loud-speaker movement comprises a V-shaped magnet M with laminated pole pieces P, which are screwed on to the ends of the V-shaped magnet. The two pole pieces carry windings W, a small gap, of course, existing between the ends of the pole pieces P. The reed R which drives the diaphragm is mounted in the following manner: The arms of the V-shaped magnet support the two ends A and B of a T-shaped member T, the reed being fixed to the middle



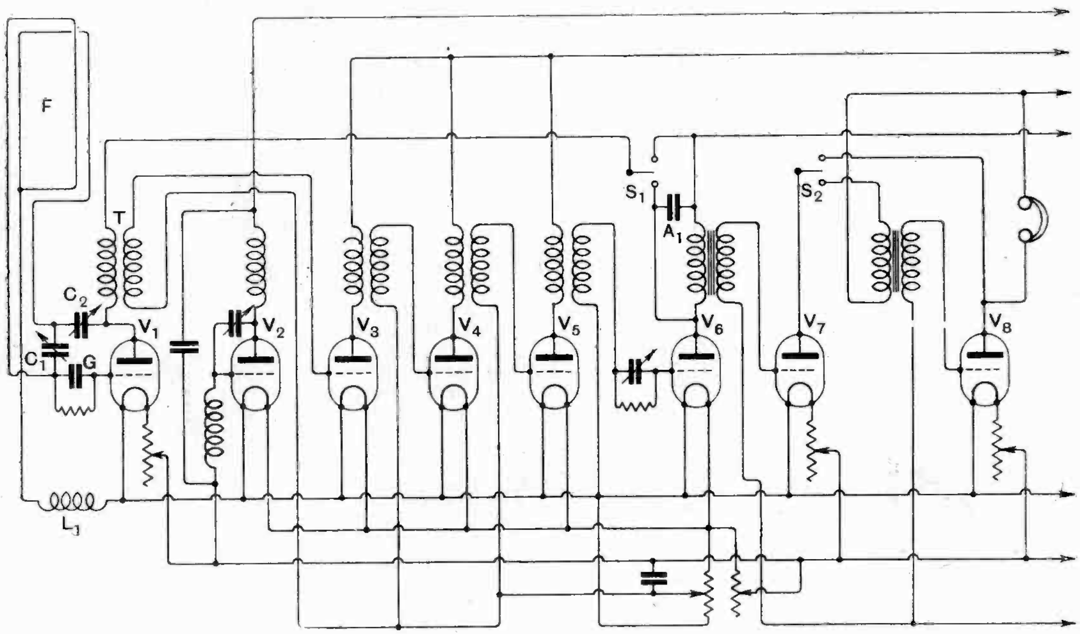
of the horizontal portion of the T-shaped member by a screw S. The remaining portion of the T-shaped member is provided with a hole H through which a screw (not shown) provided with a flanged portion working against a helical spring can pass.

Thus it will be seen that as the screwed arrangement working through the hole *H* is rotated it will cause the T-shaped member (which is of non-magnetic material) to move up and down, thereby imparting to the reed a similar motion. In this manner the distance between the reed and the pole pieces can be conveniently controlled.

