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Editorials.

Who Invented the Neutrodyne?

PERHAPS it would be advisable if, before attempting to answer this question, we asked another, viz., what is a Neutrodyne? Both of these questions are prompted by the recent visit to this country of Professor Hazeltine of the United States of America, who was entertained to lunch at the Savoy Hotel by a wireless trade paper of which Mr. Scott-Taggart is Editor, and who in the course of a subsequent speech made some very complimentary remarks about his host, which remarks are set out with suitable headlines in a recent number of one of Mr. Scott-Taggart's publications. Not without reason, however, for Professor Hazeltine is stated to have said that " while we in America call the receiver the Hazeltine neutrodyne, we should in England call it the Scott-Taggart neutrodyne."

The financial importance of the neutrodyne patents may be judged from the astounding statement that Professor Hazeltine and his associates in the Hazeltine Corporation draw patent licence fees to the extent of £120,000 per annum.

We propose to sketch briefly the history of the subject.

British Patent No. 119365 of 1918 is in the name of the British Thomson-Houston Co., but was communicated to them by the General Electric Co. of America. The inventor was, we believe, Mr. Rice. It is entitled: " Improvements in and relating to Systems for Amplification of Small Currents," and the specification opens as follows: " Our present invention relates to the amplification of electric currents of small intensity and especially currents such as are produced in an antenna by received radio signals. More particularly it relates to the use of electron discharge relays, detectors or amplifiers of the type employing an incandescent cathode or anode and a grid enclosed in an evacuated envelope for receiving radio signals.

" It has been found that under certain conditions a device of the above type produces oscillatory currents in the circuits associated therewith, and in many cases the oscillatory currents so produced interfere with the efficient reception, amplification and detection of the signals to be received. The object of our invention is to avoid the undesired production of oscillatory currents when such a device is used either as an amplifier or detector, or to serve both functions.

" It has been ascertained that the production of oscillatory currents by such a device is due to the coupling which is always present between the grid and plate circuits. This coupling is of two kinds, electromagnetic and electrostatic. When the plate and grid circuits both contain air core inductances which are not magnetically shielded from each other there will be a large leakage flux between the two and electromagnetic transfer of energy from the plate circuit to the grid circuit which may be sufficient to produce oscillations in the circuits even though the coils may be located at some distance from each other. There is in any case a certain electrostatic coupling between the two circuits by reason of the capacity between the electrodes and the capacity to ground of the circuits. This coupling alone may also be sufficient to produce oscillations. It has been proposed to neutralise the electromagnetic coupling by a second electromagnetic coupling in the opposite direction. This coupling may also be made great enough to compensate for the capacity coupling, but in case it is so arranged it will be correct only for one particular frequency and in case the tuning of either of the circuits is varied the degree of the coupling also will have to be varied.

" In carrying our invention into effect we overcome the electromagnetic coupling between the circuits which is present when air core inductances are used by enclosing the inductances in separate metal boxes. We also overcome the effect of the electrostatic coupling by impressing upon the circuits electromotive forces equal to and opposite in direction to those impressed thereon by reason of the natural capacity coupling and thereby neutralise the effect of this coupling. When this compensation is once adjusted it is effective for all frequencies to which the circuits may be tuned."

We need not continue this detailed quotation from the Patent Specification, but we may mention that the neutralisation of capacity coupling is shown both for a single valve receiver and for a three valve receiver with two stages of high frequency amplification. No claim is made for putting the coils in metal boxes, but it is stated that the coils " are so arranged as to avoid any magnetic coupling between the two circuits." We shall only reproduce the first claim which is as follows : " In a radio receiving system, an electron discharge amplifier having resonant grid and plate circuits and means for compensating for the capacity coupling between said circuits and thereby preventing the generation of oscillatory currents in said circuits which interfere with the reception of desired signals." It would take us too far in this Editorial note to discuss in detail the means described for attaining this object, but the principle will be seen from the statement in the specification that " in order to compensate for the coupling due to the natural capacity (12) between the grid and anode . . . we apply to the grid circuit through the condenser (13) an electromotive force equal and opposite to that impressed upon the grid from the anode across the capacity (12). In order to do this the cathode is connected to the central point of inductance (4), the grid is connected to one end of this inductance and condenser (13) is connected to the other." So that we have here in 1918 a fairly lucid statement of the problem and a method of solving it, using the now familiar neutralising condenser and central tapped inductance.

We do not pretend to give any opinion on the validity of this patent or of its individual claims, but we do wish to emphasise that this patent with its statement of the problem and its incentive to develop other methods of solving it, was applied for on 2nd January, 1918, and finally accepted on 3rd October, 1918, whereas Hazeltine's application was filed on 7th August, 1919, and not finally patented until 27th March, 1923. There are other Hazeltine patents, but we believe that we are right in saying that this is the first one referring to this subject ; it is entitled " Method and Electric Circuit Arrangement for Neutralising Capacity Coupling." We need not describe Hazeltine's method as it is well known ; like the original method of the B.T.-H. Co.'s patent it involves an arrangement of tapped inductance coils and neutralising condensers. The name " Neutrodyne " has been registered by Hazeltine and can strictly only be applied to his patented arrangement ; other arrangements for attaining the same result should therefore be described as neutralised or capacity-balanced or some such term. Mr. Scott-Taggart's application for a patent was not made until 2nd January, 1923, exactly five years after the B.T.-H. Co.'s application, and three and a half years after Hazeltine's, but as the latter's patent was not published in this country until 5th April, 1923, Mr. Scott-Taggart's patent takes priority in so far as it may anticipate anything in the Hazeltine patent.

Now although the B.T.-H. Co.'s patent specification shows a three valve set it omits the neutralising condenser shown in the single valve set, on the plea that "we have found that if coils having a large number of turns are employed, the capacity between the coils is so great in comparison with the capacity (12), that the effect of the latter may be neglected." Mr. Scott-Taggart's patent is therefore mainly confined to "a plurality of stages," and he had to insert a statement to the effect that he was aware of Specification No. 119365, and that he made no claim to anything described or claimed therein. The patent situation has been somewhat simplified by the sale of the Scott-Taggart patent to a person who turned out to be an agent of the Hazeltine Corporation.

With reference to Mr. Scott-Taggart's complaint that although "the Scott-Taggart patent had been published in June, 1923, in *Wireless Weekly*, and the British industry was fully aware of the inventor's claims, not a single firm approached the owner of the patent," it is interesting to note that the patent was not accepted until 2nd July, 1924, and that it was taken out in the joint names of Mr. John Scott-Taggart and Radio Communication Co., Ltd.

We do not intend to enter into any discussion as to the relative merits of the three patents,—such a discussion would be out of place,—but we think that we have given sufficient of the history of the subject to enable any reader to form his own opinion as to who it was, that in 1918 invented the neutralisation of the valve capacity, and who it was that in the following year first invented the special arrangement of neutralisation known by the name of neutrodyne.

Cathode Ray Tubes.

CONSIDERABLE attention has been devoted in recent times to the cathode ray tube, especially to its use as an oscillograph and general high frequency accessory. The well-known Western Electric tube has done much to lift this type of instrument from the grade of a laboratory experiment to an engineering device, and places an instrument of great potentialities in the hands of the wireless engineer. It must be said, however, that there is yet room for development, more especially of increased deflectional sensitivity, which is concomitant with lower anode voltages. Details are already to hand, from America, of a tube giving what is described as a bright beam at the modest potential of 50 volts. The whole subject is one worthy of more attention by makers in this country. Apart from its value as a purely measuring instrument and laboratory accessory, there are considerable possibilities in these tubes as regards their application to more ordinary wireless technique. The ideal to be aimed at is a tube of the dimensions of a large receiving power valve, perhaps even of a small transmitting valve, operating on voltages readily available at any wireless station. Perhaps the time will come when such tubes may be handled as casually as the average wireless man now handles his valves.

Power Losses in Insulating Materials.

IN *E.W. & W.E.* of May, 1925, Mr. Wilmotte, in a paper entitled "Parasitic Losses in Inductance Coils at Radio Frequencies," pointed out that phase angle in itself was not a sufficient criterion of the quality of a dielectric with respect to losses but that the true criterion was the product of the phase angle and the dielectric constant. Our attention has been drawn to the fact that this was emphasised by Mr. E. T. Hoch in a paper entitled "Power Losses in Insulating Materials," published in November, 1922, in Vol. 1, No. 2 of the *Bell System Technical Journal*. In this article Mr. Hoch says: "While no single factor of the expression can be used to represent the losses, the product of phase difference and dielectric constant can be used in this way. Furthermore, for most good insulators, this product remains fairly constant throughout a considerable range of voltage and frequency."

The Keying of Valve Transmitters.

By W. T. Ditcham, A.M.I.E.E. [R385

AT first sight the three-electrode valve appears so peculiarly adapted for easy signalling control that there would seem to be little to do to carry out a satisfactory method of keying.

As a matter of fact a completely satisfactory solution of the problem presents considerable difficulties, more particularly when signalling with large powers has to be accomplished, and although the transmitting amateur has not these particular high power difficulties to contend with, a description of various methods that have proved serviceable in commercial practice may be of interest to the experimenter.

In any keying method, whether the power is large or small, the ideal to be aimed at is that the signalling shall not appreciably affect the frequency of oscillation. If this condition is not fulfilled then it will be found that the dots are radiated on a different wavelength to the dashes, and probably that the dashes vary in wavelength throughout their length, giving a peculiar wailing note in the receiver. Constant frequency is essential in long range commercial work where sharply tuned note filters are necessary at the receiving end to reduce interference. In the case of commercial transmitters the keying system must usually be capable of operating at high speed, and when large powers are in question then it is vital that the keying does not cause dangerous voltage surges on the valves.

Valve transmitters can be classified into two main divisions :—

(*a*) Self-excited oscillators,

(*b*) Magnifiers excited by a master oscillator,

and these two groups can be further differentiated according to whether they operate on plain aerial or with coupled circuits, and whether the power supply is provided by direct current or rectified alternating current.

To each of these types different methods of keying are particularly applicable.

Considering the simplest type first, namely, the self oscillator with plain aerial, the most obvious method of keying is to open and close the grid resistance, and preferably simultaneously make and break the power supply. Numerous small power sets have been constructed with this signalling arrangement, but except for simplicity there is nothing in its favour, the note quality generally being very poor. A possible alternative is to use the key to vary the value of the grid resistance or grid-leak condenser, which operation causes a slight change in wavelength. In this arrangement the valve is not caused to stop oscillating, but marks are transmitted on one frequency and spaces on another. The method gives good quality and small key sparking, but is not likely to find favour nowadays when wavelengths are so precious.

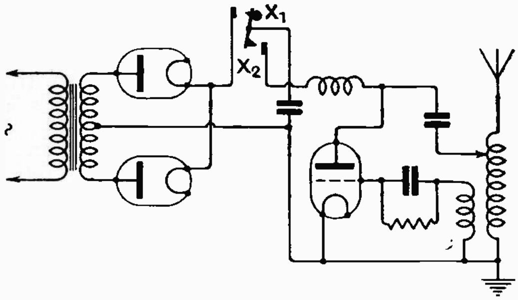


Fig. 1. *A plate keying circuit used on primitive transmitters.*

Better results are obtained with these simple transmitters by keying in the plate circuit, and this method has been much used. As the normal transmitter of power exceeding half a kilowatt or so almost always operates on a rectified alternating current supply with a smoothing circuit, although a few sets have been used employing polyphase currents fed directly to the oscillator anodes, and several high power stations work with high tension D.C., we will review a few plate circuit signalling methods suitable for this type of set. It may be noted in passing that keying cannot be carried out by simply breaking the primary of the power transformer of such a set, as the smoothing condenser will go on discharging and maintaining the valve in oscillation after the key has opened, so that except at very low speeds the signals will be so blurred as to be useless for traffic.

A method which had considerable application in sets up to some five kilowatts power is shown in Fig. 1.

In this arrangement a double-break solenoid-operated key served to isolate the smoothing condenser from the supply, and also from the oscillating valve. The reasons for the necessity of the two breaks should be understood. Clearly if the circuit was broken only at the point X_1 in the diagram then the blurring effect mentioned above would take place, and if the key was arranged to break at the point X_2 only, then the condenser would remain connected to the rectified input with no means of discharging. This would result in the condenser becoming charged to a potential equal to the peak voltage of the transformer, a voltage that might be nearly twice the normal working value. On the key reclosing obviously this high voltage would be thrown on to the valves causing a transient frequency variation, and possible damage to the oscillator. This condenser voltage rise has always to be taken into account when rectified alternating current is employed, and the valve load is removed during signalling. Fig. 2 shows an improvement, inasmuch as the primary power is also interrupted, a double armed signalling switch being employed.

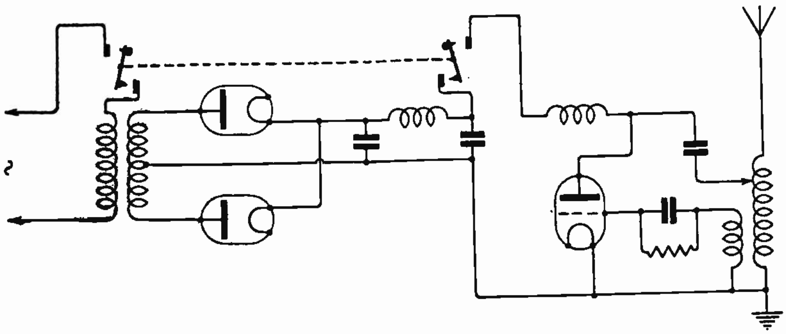


Fig. 2. *Simultaneous keying of primary and plate currents.*

It has been found that the quality of the keying note from a self-oscillating transmitter is improved if, instead of completely stopping the oscillations, the valve is allowed to continue oscillating weakly during the spacing intervals. A circuit which permits of this is shown in Fig. 3.

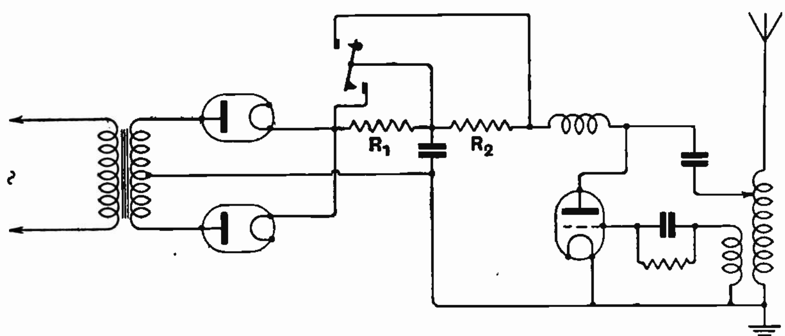


Fig. 3. *A keying circuit in which the valve can oscillate weakly during the spacing intervals.*

By suitably proportioning the two resistances R_1 and R_2 the voltage on the smoothing condenser can be maintained constant whether the key is open or closed. A variant of this method is represented in Fig. 4, where a double ended switch simultaneously operates across a high resistance in the plate circuit and a variable choke in series with the transformer primary. As before, by adjustment of the resistance and choke the condenser voltage can be kept steady during keying. This method has been used successfully with powers up to about twenty kilowatts, and at speeds of sixty words per minute.

In this arrangement L_1 and L_2 are two coupling coils connected in such a manner as to induce an equal and opposite voltage in the aerial inductance, so that under these conditions the aerial current is practically zero. Across one of these coupling coils is connected a single contact key and when this is closed obviously the coupling balance is upset and the energy in the primary circuit

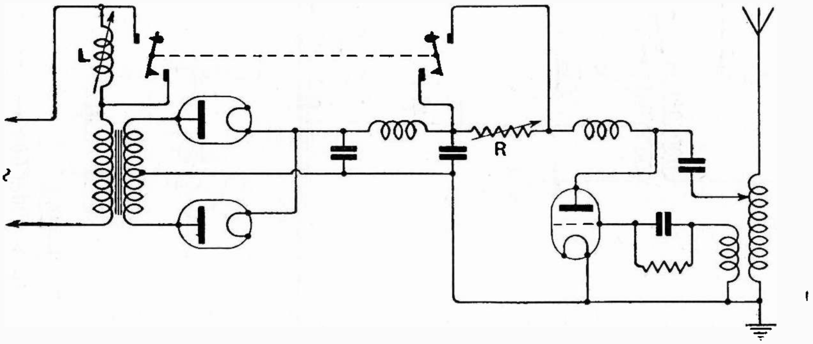


Fig. 4. *Another keying circuit which produces a spacing wave.*

All these high tension keys require an air blast across the breaks to blow out the arcs formed, and suffer from the disadvantage that contact adjustments cannot safely be made while the transmitter is in operation.

The plain aerial type of self oscillator has little application nowadays, as the wave-

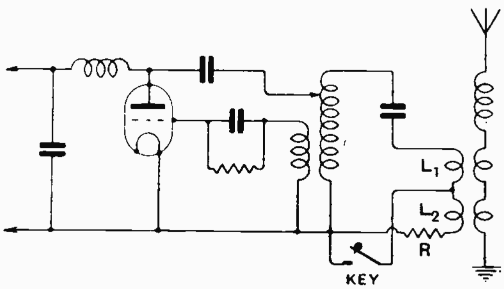


Fig. 5. *A keying method used in coupled circuit oscillators.*

length is too greatly affected by aerial movement, and the strength of the harmonics radiated is undesirable.

The coupled circuit transmitter permits of another method of signalling suitable for medium power, which has several advantages over those previously described. Fig. 5 will make this method clear.

is transferred to the aerial. In this method when the key opens the aerial load is removed from the primary circuit, and consequently the current in this circuit will increase considerably and in some cases may break down or flash across the primary condenser. To avoid this trouble a resistance marked *R* in the diagram is connected as shown, and adjusted in value so that the primary current remains unchanged. In this arrangement the voltage across the break is quite low, so that only a small contact movement is necessary, making for high speed, and adjustments can safely be made during operation. This method has been used commercially in transmitters up to about twenty kilowatts input, with air-engine driven keys capable of well over one hundred words per minute, and would probably have been widely employed but for the advent of the master oscillator or independent drive system which renders practicable simpler and cheaper keying apparatus.