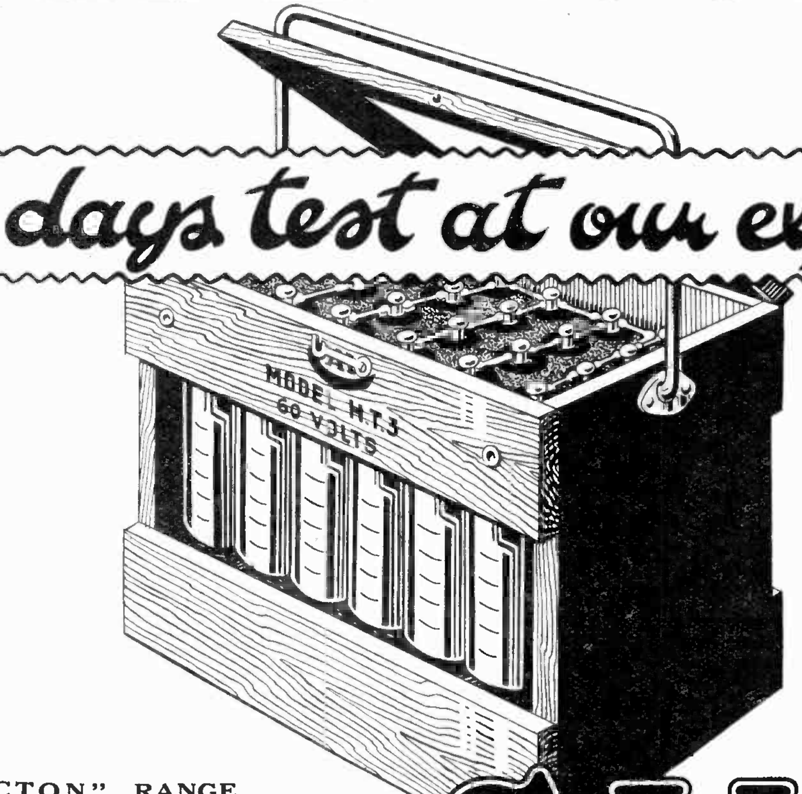
A MULTI-VALVE RECEIVER.

(*Application date, 19th October,* 1925. *No.* 261,893.)

S. L. Forbes describes in the above British Patent a receiving system which can be used either as a supersonic receiver or a "straight" circuit. The complete circuital arrangement is shown in the accompanying illustration, although only some of the components will be dealt with in detail. The input comprises a centre tap frame *F* tuned by a condenser C_1 connected through a grid condenser and leak *G* to the grid of the first detector valve V_1, while the other end of the frame is taken to the anode of the valve V_1 through a condenser C_2. The centre tap is taken to the filaments through an inductance L_1. The valve V_2 is arranged as a local oscillator for heterodyne reception either at supersonic frequency, or audible frequency if desired. The anode circuit of the valve V_1 contains a long wave selector circuit in the form of a transformer *T*. A switch S_1 enables the anode circuit of the valve V_1 to be connected either to the high tension supply direct, or through a low frequency transformer A_1. Valves V_3, V_4 and V_5 comprise an intermediate frequency amplifier, while the valve V_6 acts as the second detector, the output of which is coupled through an audio-frequency transformer A_1 to two note amplifiers V_7 and V_8, a switch S_2 cutting out the last note magnifier if desired. When it is not desired to use the receiver as a superheterodyne circuit the anode circuit of the first valve V_1 is connected directly to the audio-frequency transformer A_1, the remaining valves being disconnected from circuit.

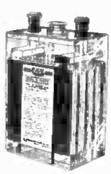


21 days test at our expense



C.A.V

"ACTON" RANGE
L.T. ACCUMULATORS



"Acton" Celluloid

Offered at prices which are strictly competitive with the lowest on the market, the "Acton Range" represents remarkable value. Each is soundly designed and well made, and maintains the high standard of performance for which all C.A.V. Accumulators are well known.

2A. 40	2-vlt.	20-amp. hrs.	(Act.)	11/0
*2A. 60	,,	30	,,	13/6
*2A. 80	,,	40	,,	16/0
2A. 100	,,	50	,,	18/6
2A. 120	,,	60	,,	21/0

4 and 6-volt. assemblies at practically pro rata prices.

* These models are repeated in moulded glass containers at the same price.

H.T. RADIO ACCUMULATORS

To prove our absolute confidence in these accumulators, we guarantee, if you are not satisfied, to accept return within 21 days from purchase date, and refund money in full provided battery is returned intact to the Agent from whom it was purchased.

C.A.V. H.T. Accumulators represent an epoch-making advance as compared with dry batteries. When dry batteries are down, they are done, and frequent renewals make them more expensive. C.A.V. H.T. Accumulators will last for years, and only need recharging, approximately, every four months. They give bigger volume and are silent in operation.

Size : 8½" × 7" × 7¾" High.

60 VOLTS.

Supplied fully charged, ready for use, and with distilled water filler

60/-

Price in U.K.

Also supplied in 30 & 90-Volts at pro rata prices.

OBTAINABLE FROM ALL RADIO SUPPLIERS

Telephone :
CHISWICK 3801
(Private Branch Exchange)

C.A.Vandervell & Co. Ltd.
ACTON, LONDON, W. 3.

Telegrams :
"VANTERIA, ACT, LONDON."

ANOTHER example of the progressive policy of the Varley Magnet Company. The new Varley Tapped Resistance possesses all the advantages of the original famous Varley Bi-Duplex Wire-Wound Anode Resistance with the added advantage of having four different values of resistance in one component.

Wireless enthusiasts will at once apprec ate the value of the Varley Tapped Resistance for

TONE CONTROL
VOLUME CONTROL
H.T. ELIMINATORS
VOLTAGE DIVIDERS

and knowing it to be Varley Bi-Duplex Wire-Wound they can rest assured of perfect purity of tone, absolute constancy under all conditions, and complete freedom from shorted or leaking turns.

This is only the beginning. We are marketing in the near future a special resistance with 6 tappings, in addition to other Bi-Duplex Wire-Wound components, particulars of which will be announced in the Wireless Press.

The Varley Bi-Duplex Wire-Wound Tapped Resistance. Complete **15/.**

Varley Bi-Duplex Wire-Wound Anode Resistances are made in a complete range of sizes up to **500,000 ohms**, prices from ... ... **4/- to 16/-**

Full particulars on application.

The Varley Multi-cellular H.F. Choke, complete 9/6

The Varley Multi-cellular H.F. Choke, for circuits of the SPLIT COIL Type. Complete 12/6

MAKE SURE IT'S VARLEY BI-DUPLEX WIRE-WOUND

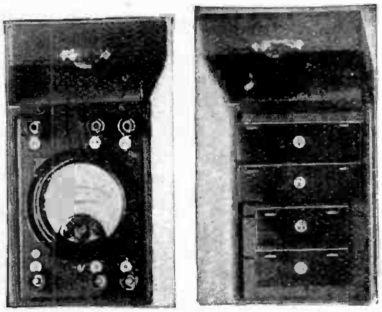
VARLEY

THE VARLEY MAGNET CO.
(Proprietors—Oliver Pell Control Ltd.)
Granville House, Arundel Street, London, W.C.2
Telephone: City 3393. V17

YOU MUST HAVE

A Model de Luxe Multi Range DIX-ONEMETER

To get High-Grade Results



"The Rolls-Royce of Radio"
Double Mirror Scale *Moulded Base*

The finest Precision Multi Measuring instrument is the **DIX-ONEMETER.** It has Mirror Scale, Knife-edge Pointer, 500 ohms per volt sensitivity, and 55 Ranges.

Do not take a Ford arrangement of a meter on a board, a clock hand pointer and a fuzzy scale for your important readings.

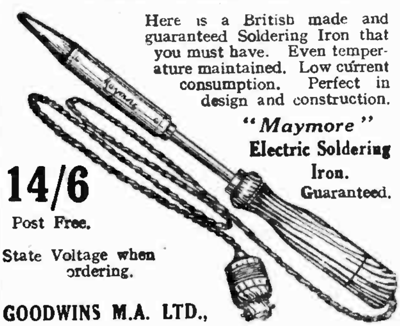
THE DIX-ONEMETER is worth own ng.
Instrument in Case 55/- **Multipliers 6/6 each**

Only obtainable from

Electradix Radios, 218, Upper Thames St., E.C.4
Radiax Ltd., Palmer Place, Holloway, N.7
Eagle Engineering Co. Ltd., Warwick
Manchester Radio Ltd., Oxford St., Manchester, or

LESLIE DIXON & CO.
218, Upper Thames St., London, E.C.4

Wireless Constructors!



Here is a British made and guaranteed Soldering Iron that you must have. Even temperature maintained. Low current consumption. Perfect in design and construction.