Given a transmitter comprising a driving oscillator and a magnifier, the simplest signalling system is obtained by keying the grid resistance of the magnifier as indicated in Fig. 6.

When the resistance is open circuited the drive oscillations, due to the rectifying action of the magnifier valve, build up a high negative voltage on the grid of this valve, effectually stopping plate current from flowing. With small power sets very good results are obtainable with this simple method.

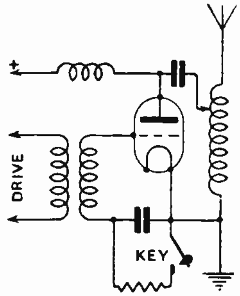


Fig. 6. *Method suitable for small power transmitters using an independent drive.*

Several of the Atlantic liners are fitted with transmitters keyed in this manner, and can despatch traffic at over one hundred words per minute.

A refinement on this method is to replace the grid resistance by the plate to filament resistance of a three-electrode valve, and signal by varying the potential on the grid of this valve ; see Fig. 7.

The key for this circuit can be so light and the contact movement so small that extremely high signalling speeds are attainable.

For sets of higher power somewhat more complicated arrangements are necessary,

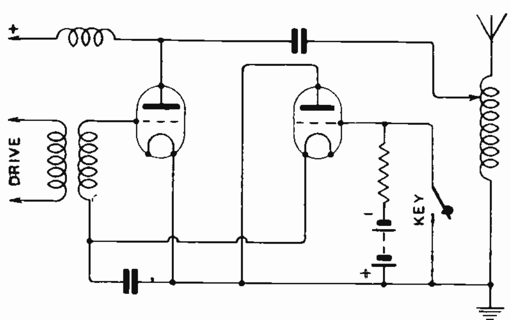


Fig. 7. *A method permitting very high signalling speeds.*

and one of the most practical is disclosed in Fig. 8.

This method is reminiscent of the Fig. 5 method inasmuch as the keying is done across one of two balanced and opposed coupling coils, but in this case the coils couple the drive oscillatory circuit to the grid of the magnifier V_1. A suitable negative bias is put on the magnifier grid, so when the key opens the contacts X_1, and the opposed coupling coils come into action the plate current is stopped, and, of course, the oscillations cease. To prevent the voltage rise when the oscillatory load is removed, an absorber valve V_2 and a resistance R_1 form part of the keying system. The absorber V_2 has a constant negative potential applied to its grid through a high resistance R_2, while a positive potential, usually generated by a small dynamo, can be applied through a second pair of contacts X_2 on the key. It will be observed that with X_1 closed and X_2 open the absorber has no effect on the

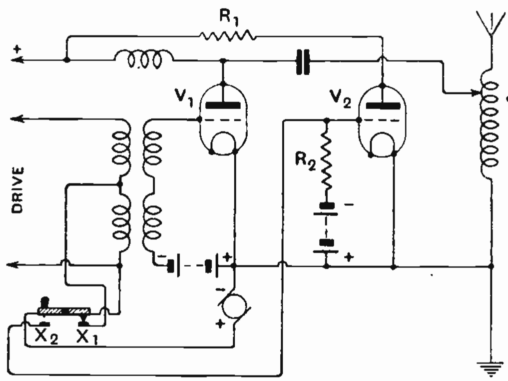


Fig. 8. *A modern method used in various commercial stations.*

circuit, but when the key opens X_1 and consequently closes X_2, the absorber grid becomes positive and plate current passes, its amount depending principally upon the value of the resistance R_1. The resistance of the valve V_2 can be made very low in this way, and therefore the actual loss in the valve is also small, the major portion of the energy absorbed being dissipated in the resistance R_1. With suitable adjustments there is no difficulty in keeping the smoothing condenser volts practically constant whether the key is on " mark " or " space." This method is used successfully at a number of long range high speed commercial stations, among them the Marconi Company's stations at Ongar, Essex.

As previously remarked, up to the present almost all medium power transmitters have relied upon rectified alternating current for the requisite high tension plate voltage, due to the fact that high voltage direct current dynamos of these powers have not been developed to the same degree of reliability as the alternator and static transformer combination, but in the case of large machines this drawback does not apply, and certain high power transmitters, the Marconi station at Carnarvon and the new Post Office station at Rugby among them, employ directly generated high tension and thus save the cost of the large number of rectifier valves that would otherwise be necessary.

The keying of these high power sets is by no means an easy matter. Owing to the fact that the high voltage dynamos possess a large self inductance, and that the plate current of the transmitter is considerable—at Carnarvon, for instance, it may exceed twenty amperes—it will be appreciated that the sudden stoppage of this current will result in very high voltage transients which can easily damage the valves. For this reason grid keying methods are unsuitable as giving too sudden a reduction in the plate current. Keying by breaking the main plate current with an air blast on the key contacts is possible, as when the key opens a gradually increasing resistance, in the form of the arc between the contacts, is inserted into the plate circuit so that the current falls with a certain time lag, which can be conveniently adjusted by the strength of the air blast. Over two hundred kilowatts has been successfully keyed like this, but it is difficult to construct a key suitable for such work which can operate for long periods at more than about eighty words per minute, a speed considered rather low in modern commercial practice.

This branch of the subject is too complicated to be more than just touched upon in this article, but judging from the results of numerous experiments one is inclined to doubt whether transmitters of this type can be keyed satisfactorily except by maintaining a considerable portion of the load on the dynamo during the " space " periods, and thus nullifying the inductive voltage surges. This implies that instead of interrupting the current from the machine, means must be provided for diverting it from the valve anodes to some absorbing circuit without any break as regards the dynamo output.

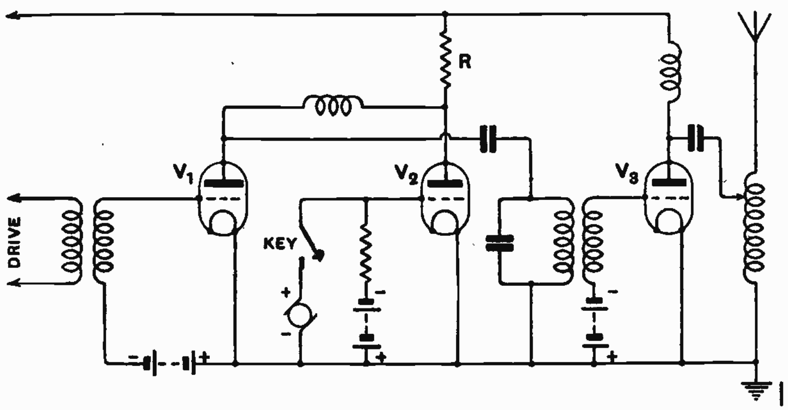


Fig. 9. *Keying method applicable to high power transmitters.* V_1 *is the intermediate magnifier,* V_3 *the main magnifier, and* V_2 *the absorbing valves.*

A method which satisfactorily incorporates this principle is set out in Fig. 9.

Here is shown a three-stage transmitter consisting of an independent drive, an intermediate magnifier, and the final or main magnifier, these two latter being supplied from a common source of high tension. The signalling apparatus comprises a bank of valves indicated as the absorber and a single contact key with associated sources of potential arranged so as to enable the absorber grids to be made positive or negative at will. A resistance *R* is seen to be common to the plate circuits of both the intermediate magnifier and the absorber, but not to the final magnifier plate.

This resistance is of such a value that the comparatively small plate current of the intermediate magnifier causes a voltage drop that does not prevent the required power being applied to this stage, so with the key open and the absorber grids consequently negative, the transmitter functions normally. When the absorber grids are rendered positive by closing the key, however, the intermediate magnifier is practically short circuited with the result that the plate current ceases immediately in the final magnifier, which it will be noted is provided with a fixed negative grid bias. By suitably proportioning the absorbing resistance and the absorbing valves any desired fraction of the main energy can thus be dissipated as a " spacing " load, with a consequent amount of relief to the dynamo windings from current fluctuations.

This article only deals with keying methods which have been used and are applicable to transmitters working on normal wavelengths, and at the present normal commercial speeds. The means and methods for obtaining the extraordinary high sending speeds possible with the modern short wave transmitters may form the subject of a future article when the experimental and patent work has been further developed.

Department of Scientific and Industrial Research. [R218

Transmissions of Wireless Waves of Standard Frequencies from the National Physical Laboratory (Station Call Sign 5HW).

DURING the last three years waves of accurately known frequency have been transmitted on the recommendation of the Radio Research Board of the Department, from the W reless Station at the National Physical Laboratory, to provide a means of checking the calibration of wave metres and other apparatus.

This transmission has consisted of eight waves covering a range of 360 to 60 kilocycles per second (833 to 5,000 metres wavelength). It is transmitted between the hours of 15.00 and 16.00 G.M.T. on alternate Tuesday afternoons.

In order to increase the usefulness of this service, arrangements have been completed, after consultation with the Post Office and others interested, for the present transmissions to be greatly extended. The new transmissions will include 16 waves. These will be transmitted in two sections, each section being transmiited once each calendar month. One part will be transmitted on the first Tuesday in the month between 15.00 and 16.00 G.M.T., while the other part will be transmited on the third Tuesday in the month between the same hours.

The system of the transmissions will be provisionally as follows :—

1. An announcement will be made in morse on plain C.W. on a wavelength of 1,500 metres that a transmission of standard waves is about to take place. This announcement will be made at 14.55 G.M.T.

2. Each standard wave will be transmitted as follows :—

(*a*) *Short Wave Programme on the first Tuesday in each month.*—The letter N followed by a number identifying the wave. This will be repeated three times and will then be followed by a dash lasting 40 seconds.

Four such dashes will be thus transmitted, each preceded by the identifying letter and number.

As far as possible the dash will begin at 20 seconds past the appropriate minute and will continue to the end of minute.

An interval of 4 minutes will elapse when the next wave of the series will be transmitted in exactly the same way.

(*b*) *Long Wave Programme on the third Tuesday in each month.*—This will be transmitted in exactly the same way as the Short Wave programme, but the identifying letter will be M. The actual programme is set out in Tables I. and II.

TABLE I.

SHORT WAVE PROGRAMME.

G.M.T.	Signal Transmitted.	Frequency, kC per sec.
14.55-15.00	Announcement in morse ...	200
15.00-15.04	N1, N1, N1,—40 sec. dash—transmitted 4 times ...	960
15.04-15.08	Silence	
15.08-15.12	N2, N2, N2,—40 sec. dash—transmitted 4 times ...	840
15.12-15.16	Silence...	
15.16-15.20	N3, etc., as above	700
15.24-15.28	N4, ,, ,, ...	580
15.32-15.36	N5, ,, ,, ...	500
15.40-15.44	N6, ,, ,, ...	360
15.48-15.52	N7, ,, ,, ...	300
15.56-16.00	N8, ,, ,, ...	260

During the pauses dashes may be heard whilst the settings and adjustments of the circuits to the next wave of the series are being made. These dashes must not be taken as part of the programme.

The announcement will consist of the general call-sign CQ de 5 HW repeated a few times and followed by the words "Short (or long) Standard wave frequency transmissions, stand by."

On one or two months in the year in which there are five Tuesdays an interval of three weeks will elapse between the transmission on the third Tuesday in that month and the next succeeding transmission.

TABLE II.

LONG WAVE PROGRAMME.

G.M.T.	Signal Transmitted.	Frequency, kC per sec.
14.55-15.00	Announcement	200
15.00-15.04	M1, M1, M1,—40 sec. dash—transmitted 4 times ...	200
15.04-15.08	Silence...	
15.08-15.12	M2, etc., as above	160
15.16-15.20	M3, ,, ,, ...	115
15.24-15.28	M4, ,, ,, ...	86
15.32-15.36	M5, ,, ,, ...	66
15.40-15.44	M6, ,, ,, ...	50
15.48-15.52	M7, ,, ,, ...	40
15.56-16.00	M8, ,, ,, ...	30

The frequencies transmitted will be highly accurate so that it will be unnecessary to transmit any corrections. The transmission of the actual frequency will therefore not take place, since the identifying letter and number serve this purpose.

The aerial current will be recorded but will not be transmitted. Information regarding the value of the current on any particular occasion will be given on request.

A few notes relative to the reception of these waves are appended.

Reception of Standard Waves.

It is presumed that the instrument under calibration by means of the waves is a self-generating valve oscillator of smoothly variable frequency. It is further essential that a tunable receiving set with detecting arrangements and headphones should be used in conjunction with the heterodyne source. The most accurate means of calibration is to set the heterodyne source until the beat tone heard between it and the incoming standard wave has a pitch equal to that of a small tuning-fork of known pitch. This will be unnecessary in the higher frequency waves but in the case of the longer waves the belt of frequency within which no beat tone is heard will represent more than one part in a thousand, whereas by using a definite beat tone of, say, 1,000 cycles per second the sensitivity of the receiving set will be high and the accuracy of setting will be much greater than can be read on the heterodyne unless it is of exceptional construction.

The frequency of the beat tone must, of course, be added to or subtracted from, that of the standard wave frequency according to which side the heterodyne source has been set. It is convenient to set the heterodyne first higher and then lower than the incoming wave using the tuning fork to obtain equality of pitch on the two sides. The frequency of the tuning fork need not then be known. The mean of the two readings on the heterodyne condenser corresponds exactly to the transmitted frequency.*

An examination of the frequencies included in the transmissions will reveal the fact that, except for a few frequencies far apart, they are not exact multiples of one another.

On this account it is possible to obtain calibrating frequencies intermediate between those actually transmitted. Thus on the long wave programme the heterodyne could be set at a frequency of 33kC. per sec. when the standard wave of 66kC. per second was under transmission. The second harmonic of the heterodyne at 66kC. per sec. will give a well defined beat with the standard wave of 66kC per sec.

The following intermediate frequencies can all be obtained in this manner without difficulty:—

Second Harmonics—33, 43, 57.5, 80, 100, 130, 150, 180, 250, 290, 350, 420, 480.

Third Harmonics—38⅓, 53⅓, 66⅔, 86⅔, 100, 120, 166⅔, 233⅓, 280, 320.

Further harmonics of the heterodyne source can be utilised, if desired, but the above series, together with the fundamental frequencies transmitted, enable nearly 50 calibration points to be obtained over the range of 10,000 to 320 metres covered by the transmissions.

Shorter wave heterodyne oscillators can, of course, be calibrated by the harmonics of an intermediate wave oscillator itself calibrated from the short standard waves. The length of the dashes and their number should enable the double adjustment to be made, first of the intermediate wave oscillator to the standard wave, and then of the short wave oscillator to the harmonic of the intermediate wave source. If this is done on one occasion no responsibility of constancy of frequency will rest upon the intermediate wave source.

The transmissions here announced will commence on 7th September with the short wave programme and will thereafter follow the sequence given.

17th August, 1926.

16, Old Queen Street,
Westminster, S.W.1.

* This assumes that over the range of condenser used there is a linear relation between capacity and frequency. If any other relation holds a small correction will be necessary to obtain the highest accuracy.

Radio-Wien.

The New High-power Vienna Broadcasting Station.*

By Prof. G. W. O. Howe, D.Sc. **[R616·5**

THE new broadcasting station at Vienna, which had been under construction for about a year, was formally opened on 30th January last. The importance attached to the occasion by the Telefunken Company, to whom the Austrian Company had awarded the contract for the complete station, is shown by the galaxy of well-known German radio engineers who were present at the function; these included Count Arco, Dr. Schapira, Dr. Rukop, Dr. Meissner, Dr. K. W. Wagner in addition to Dr. Bredow, who is the German Secretary of State, equivalent to our Postmaster-General.

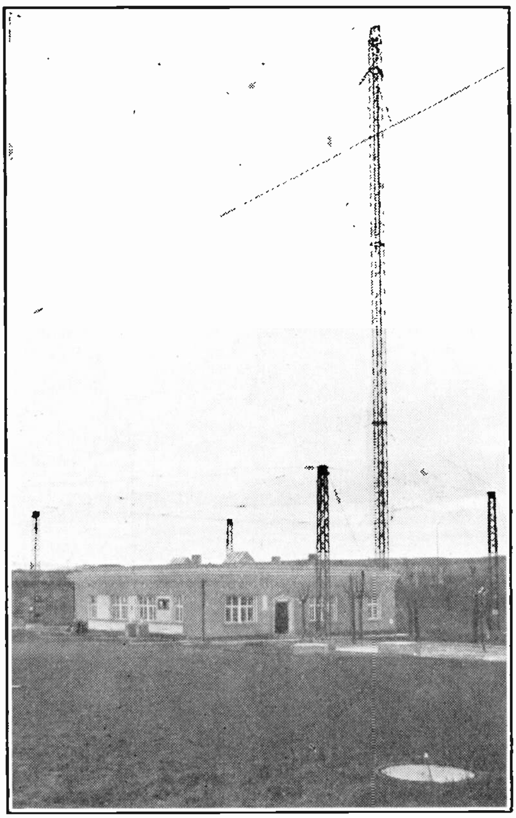


Fig. 1. *The station buildings.*

The station is erected over the old reservoirs on a hill (Rosenhügel) to the south of the city; the studio is in the city itself. The power is about ten times that of the old

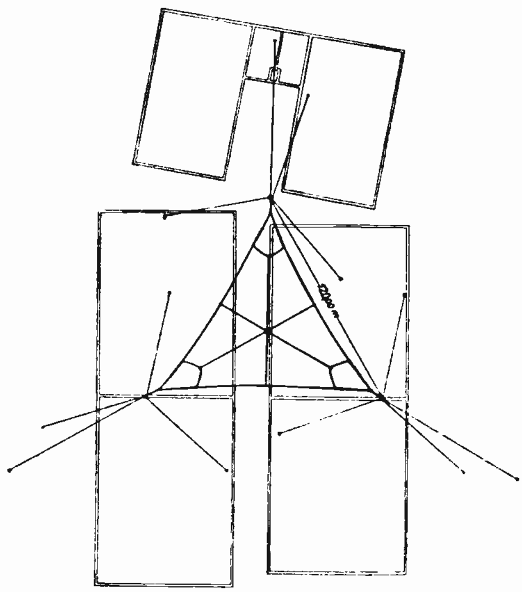


Fig. 2. *Plan of aerial.*

transmitter; for telegraphy the power supplied to the aerial on a long dash is 20kW, but for telephony this is reduced to about 7kW when not being modulated. The masts and buildings are actually erected over the arches and pillars of the reservoirs, as shown in Figs. 2 and 3. The site is considered to be a very favourable one. The three square

* From the information published in *Telefunken Zeitung*, Jan., 1926, and *Elektrotechnik & Maschinenbau*, 7th Feb., 1926, and from data kindly supplied by the Telefunken Co.

steel lattice masts 85 metres high and of 4 ft. 7 in. side, are situated at the corners of an equilateral triangle of 120 metres side; each mast weighs 50 tons and is supported by three sets each of three stays; they are insulated from the earth by means of porcelain insulators.

The station building is of one storey, 18×18×4 metres, and is connected by a special cable with the studio in the city.

The flat triangular aerial (Fig. 2) of stranded phosphor bronze wire has a 6-wire sausage-type down lead to the buildings which are situated symmetrically below the aerial. The earth-screen or counterpoise (Fig. 3) consists of a large number of radial wires carried by 12 posts at a height of 8 metres. The aerial capacity is about 1,500 cms., and its natural wavelength about 500 metres. It is tuned to the desired working frequency by a set of shortening condensers operated by a multiple contact switch (10)* and more accurately by a variometer; the aerial also contains the secondary

* These numbers in brackets refer to the various items in Fig. 6.

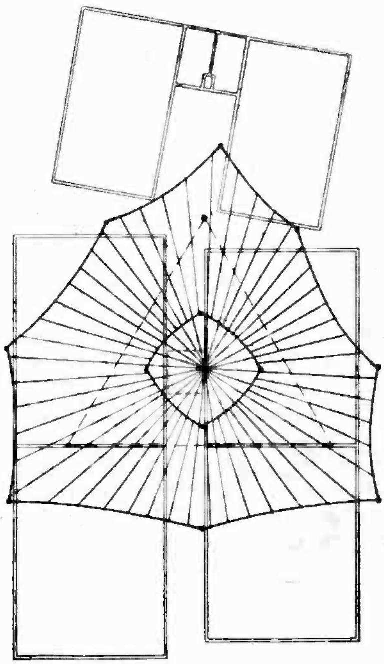


Fig. 3. *Plan of counterpoise.*

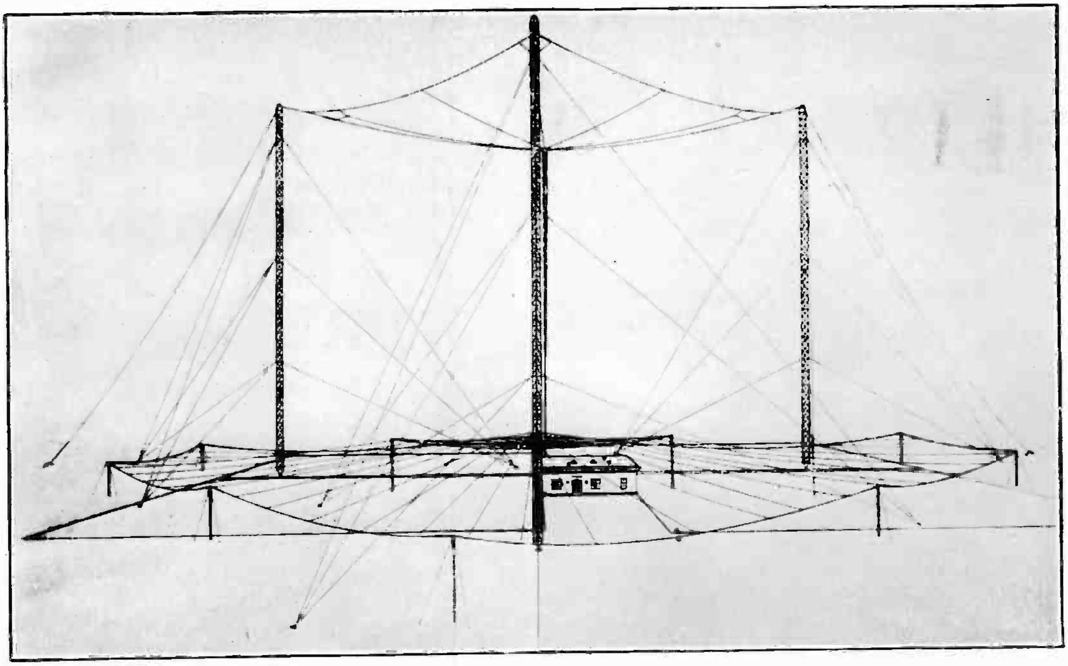


Fig. 4. *Schematic view of aerial and counterpoise.*

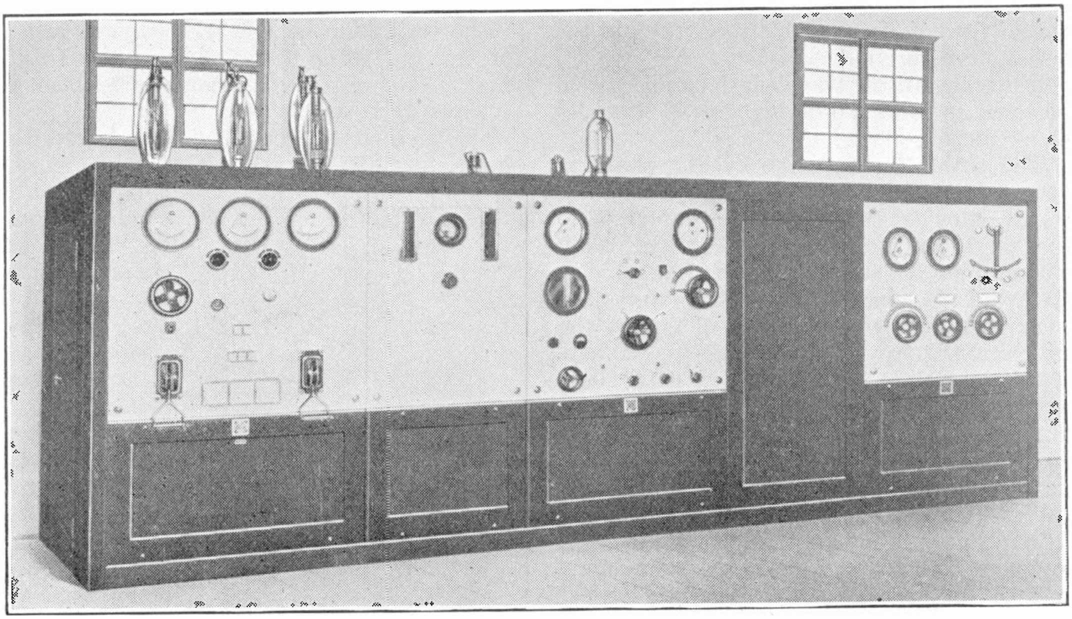


Fig. 5. *General view of transmitter.*

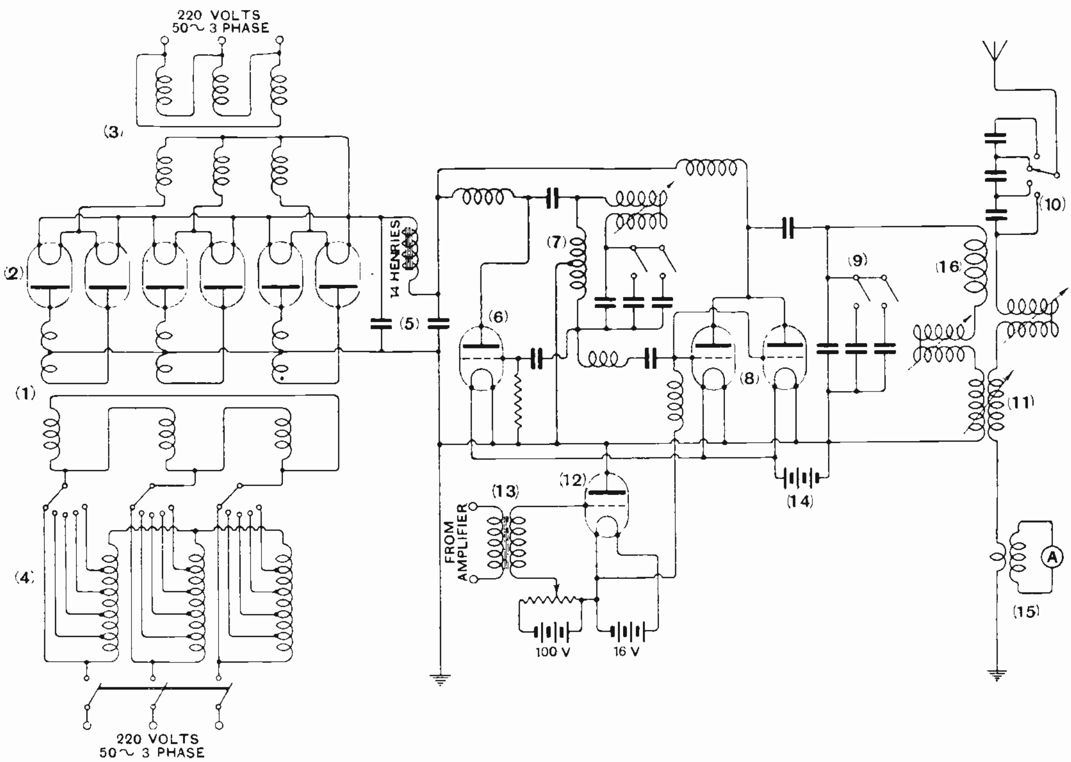


Fig. 6. *Connections of the transmitter. The numbers in brackets are explained in the list at the foot of the next page.*

coil of the coupling transformer (11) and the aerial ammeter (15).

The transmitting wavelength can be varied between 450 and 900 metres, but is normally 582.5 metres.

The power supply is 50 cycle 3-phase at 220 volts; it passes through an auto-transformer (4) with multiple tappings to the mesh-connected primary of the main transformer (1) the secondary of which has six windings, each giving 8,800 volts and each connected to the anode of one of the six rectifying valves. The filaments of these rectifying valves (2) are heated with alternating current from the step-down transformer (3), each filament taking 16 amperes at 32 volts and giving a total electron emission of about 3 amperes. The rectifying valves (Fig. 7) are the Telefunken Type RG61, suitable for continuous voltages up to 20,000, but in the present case the anode voltage is only 10,000. The total direct current power required is about 28 kilowatts, *i.e.*, 2.8 amperes at 10,000 volts, so that the average current per rectifier is only 0.47 ampere; the emission current of 3 amperes is necessarily much greater than this because each valve only passes current during a fraction of the cycle. By means of the tapped auto-transformer the voltage supplied to the main transformer can be reduced from 220 down to 90 volts.

The two smoothing condensers (5) are paper condensers of 4μF each and the smoothing choke coil of 14 henries has an open iron core to prevent the continuous current from magnetising it too strongly and thus reducing its inductance to the ripple frequency.

The oscillations are produced by the valve (6) and the circuit (7), the main power valves (8) acting as amplifiers with a tuned anode circuit (9) to which the aerial is coupled by the transformer (11). The amplified speech current received from the studio acts through the transformer (13) on the modulating valve (12) which varies the potential of the grids of the main power valves, and thus modifies their power to amplify the output of the oscillating valve (6).

The oscillation generator is a 1kW valve for 10,000 volts, Telefunken type RS47 (Fig. 8) requiring a filament current of 8 amperes at 16 volts.

The method of back coupling is clearly shown in Fig. 6. To vary the wavelength the condenser can be varied in six steps, and the inductance can be varied continuously by means of a variometer with a range from 15,000 to 80,000 cms., the fixed inductance being 160,000 cms. (1 microhenry = 1,000 cms.).

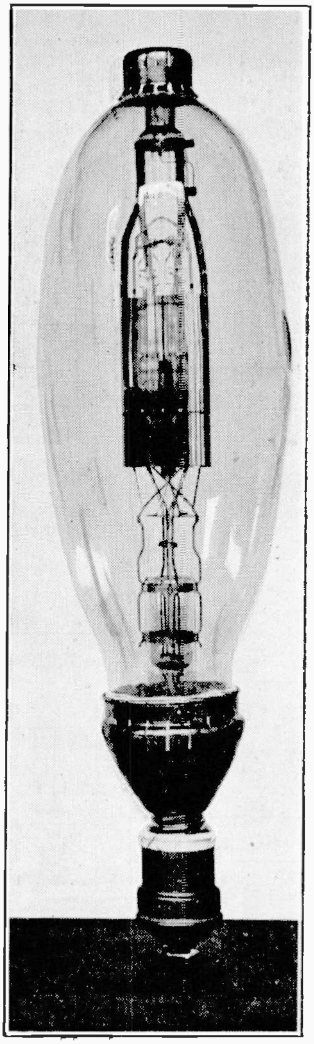


Fig. 7.
The rectifying valve RG61.

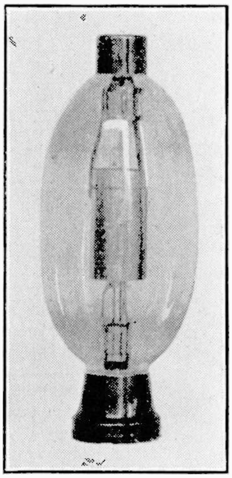


Fig. 8.
The oscillation generator valve RS47.

Explanatory details to transmitter connections given in Fig. 6: (1) Main transformer, (2) Rectifiers, (3) Filament heating transformers, (4) Tapped auto-transformer for varying the power, (5) Smoothing condensers, (6) Oscillator valve, (7) Oscillator valve circuit, (8) Main power valves, (9) Circuit of power valves (intermediate circuit), (10), Antenna shortening condenser, (11) Antenna coupling transformer, (12) Modulating valve, (13) Modulating transformer, (14) Valve filament heating battery, (15) Aerial ammeter, (16) Toroidal inductance.

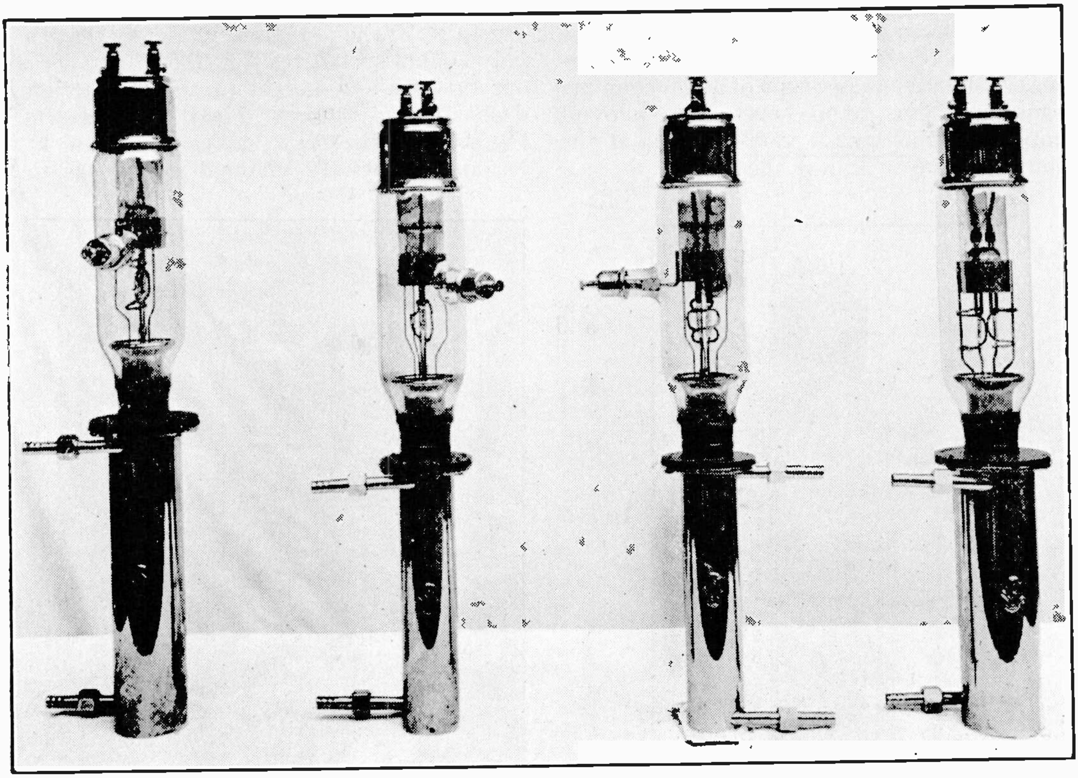


Fig. 9. *Water-cooled power valve RS204.*

The power valves are the Telefunken Type RS204, with water-cooled copper anodes (Fig. 9); the grid connection being brought out through the side of the glass cap of the valve. Each valve takes a filament current of 2.5 amperes at 35 volts and gives an emission of about 6 amperes. When giving an output of 10kW the valve has an efficiency of about 75 per cent., excluding the filament power. Two valves operate normally in parallel. It is to be noted that the power required for heating the filaments of the oscillation generating and main power valves, is obtained from accumulators, two 40 volt batteries of 1,000 ampere hours capacity being provided for the purpose, one being in use while the other is being charged; either is sufficient for 15 hours service, whereas the charging dynamo can recharge it in five hours.