***"Maymore"* Electric Soldering Iron. Guaranteed.**

14/6
Post Free.

State Voltage when ordering.

GOODWINS M.A. LTD.,
2-4, Edmund St., Birmingham.

THE RADIO SOCIETY OF GREAT BRITAIN

ANNUAL

DIARY & LOG BOOK

1927 (First Year)

Containing:
Appreciation by Senatore Marconi—Contributions by Capt. P. P. Eckersley, M.I.E.E., Admiral Sir Henry Jackson, C.B.E., J. F. Stanley, B.Sc., A.C.G.I., H. Bevan Swift, A.M.I.E.E., R. J. Hibberd, M.I.R.E., F.R.S.A., W. K. Alford. The most complete International Directory of Amateur Transmitters yet published, representing upwards of 6,000 stations. Tables, etc., and specially ruled, dated and printed **daily-diary-logging** chart covering 365 days, complete with permanent bookmark blotter. Size Foolscap 8" x 13½". Bound stout full cloth. A real Radio Log Book and work of reference, indispensable to the Engineer, Experimenter or Amateur.

ONLY A LIMITED EDITION AVAILABLE

PRICE: **3/6** *Postage 6d. From the Publishers.*

Printing-Craft Ltd. **34, RED LION SQUARE Holborn, London, W.C.1**

or through your local newsagent

PLACE YOUR ORDER NOW and avoid disappointment.

WIRELESS PICTURES and TELEVISION

By

T. THORNE BAKER, F.C.S., F.R.P.S.

At all Booksellers
Fully Illustrated 6/6 net

MR. T. THORNE BAKER will control the transmission of wireless photographs from the Paris broadcasting station "Radiola."

Read the book and see how it is done and learn how, yourself, to receive wireless pictures.

CONSTABLE & CO., LTD.
10-12, Orange Street, W.C.2

BUYERS' GUIDE.

ACCUMULATORS.—C. A. Vandervell & Co, Ltd., Acton, London, W.3.

COILS.—Graham-Farish Manufacturing Co., 17, Mason's Hill, Bromley, Kent. Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.; Pettygrew & Merriman (1925) Ltd., 2 & 4, Bucknall Street, New Oxford Street, W.C.1.

COIL HOLDERS.—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C., Pettygrew & Merriman (1925), Ltd., 2 & 4, Bucknall Street, New Oxford Street, W.C.1.

CONDENSERS (GENERAL).—Autoveyors, Ltd., 84, Victoria Street, S.W.1. Bowyer-Lowe Co., Ltd., Letchworth. Dubilier Condenser Co. (1925), Ltd., Goldhawk Road, W.12. Graham-Farish Manufacturing Co., 17, Mason's Hill, Bromley, Kent. Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. M.A.P. Ltd., 246, Gt. Lister Street, Birmingham. Marconiphone Co., Ltd., 210, Tottenham Court Road, W.1. Pettygrew & Merriman, (1925), Ltd., 2 & 4, Bucknall Street, New Oxford Street, W.C.1. W. G. Pye & Co., "Granta Works," Montague Road, Cambridge.

EBONITE.—Trelleborgs Ebonite Works, Ltd., Audrey House, E.C.2.

GALVANOMETERS (CAMBRIDGE UNIPIVOT).—Cambridge Instrument Co., Ltd., 45, Grosvenor Place, S.W.1.

GRID LEAKS.—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. Watmel Wireless Co., 332a, Goswell Road, E.C.4.

LOUD SPEAKERS.—Alfred Graham & Co., St. Andrew's Works, Crofton Park, S.E.4.

LOUD SPEAKER HORNS.—H. Maddison, 2a, Ronald's Road, Holloway Road, N.5.

MEASURING INSTRUMENTS.—F. C. Heayberd & Co., 9, Talbot Court, Eastcheap, E.C. Sifam Electrical Instrument Co., 10a, Page Street, Westminster, S.W.1. Weston Electrical Instrument Co. Ltd., 15, Great Saffron Hill, E.C.1.