The capacity of the anode circuit consists of a number of Dubilier mica condensers which can be switched in and out to vary the wavelength, the intermediate adjustment being made by means of a variometer. The main inductance takes the form of a toroidal coil (16) with an outer diameter of 40 cms., an inner diameter of 20 cms., and a length of

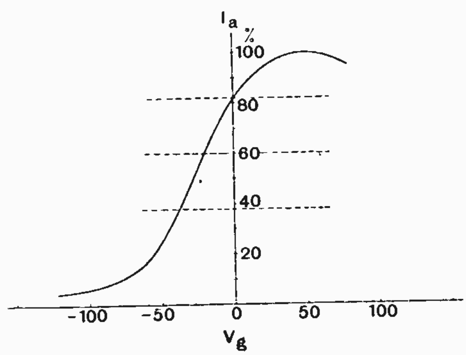


Fig. 10. *Curve showing the relation between the aerial current and the grid voltage of the modulating valve.*

14 cms., wound with multiple stranded wire (Litzendraht) and having an inductance of 70,000 cms. The variometer inductance can

be varied from 15,000 to 80,000 cms.; the inductance of the primary (outer fixed portion) of the variometer type of aerial coupling transformer is 30,000 cms. The kilovolt amperes of this circuit vary from 90 at the shortest wave to 130 at the longest.

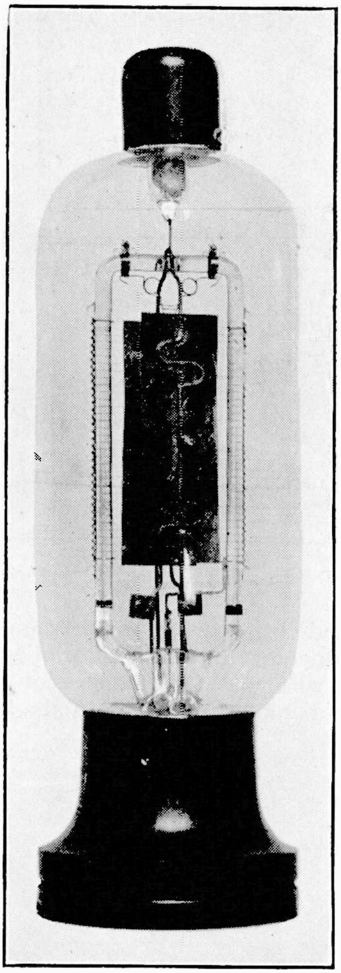


Fig. 11. *Modulating valve RV24.*

As we have already pointed out, the oscillation generator is unaffected by the modulation and delivers an effective high frequency P.D. of 600 volts to the grids of the power valves through a blocking condenser. The modulation valve (12) acts as a variable leak to these grids. In the absence of speech the grid of the valve (12) is adjusted by means of the potential divider so that the valve offers such a resistance that the aerial current is about 0.6 of its telegraphic long dash value. If no grid-leak were present, the grids of the main valves would quickly become negatively charged owing to the

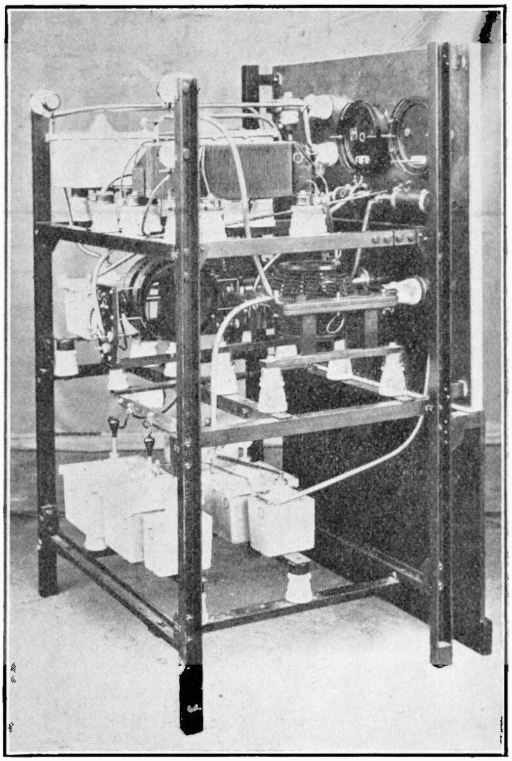


Fig. 12. *Back view of panel for control of main anode and aerial currents.*

electrons attracted to them whenever they were positive, and this negative charge would reduce the aerial current to about 1.5 per cent. of its normal value. This is an extreme case but any increase in the resistance of the modulating valve acts in this direction and reduces the aerial current. On the other hand, any decrease in the resistance makes the grids less negative and increases the aerial current. The relation between the aerial current and the grid voltage of the modulating valve is shown in Fig. 10; if the speech current momentarily lowers the grid potential to —100 volts, the resistance of the modulating valve becomes so high that the aerial current falls to a very low value, whereas if the speech current makes the grid potential +50 volts the aerial current reaches its maximum value. As a matter of fact the modulation is only allowed to vary the aerial current between about 0.4 and 0.8 of its maximum possible value, corresponding to a variation of ±35 per cent. from its mean value, as any greater modulation causes defective quality. The modulation range is indicated by the dotted lines in Fig. 10.

Two valves in parallel are actually employed for modulation; they are Telefunken Type RV24 amplifier valves of low amplification factor, that is with open grids, which allow considerable anode current to pass at zero grid voltage. A valve of this type is shown in Fig. 11; the filaments are heated from one of two special 16-volt batteries. Fig. 5 shows the control switchboard. The left hand panel controls the rectifiers, transformers, etc.; the six rectifier valves can be seen above the panel which carries a supply voltmeter, an H.T. anode voltmeter, the anode ammeter, a hand-wheel controlling the

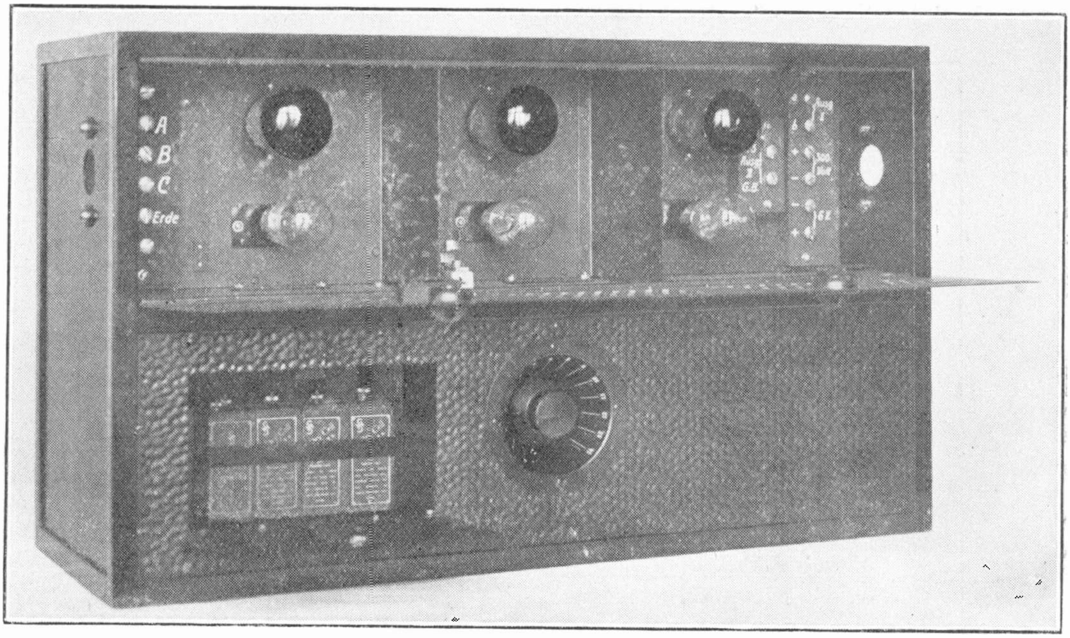


Fig. 13. *Three-stage microphone amplifier.*

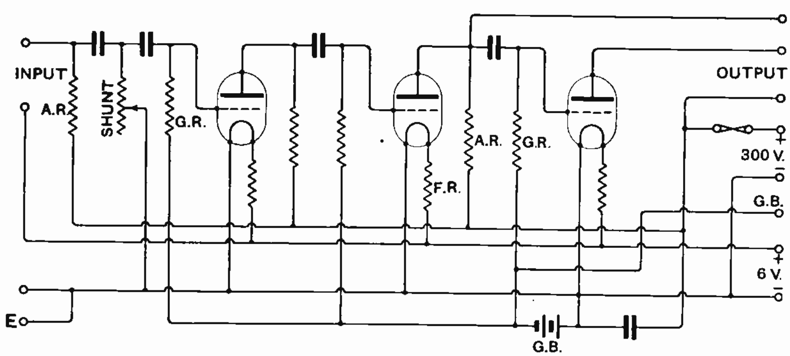


Fig. 14. *Connections of the 3-stage microphone amplifier.*

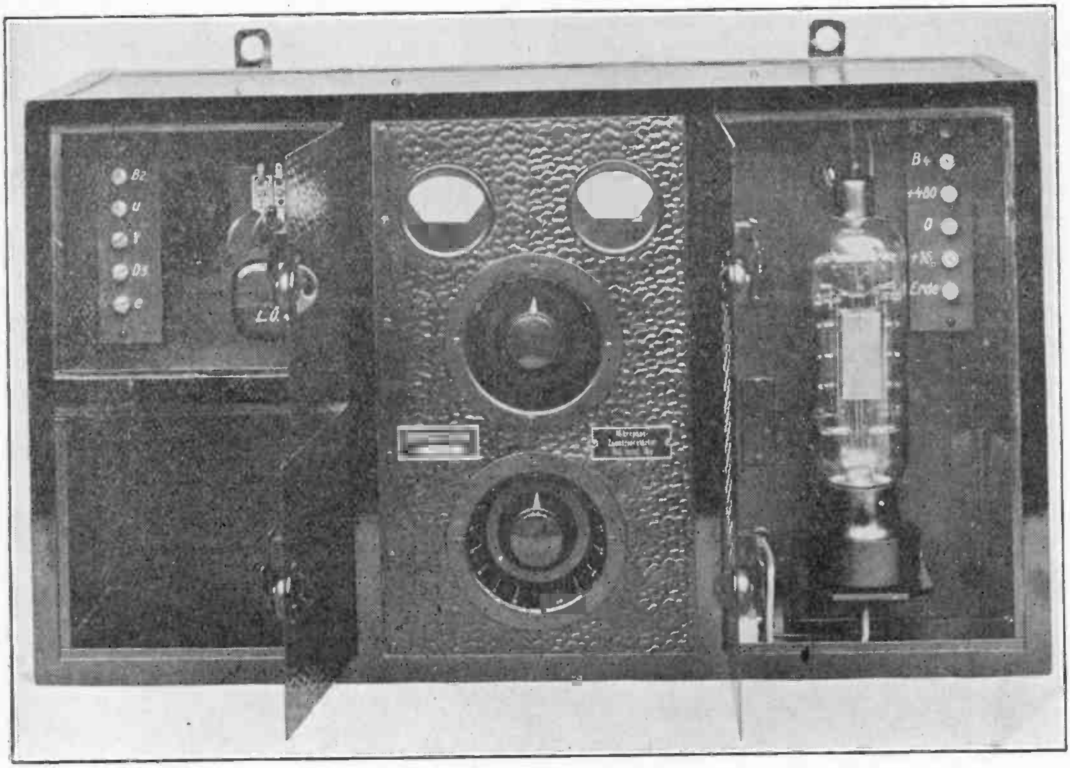


Fig. 15. *Additional 4th stage amplifier.*

tapping switch from the auto-transformer and the supply switches which are automatically opened on opening the doors behind the

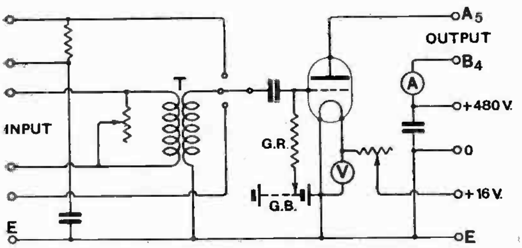


Fig. 16. *Connections of the additional 4th stage amplifier.*

switchboard. The second panel is for the control of the cooling water, the third for the oscillation generator and main power valves, and that on the right for the intermediate or main valve anode circuit and the aerial control. Fig. 12 shows a back view of the latter panel.

Adjoining the studio in Vienna are the necessary rooms for the amplifiers, batteries, and auxiliary machines for battery charging. The apparatus comprises :—

1. The microphone.
2. (*a*) Three-stage amplifier.
   (*b*) Single-stage additional amplifier, both being resistance coupled.
3. Amplifier modulation meter
4. Transmitter modulation meter.

The three-stage amplifier has BO valves, it is shown in Fig. 13 and the connections can be seen from Fig. 14. The single-stage additional amplifier which follows the former has an RV24 valve, it is shown in Fig. 15 and its connections in Fig. 16.

The modulation meter shown in Figs. 17 and 18 enables the adjustment of the amplifier to be controlled so that the correct strength of speech current is sent through the cable to the transmitting station. It is really a

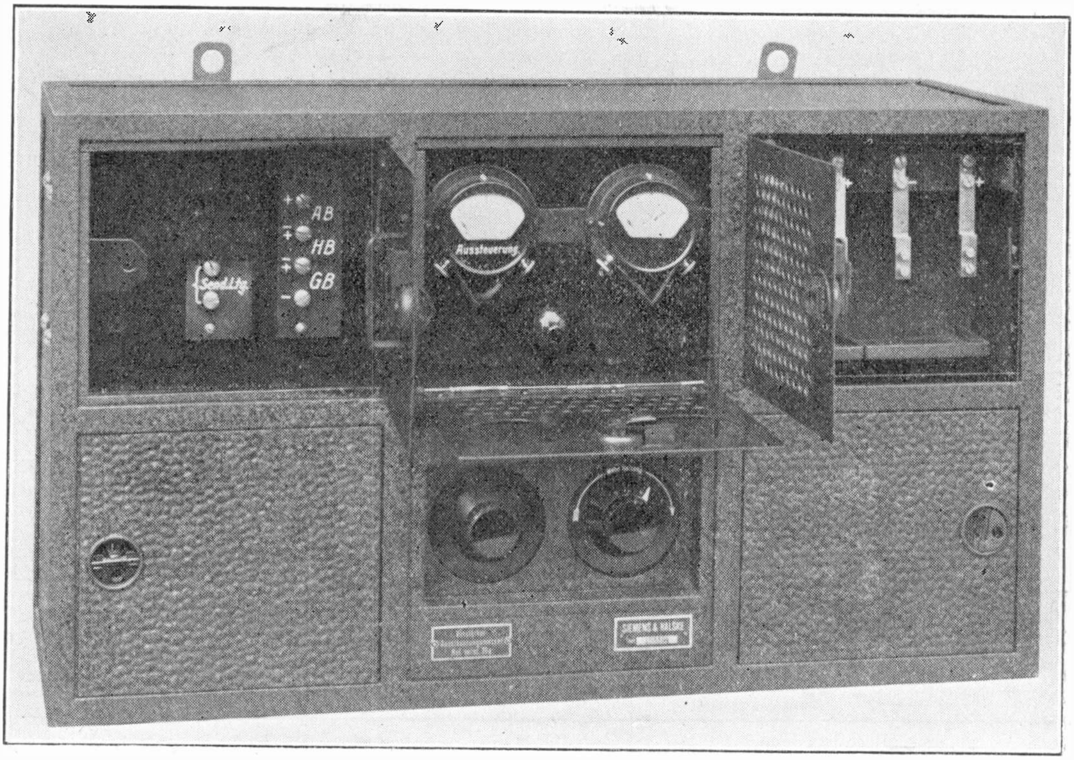


Fig. 17. *Amplifier modulation meter.*

kind of valve voltmeter. The other modulation meter shown in Figs. 19 and 21 is also in the amplifier room at the studio, but is

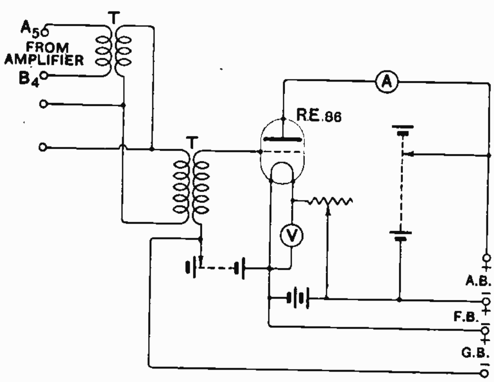


Fig. 18. *Connections of the amplifier modulation meter.*

operated by currents transmitted through the cable from the transmitting station. It enables a watch to be kept on the modulation of the aerial current. The current, induced from the aerial circuit in a suitably placed coupling coil, is rectified in the full wave rectifier shown in Figs. 20 and 22 which is at the transmitting station; the rectified currents are then taken through the cable to the modulation meter in the studio.

Special care has been devoted to the cable which connects the transmitter with the studio in Vienna. The length of this cable is about six miles, but further connections with the opera house and concert halls are to be installed. The cable has 12 conductors of 0.8 mm. diameter and 8 conductors of 1.03 mm. diameter. The former constitute six metallic signal circuits arranged as three groups each of 4 conductors; the latter constitute four metallic speech circuits. They are all paper insulated air space cores and the separate speech circuits are wound with aluminium foil with bare copper wire wound over. The complete cable core has a diameter of 18 mm., the overall diameter of the hoop-iron armoured and asphalted cable is 32 mm. The speech circuits have a resistance of 40 ohms per kilometre and a

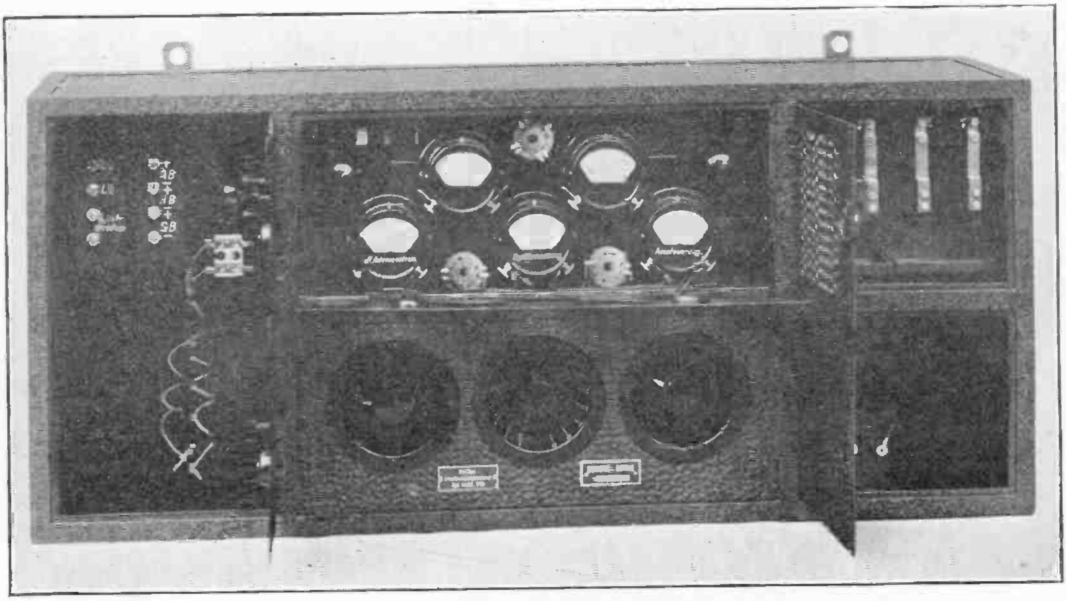


Fig. 19. *Transmission-modulation meter.*

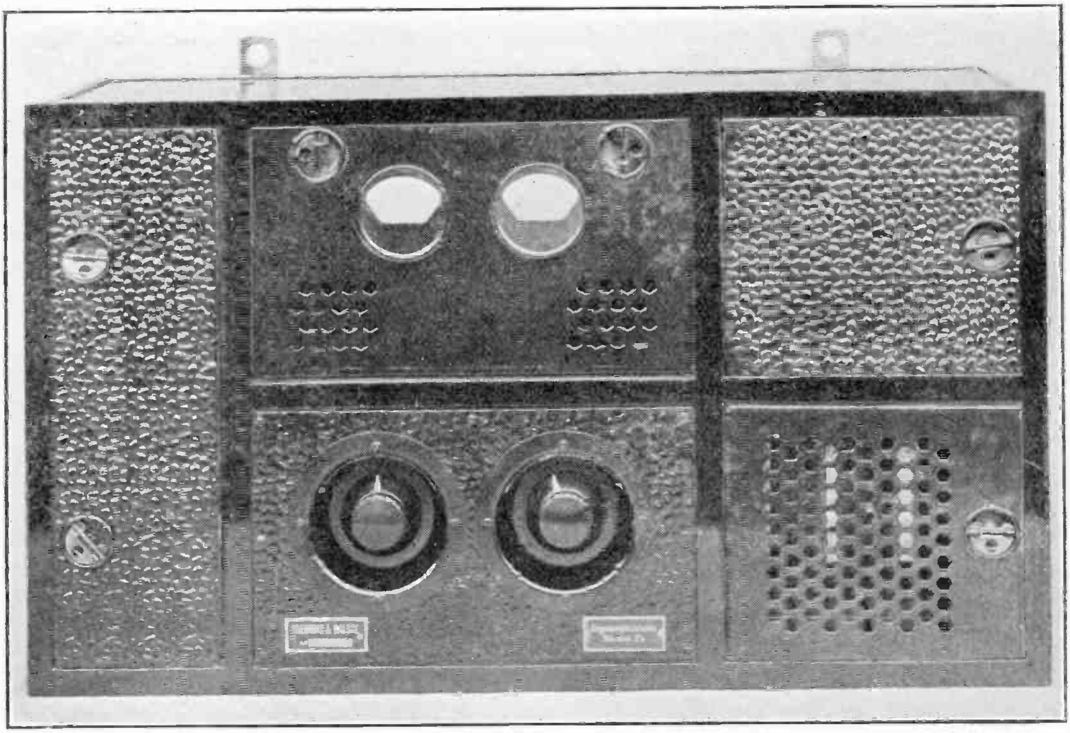


Fig. 20. *Full wave rectifier operating transmission-modulation meter.*

capacity of 0.034μF per kilometre; they are slightly loaded by means of Pupin coils and the capacities have been carefully balanced to a high degree of accuracy. This has given an improved quality of transmission. There are five loading points in the length of 9.8 kilometres and the inductance of the coils is 0.016 henry. As the result of this loading the damping constant βl increases almost linearly from 0.3 for $\omega = 3{,}000$ to 0.4 for $\omega = 25{,}000$. Beyond $\omega = 62{,}000$ the damping increases very rapidly. The characteristic impedance of the cable is practically constant at 570 ohms between $\omega = 5{,}000$ and $\omega = 25{,}000$. The amplifiers give a slightly higher amplification on the higher frequencies, thus counteracting the slight increase of damping in the cable. The cable is protected from external inductive influence by the metallic wrappings around the circuits and by the six bare copper wires which are in parallel with the lead covering. The cable was designed and supplied by Messrs. Siemens & Halske and the Austrian Siemens-Schuckert Co.

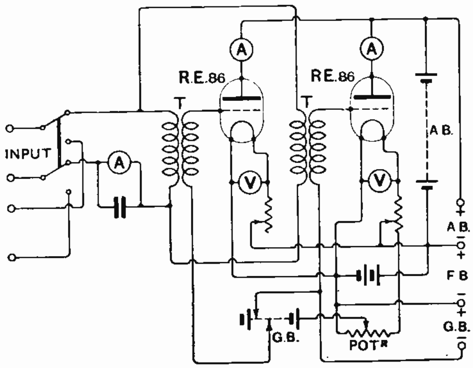


Fig. 21. *Connections of the transmission-modulation meter.*

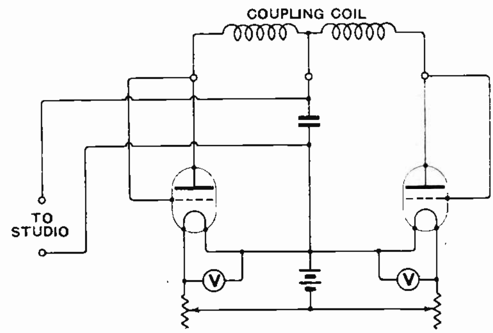


Fig. 22. *Connections of the full wave rectifier.*

The Rugby Radio Station.

THE lecture given by Mr. E. H. Shaughnessy, M.I.E.E., on the Rugby Radio Station before the Radio Society of Great Britain on 23rd June, 1926, is not reported in *E.W. & W.E.*, by arrangement with the author and the Radio Society of Great Britain.

The lecture was, as the author announced at its commencement, a *résumé* of his paper read before the Institution of Electrical Engineers. The Institution Paper was abstracted fully in the issue of *E.W. & W.E.* for May, 1926, whilst the illustrations reproduced there are substantially the same as the pictures exhibited by Mr. Shaughnessy by means of lantern slides before the Radio Society.

An Ammeter Panel.

Using an Ammeter for Several Purposes.

By E. C. Atkinson.

[R251

This note describes a panel for ammeter arranged for full-scale readings of 3, 0.6 and 0.024 amperes as well as of 3 and 12 volts. The charging current for the accumulator is shown on one scale, whilst filament current up to 0.6A is shown on another *without change of connections.*

METHODS for using a single instrument for more than one purpose have recently been described in this journal. The writer needed an ammeter for measuring filament currents up to 0.56A and a charging current of 2A. A moving-coil instrument with full-scale reading of 24mA was selected together with suitable shunts.

Negative leads to filaments and charger are connected direct to the battery, and positive terminals are joined to ammeter and shunts as shown in Fig. 1 (a).

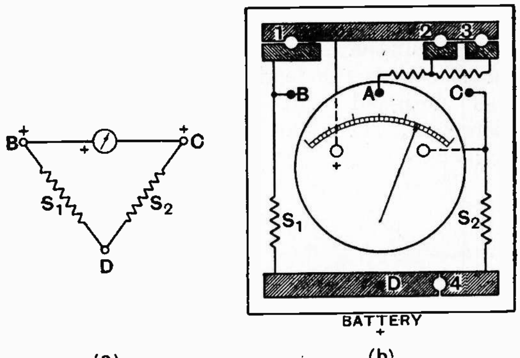


Fig. 1.

When charging, the accumulator S_2 is in series with the ammeter whilst S_1 is shunted across them. When the battery is being discharged through the filaments S_2 becomes the shunt across ammeter and S_1 in series. With suitable resistances for S_1 and S_2 it is thus possible to charge and discharge without alteration of circuits and to secure, for full-scale reading on the instrument, 3A in the first case and 0.6 in the second.

The resistances consist of the shunts supplied by the makers for use in the ordinary way, increased in each case by 0.0011 ohm.

The ammeter is mounted on a panel as shown in Fig. 1 (b), connections to outside circuits being made by plugging into holes *A B C* and *D*. When the gaps 1 and 4 are bridged by plugs, such as are used in resistance boxes, it will be seen that the connections are as in Fig. 1 (a).

A is connected to different terminals of the accumulator by a wander plug. When the plug in gap 1 is moved to 2 the instrument records voltage with full-scale reading of 3V. Using gap 3 the corresponding value is 12V. Meanwhile the filament current is passed by S_2.

Further, if battery and filament plugs are removed from the panel and connected together, the instrument is available for measuring currents in other circuits. When the plug is removed from gap 4, full-scale reading represents 24mA and anode currents can be observed.

It will be seen that the instrument is not sufficiently sensitive for accurate measurements of these currents in an ordinary receiving valve, but the saturation current can satisfactorily be measured and assistance is afforded for setting on a suitable point of the characteristic by adjusting H.T. voltage.

On the other hand, the saturation current of a power valve may exceed 24mA, and the instrument is suitable for reading the anode currents passed by such a valve in use. Observations of the movements of the needle during loud-speaker reception afford a useful means of adjusting grid and anode voltages so as to secure the best results.

The various ranges and the corresponding arrangements of terminals and plugs are shown in the following table.

Use.	Range.	Terminals.	Plugs.
Ammeter	24mA	*B—C*	1
,,	0.6A	*C—D*	1—4
,,	3A	*B—D*	1—4
Voltmeter	3V	*A—D*	2—4
,,	12V	*A—D*	3—4

The Amplification and Selectivity of a Neutralised Tuned Anode Circuit.

By N. W. McLachlan, D.Sc., M.I.E.E. **[R161 & R162**

Preliminary.

In view of the favour which the neutrodyne principle has found in the design of modern receivers, it may be of interest to consider some of the features associated with the magnification and selectivity of the arrangement. The simplest way is to deal with a tuned anode. The treatment also covers the case of 1 to 1 transformer coupling with tuned grid, provided the leakage between primary and secondary is small. It often happens that the ratio exceeds unity and in some instances the H.T. is fed to the coil at a tapping point between the extremities. For a given magnification the selectivity

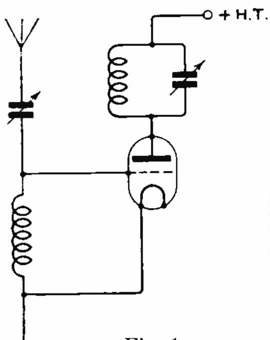


Fig. 1.
Showing the ordinary un-neutralised tuned anode.

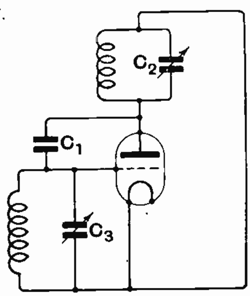


Fig. 2.
Showing the circuit equivalent to Fig. 1.

can be enhanced in this way. These cases require modified treatment and are not included here.

Let us glance at the circuit illustrated in Fig. 1. It is so familiar and is likely to be a bit of past history soon. The arrangement in question is the "tuned anode." There is no attempt at neutralisation of the valve capacity. This capacitative attribute is used to attain enhanced sensitivity and selectivity at the expense of stability. Now the sensitivity arises from an inherent tendency to oscillation possessed by the system. It increases with augmented aerial and anode inductances and with reduced resistances of same. Assuming the resistance of the grid-leak to the succeeding valve to be large in comparison with the impedances of the other components, its effect as a damper across the valve can be neglected. Moreover, the circuit may be redrawn, as shown in Fig. 2, where the condenser C_3 between the grid and the filament negative is assumed to represent the equivalent aerial capacity and the small condenser C_1 is the valve capacity. The H.T. and L.T. batteries have been omitted.

It is quite easy to see that any potential variations between the grid and filament are transmitted to the anode by C_1. Furthermore, if the tuning adjustments are correct, thereby giving the proper phasing, and the inductances are ample, the system will be regenerative and oscillation will ensue. There is clearly an art in the design of a circuit of this nature to get smooth operation, so that tuning is not beset by a series of "flops" into oscillation as the condensers are rotated. This tendency is curbed by the aerial damping, but for the set to run serenely into oscillation requires certain modification if a band of wavelengths is to be covered.

Perhaps it may be of interest if this circuit is compared with one well known for short-wave oscillation. As a matter of fact, quite satisfactory oscillation can be got with a circuit of this nature at long wavelengths. This is well known when a cascaded amplifier oscillates. The oscillations are then certainly "unsatisfactory." The circuit in question is indicated in Fig. 3 where C_1 represents valve capacity plus

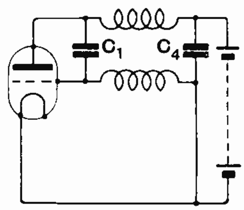


Fig. 3. *A well-known short wave circuit for generating oscillations. The circuit is identical with Fig. 2 if C_4 is large and if C_2 and C_3 are omitted from the latter figure.*

added capacity to vary the wavelength. In Fig. 4 is shown two arrangements of the same circuit. Diagram (a) shows C_4 short-circuited, *i.e.*, C_4 is infinity. This arrangement would work if the H.T. battery did not polarise the grid and render the valve *hors de combat*. The condenser C_4 of Fig. 3 serves the purpose, therefore, of preventing the H.T. getting on the grid and causing saturation of the valve. When C_4 is large enough, it acts as a by-pass condenser on the H.T. battery. It can, of course, be made variable to obtain accurate tuning when C_1 is small in comparison. So far as preserving the grid from polarisation is concerned, it is possible to insert a condenser, as shown in (b). This, however, completely isolates the grid and is useless. We are therefore brought back on the arrangement of Fig. 3.

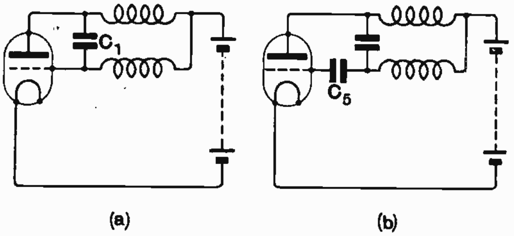


Fig. 4. *Showing (a) Fig. 3 with C_4 infinite and (b) a condenser C_5 to prevent polarisation of the grid by the H.T. battery.*

Reverting to our original tuned anode circuit, if we incorporate the H.T. battery with a shunting condenser, the result is depicted in Fig. 5 (a). Then by adding condensers across the coils of Fig. 3 we get Fig. 5 (b) which is identical with Fig. 5 (a). Put in another way, if we imagine the condensers C_2 C_3 of Fig. 5 (a) gradually to decrease to zero the circuit ultimately resolves itself into Fig. 3.

Magnification with Neutralised Tuned Anode.

The next aspect of our subject is related to the magnification obtainable from a tuned anode. Where neutralisation of the valve capacity is not effected, the magnification depends upon so many conditions which vary from receiver to receiver that a computation would be unsatisfactory. On the other hand if we assume complete neutralisation of the valve capacity and that there are no extraneous influences, *e.g.*, direct pick up on the anode coil, interaction between the coil and the remainder of the circuit, stray capacities, etc., the problem resolves itself into one capable of computation. In Fig. 6(b), we have the usual tuned anode followed by some form of coupling to the next valve

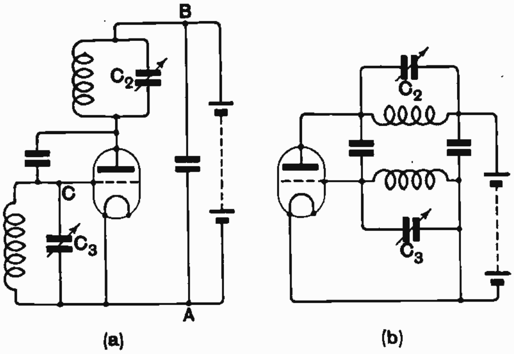


Fig. 5. *Illustrating the similarity of circuits of Figs. 2 and 3.*

which may or may not be a detector. If the resistance of the grid-leak be large enough compared with the valve resistance, it can be neglected. The simplified equivalent circuit is shown in Fig. 6 (c). Here A represents an alternator whose voltage is equal to the E.M.F. between grid and filament multiplied by the magnification factor of the valve. The tuned anode is connected in series with the alternator and with a resistance ρ equal to the internal resistance of the valve. Obviously the voltage across C cannot exceed that of the alternator (e). Actually it is always less than e due to the ohmic drop down ρ, *i.e.*, due to the internal resistance of the valve. The voltage across C (Fig. 6 (c)) is applied to the grid and filament of the next valve without reduction provided the coupling condenser C_1 of Fig. 6 (b) is free from loss and its impedance is small compared with the grid-leak r_1. Assuming this to hold good, as it ought in a properly designed set, the voltage across C is given by the quantity $e \times$ vector sum of impedance of ρ and of $L\ C\ R$. Taking the tuned circuit first, there are two branches in parallel and if we get the admittance of each and add, the reciprocal of the sum will be the combined impedance.

Admittance of inductive branch is $1/R+j\omega L$ where $j=\sqrt{-1}$ and $\omega=2\pi f$. Admittance of condenser branch is $j\omega C$. Adding these two quantities we get

$$\text{Admittance}=(1/R+j\omega L)+j\omega C \quad .. \quad (1)$$

$$=\frac{1+j\omega CR-\omega^2 LC}{R+j\omega L}$$

$$=\frac{A+j\omega CR}{R+j\omega L} \quad .. \quad .. \quad (2)$$

where $A=1-\omega^2 LC$.