PERIODICALS.—"Journal of Scientific Instruments," "Institute of Physics," 90, Great Russell Street, W.C.1. Printing Craft, Ltd., 34, Red Lion Square, W.C.

QSL CARDS.—E. H. Appleby, The Croft, Willesden, N.W.10.

RESISTANCES (ANODE).—Varley Magnet Co., Woolwich, S.E.18.

RESISTANCES (FILAMENT).—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.

TERMINALS (SPECIAL TYPE).—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. M.A.P., Ltd., 246, Great Lister Street, Birmingham. Pettygrew & Merriman (1925), Ltd., 2 & 4, Bucknall Street, New Oxford Street, W.C.1.

TOOLS.—Goodwins M.A. Ltd., 2-4, Edmund Street, Birmingham.

TRANSFORMERS.—Ferranti Ltd., Hollinwood, Lancs.

TRANSFORMERS (L.F.).—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. W. G. Pye & Co., "Granta Works," Montague Road, Cambridge.

VALVES.—A. C. Cossor, Ltd., Highbury Grove, London, N.5. General Electric Co., Ltd., Kingsway, W.C. Marconiphone Co., Ltd., 210, Tottenham Court Road, W.1. Metro-Vick Supplies, Ltd., 145/147, Charing Cross Road, W.C.1. The Mullard Wireless Service Co., Ltd., Mullard House, Denmark Street, London, W.C.2.

VERNIER ATTACHMENTS.—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. M.A.P., Ltd., 246, Great Lister Street, Birmingham.

VOLTMETERS.—Radios, 218, Upper Thames Street, E.C.4. Sifam Electrical Instrument Co., 10a, Page Street, Westminster, S.W.1.

PREPAID PARAGRAPH ADVERTISEMENTS.

The charges for prepaid advertisements are as follows :—

AUCTIONEERS' & OFFICIAL ANNOUNCEMENTS.—*Advertisements under this heading are inserted at a charge of 11s. per single column inch.*

TRADE & MISCELLANEOUS.—2s. *for* 12 *words and 2d. for each additional word.*

PRIVATE SALE & EXCHANGE.—*Advertisements are inserted in this section at the rate of* One Penny *per word : minimum charge per advertisement* One Shilling. *All advertisements, without exception, must be prepaid to ensure insertion. Single letters or figures are charged as words, and a compound word as two words. The advertiser's name and address are charged for.*

" Box " replies, *care of these offices, are charged* 6d. *extra to cover postages. The following words must appear at end of advertisement : " Box—— EXPERIMENTAL WIRELESS Offices," for which usual rate will be charged. (Advertisers need not include our full address.)* When replying to a " Box No." advt., *address your envelope : Advertiser, Box ——,* EXPERIMENTAL WIRELESS & WIRELESS ENGINEER, *Dorset House, Tudor Street, London, E.C.4.*

Advertisers who wish to separate *their announcements into distinct paragraphs must have not less than* 12 *words in any one paragraph, followed by the word " Below "—which is charged for.*

Remittances should be made by Postal Order or Stamps, and sent to the Advertisement Manager, EXPERIMENTAL WIRELESS & WIRELESS ENGINEER, *Dorset House, Tudor Street, London, E.C.4.*

PRESS DAY.—EXPERIMENTAL WIRELESS & WIRELESS ENGINEER *is published on the first of each month, and copy for advertisements should reach the Advertisement Manager, Dorset House, Tudor Street, London, E.C.4, not later than first post on the 16th of the month preceding.*

COPY FOR ADVERTISEMENTS *is subject to the approval of the Proprietors, who retain the liberty to withhold any advertisement which they regard as unsuitable for publication in this journal. The Proprietors are not responsible for clerical or printers' errors, although every care is taken to avoid mistakes, nor will they accept responsibility for any blocks left in their possession for a period of more than 12 months.*

ORDERS & CHEQUES *should be made payable to* ILIFFE & SONS, LTD., *and crossed " and Co." Treasury Notes, being untraceable if lost in transit, should not be sent as remittances.*

ALL ADVERTISEMENTS MUST BE PREPAID.

OUR DEPOSIT SYSTEM.

We will receive from intending purchasers the purchase money of any article advertised or sold by our advertisers, and will acknowledge its receipt to both the Depositor and the Vendor, whose full names and addresses must be given. Unless otherwise arranged beforehand between the parties, it is understood that all goods are sent on approval, and that each person pays carriage one way if the goods are returned. The deposit is retained by us until we are advised of the completion of the purchase, or of the articles having been returned and accepted. In addition to the amount of the deposit, a fee of 1s. *for the sum of £1 and under, and* 1s. 6d. *for amounts in excess of £1 to cover postage, etc., must be remitted at the same time, and sent to the Advertisement Manager,* EXPERIMENTAL WIRELESS & WIRELESS ENGINEER, *Dorset House, Tudor Street, London, E.C.4. In cases of persons not resident within the United Kingdom, double fees are charged.*

The fee should be sent in Stamps or by Postal Order as a separate amount.

The amount of the deposit must be sent either by Postal Order or Registered Letter. (Cheques cannot be accepted.)

In cases of exchanges, money to the value of the article should be deposited by each party. We cannot receive the articles themselves.

PATENT AGENTS.

W. Bryson, B.Sc., Chartered Patent Agent, 29, Southampton Buildings, W.C.2. Phone : Holborn 672. [0110

A. P. Thurston, D.Sc., M.I.A.E., F.R.Ae.S., 369, High Holborn, W.C.1. Phone : Holborn 2542. Patents, Trade Marks, Designs. [0122

The Wireless AND RADIO REVIEW World

Covers Every Wireless Interest

EVERY WEDNESDAY

3D.

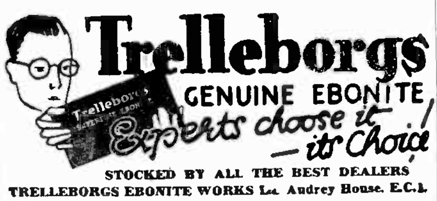
Publishers : ILIFFE & SONS LTD., Dorset House, Tudor Street, London, E.C.4

LISTENING-IN

to foreign stations is spoiled by the language difficulty, the only practical solution to which is Esperanto.

Send 6d for the " Radio Packet," which contains full particulars and a copy of the International Radio Manual, to the

BRITISH ESPERANTO ASSOCIATION, 142, High Holborn, London, W.C.1



STOCKED BY ALL THE BEST DEALERS
TRELLEBORGS EBONITE WORKS Ltd. Audrey House. E.C.1.

WOOD-HORNS

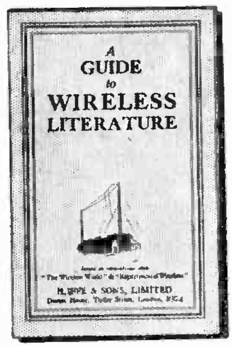
The Manufacturer is

H. MADDISON

2a, Ronald's Rd., Holloway Rd., HIGHBURY, N.5

There's only one best, " THE ALLWOODORN " is that one. Send for list, Lissenola-Amplion —T.M.C. units supplied complete with horn if desired.

INDEX TO ADVERTISERS.



SEND FOR YOUR

FREE COPY

TO-DAY!

THIS BOOKLET, " A Guide to Wireless Literature," contains particulars of some volumes issued in conjunction with " Experimental Wireless," and of particular interest and value to all advanced wireless workers. A FREE copy will gladly be sent on request to the Publishers :

ILIFFE & SONS LIMITED
Dorset House, Tudor Street
LONDON, E.C.4.

Printed for the Proprietors, ILIFFE & SONS, Limited, Dorset House, Tudor Street, London, E.C.4, by VACHER & SONS, Ltd., Westminster House, Great Smith Street, London, S.W.1.
Sole Agents for Australasia—GORDON & GOTCH (AUSTRALASIA), Ltd.
Sole Agen... AGENCY, Ltd.