This formula shows that the tuned circuit at resonance is equivalent to a condenser of capacity C in series with a resistance L/CR as depicted in Fig. 7 (a). In Fig 7 (b) is shown the vector diagram for the circuit of Fig. 7 (a). At the radio frequencies which obtain in Broadcasting, $1/\omega C$ is usually small compared with L/CR, so that for all practical purposes, unless a really bad coil is used, the impedance of the tuned circuit at resonance can be regarded as that of an inductionless resistance of value L/CR. The condition

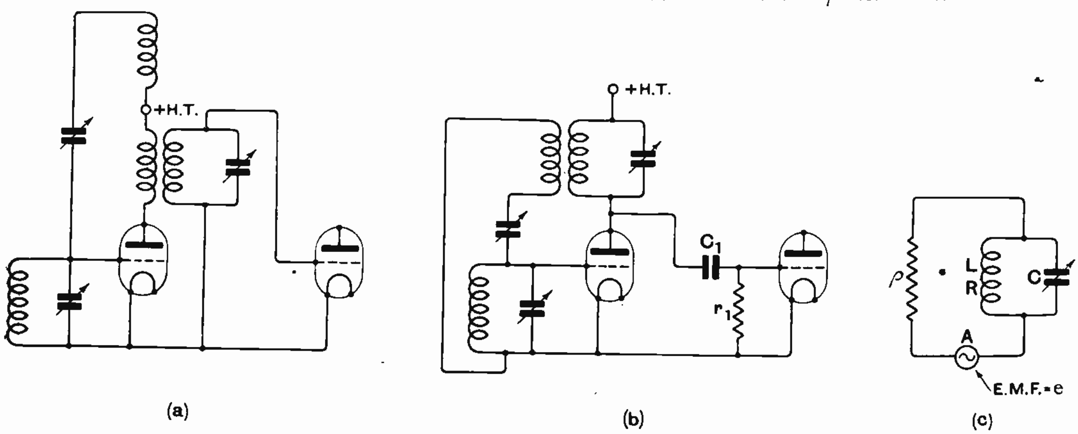


Fig. 6.

(a) Showing transformer coupling with neutralising condenser.
(b) Neutralised tuned anode with condenser resistance coupling to next valve.
(c) Circuit equivalent to anode circuit of first valve in (a) or (b) where ρ represents the internal resistance of the valve.

Hence Impedance $=1/\text{Admittance}$

$$=\frac{R+j\omega L}{A+j\omega CR} \quad .. \quad .. \quad (3)$$

Now at resonance $\omega^2 LC=1$ or $\omega^2 LC-1=0$; hence $A=0$.

Thus at resonance the impedance is given by

$$\frac{R+j\omega L}{j\omega CR}=1/j\omega C+\frac{L}{CR} \quad .. \quad (4)$$

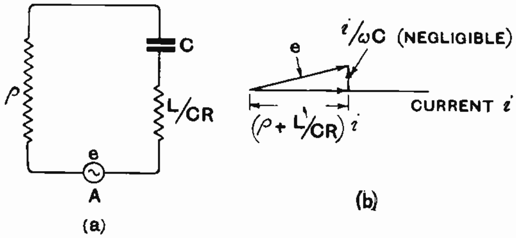


Fig. 7. *Showing that at resonance the tuned anode combination is equivalent to a condenser* C *in series with an inductionless resistance* L/CR, *the whole being in series with* E.M.F., e *and valve resistance ρ.*

$\omega^2 LC=1$ signifies resonance of the tuned circuit, but as we have seen, the equivalent circuit is a condenser of capacity C in series with a resistance L/CR. Now it is possible to adjust the value of the condenser so that the circuit acts purely as a non-inductive resistance. To obtain this condition it is necessary to equate the reactance to zero. By rationalising the denominator of equation (3) we get

$$Z=\frac{R+j\omega(AL-CR^2)}{A^2+\omega^2 C^2 R^2} \quad .. \quad (5)$$

so that for zero reactance (unity power factor)

$$AL-CR^2=0$$

$$\therefore \quad (1-\omega^2 LC)L=CR^2$$

or

$$\omega^2 LC=1-\frac{CR^2}{L} \quad .. \quad (6)$$

At resonance $\omega^2 LC=1$, so that for zero reactance the value of $\omega^2 LC$ is decreased by

CR^2/L. Taking $C=150\mu\mu F$, $R=7$ ohms, $L=250\mu H$, we get

$$CR^2/L = \frac{150\times 10^{-12}\times 49}{250 \quad 10^{-6}} \doteqdot 3\times 10^{-5}$$

Thus the variation is only three parts in one hundred thousand and can therefore be neglected. So far as varying the condenser C is concerned, to come into tune with an incoming signal of definite wavelength (ω fixed) we have at resonance

$$\omega^2LC=1 \text{ or } C=1/\omega^2L,$$

and for zero reactance

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

Since R^2/L is small compared with ω^2L it can be neglected, so that $C\doteqdot 1/\omega^2L$ and the variation in C at resonance and at zero reactance is beyond the limit of practical consideration at wavelengths of 300 to 500 metres.

Applying our previous formula to find the voltage across the tuned circuit at resonance (L/CR = a res.) we have

$$e_2 = e\frac{L}{CR}\cdot\frac{1}{\frac{L}{CR}+\rho}$$

$$=e\left[\frac{1}{1+\frac{CR\rho}{L}}\right]$$

or effective magnification per stage

$$=\frac{me_2}{e}=\frac{m}{1+\frac{CR\rho}{L}} \quad \cdot\cdot \quad (7)$$

where m is the magnification factor of the valve.

Having obtained this simple formula (7), the next step is to discover how the effective magnification per stage with a given coil varies with the wavelength of the tuned circuit. Assume that over a band of wavelengths from 300 to 500 metres the ratio L/R is sensibly constant and that $R=7$ ohms, $L=250$ microhenries, $m=7$, $\rho=22{,}000$ (D.E.3 valve). The only variable is the capacity C which includes the self-capacity of the coil. By giving C different values the results in Table I. were computed using (7).

The results are shown pictorially in Fig. 8 from which it is clear that the amplification decreases with increase in capacity provided R/L remains constant. At the lower wavelengths R will increase so that the actual

TABLE I.

Showing valve magnification with tuned anode and complete valve capacity neutralisation at various wavelengths using a D.E.3.

λ metres.	C $\mu\mu$F.	Effective valve mag.	% valve mag.
300	100	6.56	0.94
367	150	6.41	0.91
424	200	6.23	0.89
475	250	6.09	0.87
520	300	5.95	0.85

curve will tend to follow the dotted line. In an H.F. neutrodyne amplifier, employing tuned anodes, the magnification would be expected to fall off with increase in wavelength and this actually occurs in practice.

The next point to which attention may be directed is the influence of the size of the condenser at some specified wavelength. Suppose we choose 367 metres, which is somewhere in the vicinity of 2LO, and assume the ratio R/L for the various coils is constant for various inductances, the magnification formula (5) is

$$\frac{m}{1+\frac{CR\rho}{L}}=\frac{7}{1+6\times 10^{-4}C}$$

since ρ and R/L are unaltered. Giving C the same values as before and altering the inductance to preserve a wavelength of

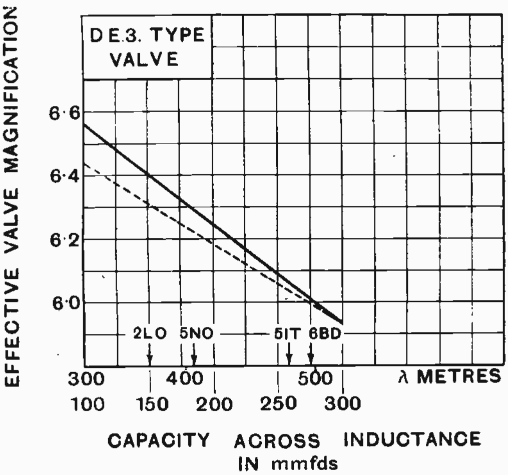


Fig. 8. *Showing decrease in magnification with increase in wavelength (due to increase in capacity of anode tuning condenser). Calculated for D.E.3 valve for which* m=7 *and* ρ=22,000 *ohms.*

367 metres we get a curve identical with that of Fig. 8. To avoid confusion this has been redrawn in Fig. 9 and extra points added to include larger capacities. It will be obvious that with a given valve when the wavelength is fixed and the ratio R/L constant, the magnification decreases with increase in the capacity across the coil. Thus for sensitivity a small condenser and a large inductance is required, especially if there are several valves in cascade. Taking a condenser of $700\mu\mu$F, *i.e.*, 0.0007μF, the percentage of the possible magnification is about 70. With three of these in cascade it would be $100 \times (0.7)^3 = 100 \times 0.34 = 34$ per cent. Hence the voltage to the grid of the power valve would be reduced to 1/3, and the intensity from a loud speaker to 1/9. Put in another way, if the signals in a pair of phones were inaudible they might become audible when increased nine times by using anode tuning condensers of smaller capacity.

We come now to the influence of the resistance of the coil or more generally to the effect of varying the ratio R/L. The curves

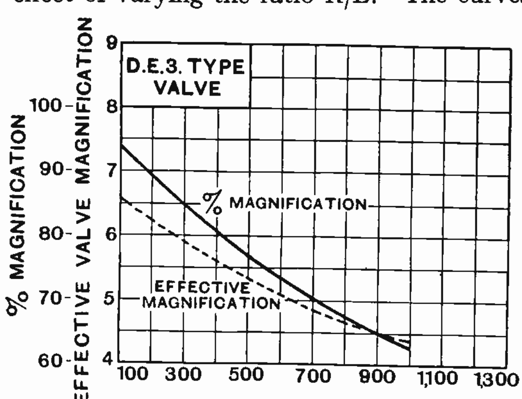


Fig. 9. *Showing decrease in magnification with increase in capacity at a given wavelength, the inductance being gradually reduced as the condenser is increased (D.E.3 valve).*

of Fig. 8 were based on a resistance of 7 ohms with an inductance of 250 microhenries. Now let us take a wavelength of 367 metres and vary the resistance of the coil whilst preserving a constant inductance. The percentage magnification is given by

$$100\Big/\left(1+\frac{150\times10^{-12}\times22{,}000R}{250\times10^{-6}}\right)$$
$$=100/(1+1.32\times10^{-2}R)$$

The various values associated with the problem are given in Table II.

There is no need to plot these figures. They show clearly that to get as large a percentage of the "m" value out of the valve, the resistance should be as small as possible. So long, however, as the resistance is not too

TABLE II.

$\lambda = 367$ metres, $L = 250$ microhenries, $C = 150\mu\mu$F.

R ohms.	% magnification.	Effective valve magnification.
3	0.96	6.7
5	0.94	6.6
7	0.92	6.4
9	0.89	6.2
11	0.87	6.1
15	0.84	5.9
19	0.8	5.6

large the magnification does not fall off very much, except of course in a cascade system, where the resistance should be kept down.

Lastly there is the valve resistance ρ. This would be a very simple issue provided the "m" value were constant for different resistances. But as is well known, when "m" increases ρ usually increases too. There are, however, a number of valves of different classes in which the variation in "m" is relatively small compared with that of ρ. For instance, for a D.E.3, $m = 7$ and $\rho = 22{,}000$, whilst for a D.E.8 L.F. $m = 7$, whilst $\rho = 8{,}000$.* If in the preceding examples a D.E.8 had been used instead of a D.E.3 the lower resistance would have enabled the same magnification to be obtained with larger condensers and larger coil resistances. But as there is no particular point in using large condensers and resistances, and since the magnification is tolerably good already, there would not be much gained in using D.E.8 valves of 8,000 ohms internal resistance. In fact there would be a loss of 0.06 amp filament current per valve and an extra 2 volts needed.

Going to the other side of the question, suppose the D.E.3 is replaced by a D.E.3B, m is now 17 and $\rho = 50{,}000$. Taking our original coil at 367 metres, we find that the

* This ρ value is specified by the makers, but they are on the low side. The actual value is more nearly 14,000. (See *Wireless World*, 6th January, 1926.)

percentage magnification is 83 and the valve magnification 14. These compare very favourably with the corresponding values 91 per cent. and 6.4 for a D.E.3. In fact the magnification is doubled, provided of course the D.E.3B is not defective and an adequate H.T. is used. This raises the question of using D.E.3B valves. There is no reason why they should not be incorporated in an H.F. amplifier, but the H.T. will have to be greater than that for a D.E.3, and to avoid damping, it is advisable to put a little bias on the grid. The bias should be sufficient to avoid grid current when strong jamming is prevalent. With a high resistance valve the influence of a large condenser or a large coil resistance is quite marked. Using a D.E.3, a coil resistance of 15 ohms gives a percentage magnification of 84, whilst with a D.E.3B the value is 69 per cent., but the actual magnification is 12. Moreover for efficient amplification with a high resistance valve particular care must be exercised to keep C and R as small as practicable.

We have examined the influence of capacity, inductance, coil resistance and valve resistance on the amplification of a neutralised tuned anode circuit. It now remains to be seen what effect these variable components have upon the *selectivity* of the arrangement.

Selectivity of the Neutralised Tuned Anode.

To arrive at a solution of this problem we must invoke the aid of a little more mathematical analysis. The impedance of the tuned circuit *at any frequency* is given by equation (3) which reads

$$Z=\frac{R+j\omega L}{A+j\omega CR}.$$

When the denominator of this expression is rationalised to eliminate $j, (\sqrt{-1})$, we get as a first step

$$Z=\frac{R+j\omega L}{A+j\omega CR}\cdot\frac{(A-j\omega CR)}{(A-j\omega CR)}$$

$$=\frac{R+j\omega(AL-CR^2)}{A^2+\omega^2C^2R^2}$$

$$=R_0+j\omega P \quad \ldots \quad (8)$$

where

$$R_0=\frac{R}{A^2+\omega^2C^2R^2} \text{ and } P=\frac{AL-CR^2}{A^2+\omega^2C^2R^2}$$

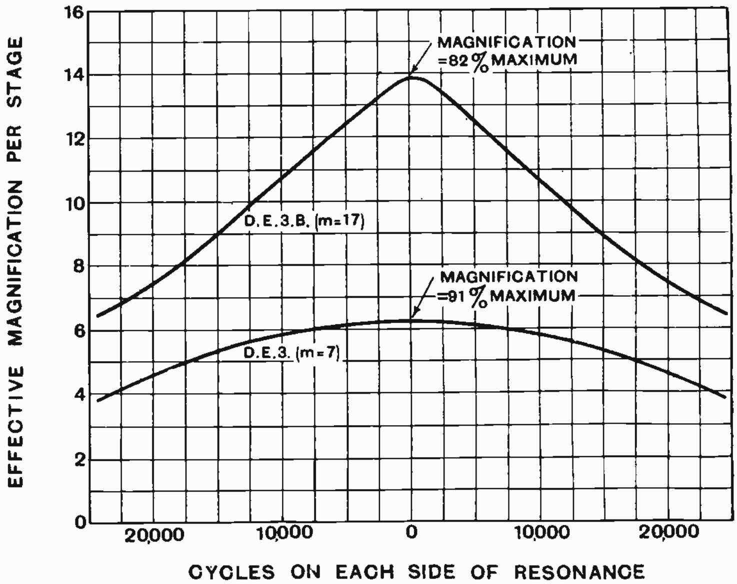


Fig. 10a. *Showing magnification curves for tuned anode with D.E.3 and D.E.3B valves.*

= an inductionless resistance R_0 + a reactance of value ωP.

For purposes of computation, the numerical value of Z is found from the expression $[R_0^2+\omega^2P^2]^{\frac{1}{2}}=Z_0$. To determine the selectivity curve showing the relation between effective valve magnification and frequency when the condenser is set on a given station, it is necessary to obtain the ratio

$$\frac{\text{impedance of tuned circuit}}{\text{imped. of valve + imped. of tuned circuit}}$$

for a band of frequencies ± 3 per cent. of the central setting of the condenser.

This ratio is equal to the expression

$$\frac{(R_0^2+\omega^2P^2)^{\frac{1}{2}}}{[(R_0+\rho)^2+\omega^2P^2]^{\frac{1}{2}}} \quad \cdots \quad \cdots \quad (9)$$

The effective valve magnification m_e = m × expression (9).

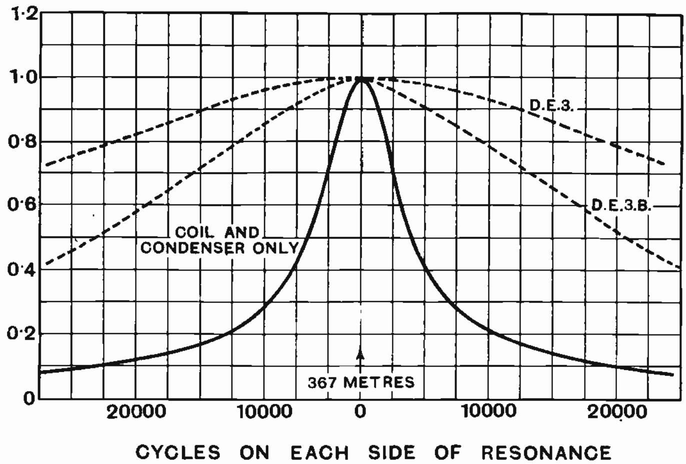


Fig. 10b. *Showing relative selectivity curves of tuned anode with and without valve damping.*

This can be written

$$m_e=\frac{[R^2+\omega^2K^2]^{\frac{1}{2}}}{[\{R+\rho(A^2+\omega^2C^2R^2)\}^2+\omega^2K^2]^{\frac{1}{2}}} \cdot\cdot \quad (10)$$

where $K=AL-CR^2$, and $A=1-\omega^2LC$.

Taking our previous coil and using a D.E.3 valve with ρ = 22,000 ohms, we can at a wavelength of, say, 367 metres obtain from (10) the magnification for frequencies on both sides of this tune point, since all the quantities excepting ω are constant. The result of this calculation is illustrated in Fig. 10 (a) (b). Curves for a D.E.3B valve and for the coil and condenser devoid of valve damping have been added. Compared with the circuit alone, *i.e.*, devoid of valve damping, the other curves show an absence of selectivity and if the data under the curves is consulted the reason will be obvious. The resistances equivalent to the valve damping to be added to the coil resistance are so large, that the selectivity is reduced considerably, although the maximum magnification is altered but little. Take, for example, a frequency 15,000 cycles from the tune point, we find the selectivity of the circuit* alone is 4.6 that with the D.E.3B, and 6.1 times that with the D.E.3.

An inspection of the curves will reveal the fact that the D.E.3B valve gives greater selectivity and greater magnification than the D.E.3.

The explanation of this is as follows :—

(1) The selectivity is enhanced owing to the impedance of the tuned circuit when off the tune point being a smaller proportion of the total impedance (with a high impedance valve) ;

(2) The magnification is augmented due to the greater "m" value of the D.E.3B valve.

We have already seen that the magnification with any given valve falls away with increase in the capacity of the condenser whether the wavelength is constant or

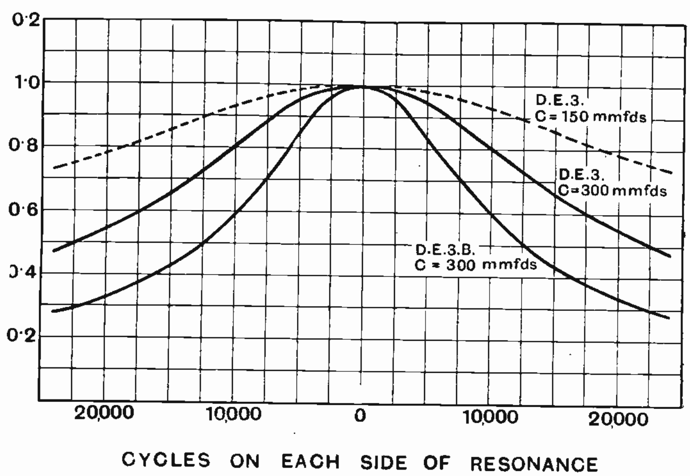


Fig. 11. *Curves showing gain in selectivity with a large condenser across tuning coil.*

* Ratio of ordinates—a purely arbitrary mode of measurement for purposes of illustration.

variable. Thus the magnification of a multi-stage tuned anode amplifier will be greater at 250 metres than at 500 metres, provided the conditions assumed herein are not violated.

The last topic which we have to consider is the influence of the condenser on the selectivity. Taking equation (10) and using a wavelength of 367 metres, as in the preceding example, the condenser will be fixed as $300\mu\mu F$ ($0.0003\mu F$) or about twice its former value. The values of L and R will be halved, and L/R remains constant. The resulting curves are plotted in Fig. 11, whilst the curve for a capacity of $150\mu\mu F$ is also given in order that the influence of the augmented capacity can be recognised at a glance.

Summary of Results for Neutralised Tuned Anode at any given Wavelength.

(1) The magnification per stage can never exceed the "m" value of the valve (excluding anode taps and ratio transformers greater than unity).

(2) The magnification increases with increase in inductance. There is a limit to L owing to the self-capacity of the coil. In this case the value of L/C_sR should be as small as possible, *i.e.*, the self-capacity should be kept down.

(3) The magnification decreases with increase in capacity.

(4) The magnification decreases with increase in valve resistance (ρ) provided "m" is constant.

(5) The magnification increases with "m" provided ρ is constant, so that (4) and (5) means a sort of compromise. In general, unless the set is badly designed, the magnification will increase with "m" provided ρ/m does not increase too much.

(6) The effect of the preceding factors on "selectivity" is exactly the opposite of that on magnification, *i.e.*, a large condenser or a large ρ gives selectivity. Thus with adequate H.T. a D.E.3B is a better valve than a D.E.3, because it gives more magnification and better selectivity, provided, of course, trouble is not experienced due to stray capacities and coil interaction introduced by the larger A.C. in the coils in virtue of the increased step up per stage. For a given magnification the number of stages would be less for D.E.3B's than for D.E.3's, but care would have to be exercised regarding the stability. Assuming an average of five per stage with a D.E.3 and 10 with a D.E.3B, four stages of D.E.3 yield 625, whilst three stages of D.E.3B yield 1,000 and perhaps a little oscillation !

(7) The magnification increases with decrease in coil resistance, but unless the resistance is really large, *i.e.*, L/R is poor, its effect is not very marked. So far as selectivity is concerned the coil resistance is often swamped by valve damping so that it does not play a very important factor with a low ρ value.

(8) Where a band of wavelengths, say 250 to 550 metres, are covered by a fixed coil and a variable condenser, the magnification decreases at the longer wavelengths, but the selectivity increases, *i.e.*, one is secured at the expense of the other.

It may be advisable to mention that throughout the article we have tacitly assumed the valves to be operated with grid bias and that the excursions of grid potential are small, the H.T. voltage being adequate for operation on a linear part of the characteristic thus avoiding rectification. The "m" and ρ values actually depend upon the H.T. volts, the grid bias and the class of valve used. It should be noted that practical results may not always tally with the calculations given here owing to variations in "m" and ρ. There is in general a tendency for ρ values to be high, especially with small H.T., so that one has to be on the look out for reduced magnification. For example, an average of 4 per stage is nearer the mark for a D.E.3 than 5 quoted above. Personally I always endeavour to cut the filament current down to a minimum. One can obtain a good deal greater magnification with four dull emitters of the D.E.3 class than with one of the D.E.5 class—even though it is a D.E.5B—with a smaller watt loss on the filaments. For those to whom filament current is a minor consideration this argument is obviously inapplicable.

A Direct Current Test Set.

By T. S. Skeet. **[R384**

THE writer realised at an early date, along, no doubt, with many other experimenters, that serious electrical experimental work of any description is impossible without suitable measuring instruments. This article describes a test set arranged to cover the many requirements of

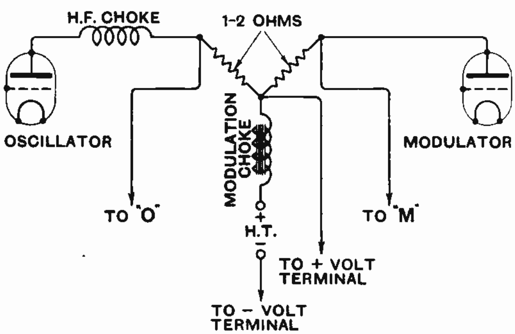


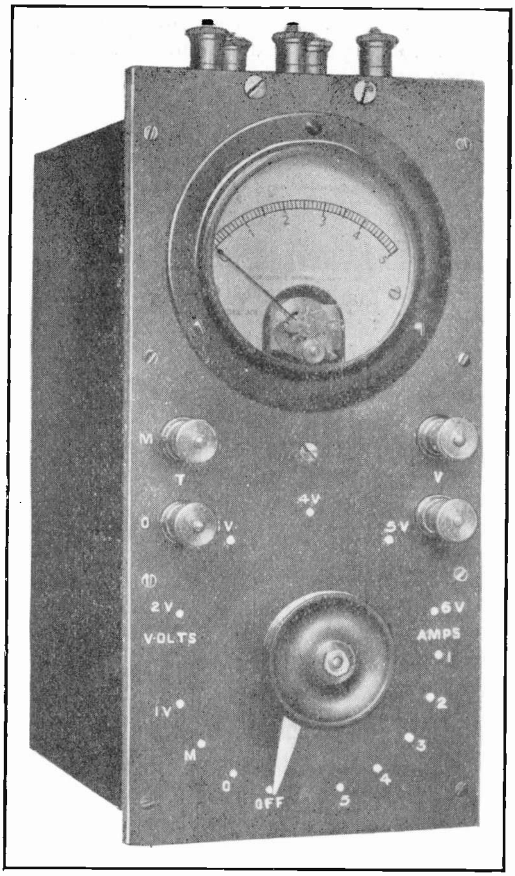
Fig. 1.

the experimenter, whose hobby is either transmission or reception. By means of the switch which can be seen in the photographs, the meter is arranged to give full scale readings of 1,000V, 100V, 10V, 5V, 0.5V, and 0.1V. The use of the terminals on the top of the instrument, combined with the use of the switch, enables full scale current readings of 10A, 5A, 2½A, 500 mA, and 50 mA to be obtained. At the switch setting of 0.1V the resistance of the instrument is only 20 ohms, and this scale can be used for 5 mA full scale reading.

The set was designed to form one unit of a transmitting set, which has not yet materialised, and the two terminals, marked *O* and *M*, with their corresponding switch studs, were intended for reading by means of external shunts, the current fed to the oscillator and modulator valves respectively, of a choke coupled 10-watt transmitter. The 1,000V scale, whose switch stud is adjacent to the (*M*) stud, being intended to read the voltage of the supply.

The arrangement of the connections to the transmitter to enable this to be done without additional switching is shown in Fig. 1.

It will be seen that when the supply voltage is being measured the modulation choke is in series with the meter, but as the resistance of the meter at the 1,000V setting is 200,000 ohms and the choke approximately 4,000 ohms the error introduced into the reading is not more than 2 per cent.



Front view of set, showing meter.

As the set was not required for immediate use in the transmitter, the general utility has been increased by the addition, inside the case, of a 4.5V pocket lamp battery.

This battery is connected between the negative volt terminal and the terminal marked *M*, the original wire being taken off.

The positive volt terminal and the one marked *M* can now be used with the switch set to 5V for tracing wiring and general testing purposes.

The constructional details are as follows :—

The meter is a Western model 301 milliammeter with full scale reading 5 mA, and its resistance is approximately 11 ohms. This small full-scale current is a great advantage, when the instrument is used for measuring the supply on a low power transmitter ; owing to the fact that the current may be fed through high resistance rectifiers and smoothing filters. If a meter is used which takes, say, 15 mA, the meter load is comparable to the transmitter load, and the voltage indicated by the meter will be very

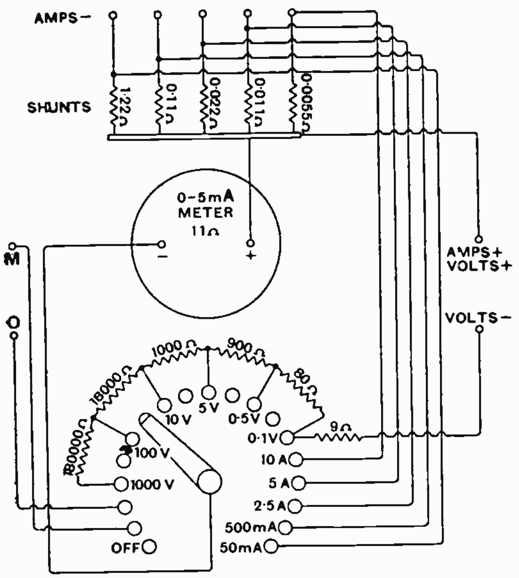


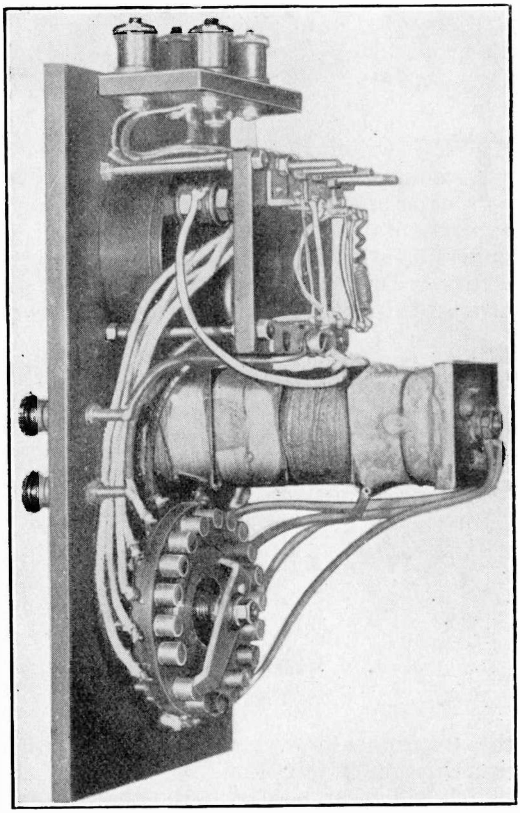
Fig. 2.

The internal connections of the test set.

much lower than that normally supplied to the valves with the meter out of circuit.

Cheaper meters may be obtained, but the writer recommends the type mentioned above.

The resistances required in the voltmeter circuit are as shown in Fig 2. The high resistances were wound with 47 gauge Eureka



Side view showing resistance bobbin.

double-covered silk wire, one ounce of which cost 7s. 6d., and sufficed for all the coils. The resistance of the ounce of wire was approximately 280,000 ohms.

The projecting object perpendicular to the face of the instrument, which can be seen in the photographs, is the former on which the higher resistances are wound.

Owing to the fact that the winding must stand a potential difference between its ends of 1,000V, and that 47 gauge Eureka gets warm with 5 mA flowing continuously, a straight winding on a bobbin was not considered safe.

The former was made to the shape of a four-cornered cage. Stiff wire was threaded through holes in the ends and division pieces and through pieces of large sized Sistoflex, the end pieces being held at the correct distance apart by means of nuts on a 2 B.A. threaded rod through the centre.

After the winding was completed the coil was immersed in molten paraffin to preserve the insulation. The four resistances of lower value are wound with somewhat larger wire, on a spool carried on the underside of the shunt panel. The shunts, which are carried on an auxiliary panel mounted on screwed legs behind the meter, have resistances of approximately the values given in Fig 1. It is not suggested, however, that the shunts be made by calculation and measurement; in the case of the instrument in question, the shunts were made of various sizes of high resistance wire, and were adjusted by scraping in the larger sizes, and by trial and error in the small sizes, whilst the instrument was carrying current in series with a standard meter. The check readings should be taken when the shunt lugs are cold, as the heat due to the soldering will cause quite a large deflection on such an instrument, due to the thermo-electric E.M.F. which is set up.

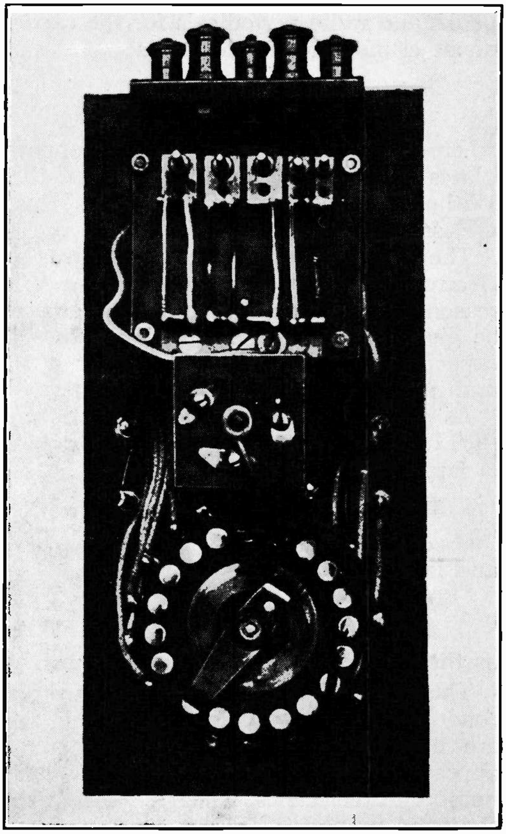
The switch may be made from the type of parts sold for wireless purposes, but something more workmanlike was preferred, and the under panel switch was constructed with properly faced contacts and a rotary lever ground into position on contacts and centre disc. The lever is insulated from the shaft by means of ebonite bushes.

It will be noticed from the diagram that there is a dead stud between each pair of live volt-studs, which is used to prevent accidental contact with a lower resistance than it is intended to use. This precaution is not necessary in the case of the current studs, as only one stud will be "alive" at any one time.

Particular attention should be paid to the soldering of the shunt, as a breakage of a shunt connection whilst the meter is in use for measuring current would result in a burnt-out moving coil, the cost of repair to which, as the writer knows to his regret, is almost 50 per cent. of the original cost of the instrument.

The 0.5V and 0.1V scales are used for measuring voltage drops in leads, switch contacts, etc., and for measuring thermo-electric E.M.Fs. Whilst general tests which may be made with such an instrument are too obvious to need description, a use for which the meter has proved invaluable might with advantage be described, viz., the testing of an amplifier valve, whether power type or otherwise, for correct grid bias.

The 5 mA or 50 mA circuit of the meter is included in the anode circuit of the valve to be tested, and the indications noted when strong telephony is being received. If the needle gives decided kicks to the right (increase of current) the negative grid potential is too great, whilst if the needle kicks to the left the reverse is the case.



Back view, showing shunts.

In conclusion, the writer would like to add that, although good results are sometimes obtained by the trial and error method, such a method is painfully slow, and if knowledge is to be gained as a result of the experiments, systematic measurement is essential.

Common Errors in Condenser Calculations.

Making Condensers to Accurate Values.

By E. H. W. Banner, M.Sc., A.Inst.P. [R127.2

FOR the manufacture of small condensers for radio sets formulæ are usually given without any qualification, with the result that a condenser apparently exactly similar to the calculated dimensions when tested is far from its expected value. The formula given in most elementary text-books and radio periodicals for the capacity of an elementary condenser is

$$C = \frac{A}{4\pi d}$$

where A is the area of one of the two opposing plates and d is the distance between them. Without a statement of the units this is useless.

The capacity C, calculated as above, is in electrostatic units, or centimetres. The reason why the unit is the centimetre will be given later. For practical purposes the capacity is required in farads (or a sub-multiple, microfarads).

As there are 9×10^{11} electrostatic units (E.S.U.) of capacity in one farad the capacity in farads becomes

$$\frac{A}{4\pi d \times 9 \times 10^{11}}$$

and in microfarads

$$\frac{A}{4\pi d \times 9 \times 10^{5}}$$

as there are 10^6 microfarads in a farad.

The formula now applies to a two-plate condenser with air dielectric. When there are more than two plates, the factor N appears in the numerator, where N is the number of dielectrics, which is one less than the total number of plates or electrodes in the condenser. When the dielectric used is not air the capacity is increased by the dielectric constant of the material used. The dielectric constant of a substance is denoted by ϵ (in old books by K or $S.I.C.$).

The formula is now

$$\frac{NA\epsilon}{4\pi d \times 9 \times 10^{5}}\ \mu\text{F} = \frac{.0884}{10^6}\ \frac{NA\epsilon}{d}\ \mu\text{F}$$

when A is the area of each plate in square centimetres, and d the thickness of the dielectric in centimetres. The formula as given, however, is approximate only, the approximation depending on the ratio of the dimensions of the plates to their distance apart, which is the thickness of the dielectric.

The reason for this approximation is quite obvious from a study of a diagram showing the lines of electric stress between the plates of a condenser (see Fig. 1). At the centre of the plates the lines of force are straight, and take the shortest path across the gap. Towards the ends the lines bulge outwards, and outside the limits of the plates curves are obtained which extend right around to the backs of the plates. It is this bulging that causes the formula to be incorrect.

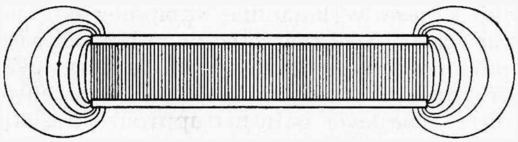


Fig. 1. *Showing the distribution of the lines of force between the charged plates of a condenser.*

Within the limits of the straight-line area of the plates the formula holds good, but as the edge-effects, as they are termed, are manifest in any size of condenser, it follows that to reduce the edge effects the area should be large or the distance apart small. This is better expressed by saying that the ratio of area (or dimensions) of the plates to the distance apart should be as great as possible. If the area is several square centimetres and the dielectric only a few thousands of an inch thick, the approximation is sufficiently near to be used.

When the ratio is not large, and a nearer value is required the formula below, which takes into account the fringing at the ends, should be used.

Consider two opposing surfaces as in Fig. 2, and neglect for the present the further edges, and the edges in a plane perpendicular to that of the paper. Fringing or spreading of the lines takes place at the edges and as a close approximation the length a may be considered to be increased by an amount $d/2\pi$ with no fringing or edge effect.

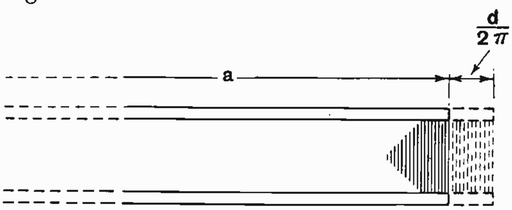


Fig. 2. *Showing how the edge effect may be allowed for in calculations by assuming an increase $d/2\pi$ in the length of the condenser plate.*

d, as before, is the distance between the plates in the same units as the length a, and in the numerical formulæ given, in centimetres.

For this approximation to hold, d must be less than the dimensions of the plates, which is nearly always the case in practice.

It is also incorrect if the thickness of the plate, measured in the direction of d, is great, but in condensers the plates are always thin, and so the approximation is sufficiently close to be of use.

Applying this correction to a practical case, circular plates will first be considered, the two plates being presupposed coaxial, parallel and of equal area.

The imaginary strip of plate $d/2\pi$ to account for the fringing obviously extends all round the edges and so the effective radius of one plate is

$$r + \frac{d}{2\pi}$$

where r is the measured radius.

The effective area is $\left(r + \dfrac{d}{2\pi}\right)^2$

For a pair of rectangular plates the strip of width $d/2\pi$ has to be added at each edge as before, and so if the physical dimensions are a, b, the effective dimensions are

$$a + \frac{d}{\pi} \text{ and } b + \frac{d}{\pi}$$

as the fringing is manifest at both extremities of the plates, in each plane, as in Fig. 3.

The area being two-dimensioned, the strip d has to be added to the dimension b, in the plane of a.

Fig. 3 shows the rectangular plate a b with the imaginary strips added, and it will be seen that the strips do not account for the whole area, as the corners have no addition for fringing.

This correction is small, but it may be allowed for by adding to the effective area as already defined the area of a circle radius $d/2\pi$, as the four corners require quadrants of a circle to complete them.

The complete expression for the effective area of a rectangular plate system is thus expressed as

$$\left(a + \frac{d}{\pi}\right)\left(b + \frac{d}{\pi}\right) + \pi\left(\frac{d}{2\pi}\right)^2$$

Neglecting edge effects, the capacity between two opposing electrodes is independent of their shape, for a given area, and other conditions being constant. When the edge effect is considered it will be seen that the capacity is not independent of the components of the area, as the length of the additional strip of width $d/2\pi$ depends on the circumference of the electrodes and not on their area.

For example, consider a system of two equal rectangular plates of sides 4 cm. × 2 cm. and suppose that $d/2\pi = \frac{1}{2}$, for simplicity, although the ratio is large for a practical case.

The actual area is 8 cm.² but the effective area is

$$(4+1)(2+1) + \pi(\tfrac{1}{2})^2 = 15.78 \text{ cm.}^2$$

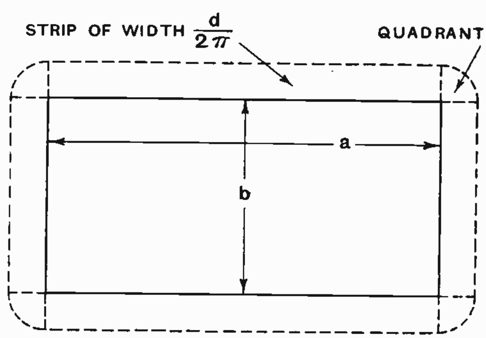


Fig. 3. *Showing the effective size of a rectangular condenser plate.*

For circular plates of area = 8 cm.², the radius is (nearly) 1.6 cm. The effective area is

$$\pi\left(r + \frac{d^2}{2\pi}\right) = 13.9\text{cm.}^2, \text{ which is about}$$

12 per cent. less than that of the rectangular plates.

In practice $d/2\pi$ will be considerably less than .5, except for the case of small condensers for high voltages, when the dimension d is determined by the voltage to be used.

It is to condensers of this nature that the corrections for edge effects are most necessary.

In the formulæ given at the commencement of the paper the effective area, as determined from the foregoing, should be used as A.

When the exact result is required, the following formula by Kirchhoff must be used. This applies to circular plates; for rectangular plates the formula is much more complicated.

$$C=\frac{\pi r^2}{4\pi d}+\frac{r}{4\pi d}\times\left\{d \log_\epsilon \frac{16\pi r(d+t)}{ed^2}+t \log_\epsilon \frac{d+t}{t}\right\}+c'$$

where C' is any part of the capacity which does not change with d.

r is the radius of the discs. } cm.
d „ distance between plates } cm.
t „ thickness of plates. } cm.
ϵ „ base of the Naperian logarithms.

This is in E.S.U. and for air dielectrics.

The two difficulties in making a condenser to a given specification are in measuring the true thickness of the dielectric and in knowing the actual dielectric constant of the material used. For any condensers other than those with an air dielectric these two difficulties are far greater than is generally realised. If the dielectric is measured with a micrometer to be one thousandth of an inch, an error in the spacing of one thousandth of an inch, which is quite small and easily obtained, means that the actual capacity is altered by a factor of two. If mica is used, it may be found that the mean thickness is one thousandth, to considerable accuracy, if a good micrometer is used, but the source of error is then in the air film which is usually present. A film of air of one thousandth of an inch would make an appreciable difference to the resultant capacity, and is difficult to eliminate. In general, it can be minimised by having thick dielectrics, great pressure as soon as assembled, or impregnation with varnish and drying under pressure.

The other source of error is in the dielectric constant of the material. If the figure is looked up in different books very different values will result. For example, mica is given as about 2.5 in some books and 7 in others. Here is a source of error having a maximum of 7/2.5, which upsets any calculation. Possibly the best way of overcoming this difficulty is to make up a condenser of dimensions known to a good degree of accuracy, especially as to thickness of the mica. Then the condenser can be tested by a standardising laboratory, and from the formula the value of ϵ can be worked out. This value can then be inserted in the calculations for the required condenser. This assumes that the two samples of mica will have the same values, which is likely if they are split from the same slab.

As a rule, the capacity of a small condenser made up to calculations cannot be relied on to more than about $\pm$ 25 per cent. accuracy. That is, if the condenser is nominally .01μF (microfarad) it may be anything from .0075 to .0125μF, unless great precautions were taken in measuring the dielectric accurately and in the total exclusion of air, also in knowing the correct value of the dielectric constant.

The capacity of a sphere in free space, of radius r cm., charged with Q units of electricity has a potential at any point d from the centre of the sphere of $v=Q/d$ (E.S.U.). The potential of the sphere is Qr and from this $r=Qv$. Now, by definition $C=Q/v$, therefore $C=r$ or the capacity in E.S.U. is numerically equal to the radius of the sphere. A sphere of radius 1 cm. therefore has a capacity, in free space, of 1 cm. or 1 electrostatic unit. This explains why the unit of capacity is the cm.

Mathematics for Wireless Amateurs.

By F. M. Colebrook, B.Sc., A.C.G.I., D.I.C. [510

(Continued from page 498 of August issue.)

(4) Indices. (A) Definition of an Index.

THE first four instalments of this series have been devoted to a very thorough discussion of the four fundamental operations of Algebra. The present section will deal with a very important set of ideas derived directly from the ideas of multiplication and division.

Consider the product

$$a \times b \times c \times d \ \ldots \ n \text{ factors in all,}$$

where n is of necessity a positive integer, and the other letters have the full significance of algebraic letter symbols. Now suppose that the factors are all equal to each other. Then the product takes the form

$$a \times a \times a \times a \ \ldots \ n \text{ factors.}$$

Now just as the sum of n a's was abbreviated into $a \times n$, so the product of n a's similarly lends itself to abbreviation, and the accepted form of abbreviation is

$$a \times a \times a \times a \ \ldots \ n \text{ factors} = (i.e. \text{ is written}) \ a^n.$$

The double symbol on the right is spoken of as "a to the nth" or "the nth power of a." It follows from this definition that n must be a positive integer.

(B) The Index Law.

From the definition of an index,

$$\begin{aligned} a^m \times a^n &= (a \times a \times a \times a \ \ldots \ m \text{ factors}) \\ &\quad \times (a \times a \times a \times a \ \ldots \ n \text{ factors}) \\ &= (a \times a \times a \times a \times a \times a \ \ldots \ m+n \text{ factors}) \\ &= a^{(m+n)} \end{aligned}$$

i.e., $$a^m \times a^n = a^{(m+n)}$$

The general result symbolised in this formula will be referred to hereafter as the Index Law.

(B1) The Negative "Index."

The word "index" is put in inverted commas to emphasise the fact that this is only "a manner o' speaking." An index is a positive integer, but it is very convenient to allow a negative number to masquerade as an index for the following reason.

Consider the fraction a^m/a^n. If $m > n$, a^m can be written $a^m = a^{m-n+n} = a^{m-n} \times a^n$ by the Index Law, so that

$$a^m/a^n = (a^{m-n} \times a^n)/a^n = a^{m-n}$$

(see para. (E2) of Section 3). On the other hand, if $m < n$ it can obviously be shown in exactly the same manner that

$$a^m/a^n = 1/a^{n-m}.$$

Now this double result, depending on whether $m > n$ or $m < n$ involves a deal of tiresome conversation and would be a great nuisance in practice. The nuisance can be avoided in this way. Let us write $1/a^n$ in the form a^{-n}. The symbol a^{-n} is in itself quite meaningless, so we are quite at liberty to attach the above meaning to it if we so desire, and if any useful purpose will be served by doing so. Notice carefully, however, that the $-n$ in a^{-n} is not strictly speaking an index, and a^{-n} is nothing more than *a way of writing* $1/a^n$. On this understanding,

$$a^m/a^n = a^m \times a^{-n}$$

Now if $m > n$, $a^m/a^n = a^{m-n}$ as shown above

i.e. $$\begin{aligned} a^m \times a^{-n} &= a^{m-n} \\ &= a^{m+(-n)} \end{aligned}$$

which shows that the $-n$ can be treated as if it were a genuine index, obeying the Index Law. Moreover, both cases are now included in the one formula, for if $m < n$, then, as shown above

$$a^m/a^n = 1/a^{n-m}$$

and $1/a^{n-m}$, in virtue of the meaning that we have attached to a negative number written as an index, can be put in the form

$$\begin{aligned} 1/a^{n-m} &= 1/a^{-(m-n)} \\ &= a^{m-n} \end{aligned}$$

Thus the meaning that we have arbitrarily assigned to a negative number written as an index has the advantage that such negative numbers can be treated as if they were genuine indices obeying the Index Law, and an index can if necessary be allowed to assume a negative value without causing us to rewrite the resulting expressions in some other form.

(B2) **The Zero "Index."**

Again, there is strictly speaking no such thing as the zero index. However, consider a^m/a^n when n becomes equal to m. In accordance with the ideas explained in the preceding paragraph

$$a^m/a^m = a^{(m-m)} = a^0$$

and since a^m/a^m is unity, it follows that a^0 is unity for all finite values of a. (Notice that if $a=0$, a^0 becomes the germ of insanity described in para. (E4) of Section 3, so don't let $a=0$ in a^0). Thus a^0, an idea which is incomprehensible in itself, is really nothing more than a convenient way of writing a^m/a^m,* and its value is unity for all finite values of a except $a=0$.

(B3) **Repeated Products of Powers.**

Since $a^m \times a^n = a^{m+n}$ for positive or negative values of m or n, it follows from the Law of Association that

$$a^m \times a^n \times a^p \times a^q \ldots r \text{ factors} = a^{m+n+p+q+ \ldots r \text{ terms}}$$

and if $m=n=p=$etc.

this becomes

$$a^m \times a^m \times a^m \times a^m \ldots r \text{ factors} = a^{m+m+m+ \ldots r \text{ terms}}$$

i.e. $(a^m)^r = a^{m \times r} = a^{mr}$

As an exercise the reader is recommended to show from first principles that this is true for negative values of m and r, *e.g.*, $-p$ and $-q$, where p and q are positive. This amounts to showing that

$$1/(1/a^p)^q = a^{pq} \quad \left(i.e., \frac{1}{\left(\frac{1}{a^p}\right)^q} = a^{pq} \right)$$

(B4) **Powers of Products and Quotients.**

By writing out in full it will be found quite easy to show that for positive or negative values of n

$$(a \times b)^n = a^n \times b^n$$

and $$(a/b)^n = a^n/b^n$$

As a particular case of the latter, when $a=1$

$$(1/b)^n = 1^n/b^n = 1/b^n.$$

By writing $1/b$ as b^{-1} this is seen to be a special case of the result proved in para. (B3). Notice further that

$$(1/b)^{-n} = b^n.$$

(C) **Roots.**

Consider the statement

$$a \times a \times a \times a \ldots n \text{ factors} = a^n = b.$$

Here the number b is described as being made up of n factors each equal to a. Similarly a could be described in terms of b and n as that number, n factors each equal to which would give the number b. There is in fact a recognised way of writing this, *i.e.*

$$a = \sqrt[n]{b}$$

a is described as the nth root of b. Thus since

$$2 \times 2 \times 2 \times 2 = 2^4 = 16, \quad 2 = \sqrt[4]{16}$$

and 2 is described as the fourth root of 16. The definition of the nth root of b is clearly

$$(\sqrt[n]{b})^n = b.$$

There is no special magic about this way of writing the nth root of b, and if we wished to emphasise the analogy with the index form it could equally well be written

$$b^{n'}$$

the dash serving to distinguish it from b^n. Using this way of writing, the definition of $a^{n'}$ would be

$$(a^{n'})^n = a$$

Comparison of this definition with the result obtained above, *i.e.*

$$(a^n)^m = a^{mn}$$

suggests an even better way of writing the nth root of a. Suppose we write it as $a^{\frac{1}{n}}$. Then the definition of $a^{\frac{1}{n}}$ is

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

which is in agreement with the formula $(a^m)^n = a^{mn}$, for it can be put

$$(a^{\frac{1}{n}})^n = a^{\frac{1}{n} \times n} = a^1 = a.$$

Notice carefully that $a^{\frac{1}{n}}$ is only *a convenient way of writing* $\sqrt[n]{a}$. The $1/n$ is not really

* Some more advanced students will possibly object that a^0 must be something more than the convenient mathematical fiction that it is here stated to be, since it is a form which frequently occurs in practical physics. For instance, take some quantity which changes with time according to the formula $x = x_0 a^{bt}$ where x_0, a, and b are constant numbers. When $t=0$ the value of x is $x_0 a^{b0}$, *i.e.*, x_0. It must be remembered, however, that t really represents an *interval* of time and should ideally be written in the form $t_2 - t_1$. The condition $t=0$ is thus really the condition $t_2 = t_1$, which is in agreement with the above discussion of a^0.

an index and the application of the above formula in the manner shown does not follow from the Index Law but from the definition of $a^{\frac{1}{n}}$.

It will be convenient to carry this notation one stage further, for, as the definition of the qth root of a^p we have

$$(\sqrt[q]{a^p})^q = a^p$$

and if $(\sqrt[q]{a^p})$ is written in the form $a^{\frac{p}{q}}$ this becomes

$$(a^{\frac{p}{q}})^q = a^p$$

which again is in agreement with the formula

$$(a^n)^m = a^{nm}$$

This suggests that $a^{\frac{p}{q}}$ will prove to be a convenient way of writing the qth root of a^p, so that we have as the definition of $a^{\frac{p}{q}}$ the statement

$$(a^{\frac{p}{q}})^q = a^p$$

We must now see to what extent the p/q in $a^{\frac{p}{q}}$ can be treated as if it really were an index.

(C1) Product of Roots.

Since $(a^{\frac{p}{q}})^q = a^p$

$\{(a^{\frac{p}{q}})^q\}^s = a^{ps}$

i.e., $(a^{\frac{p}{q}})^{qs} = a^{ps}$ by para. (B3).

Similarly $(a^{\frac{r}{s}})^{qs} = a^{rq}$

Therefore $(a^{\frac{p}{q}})^{qs} \times (a^{\frac{r}{s}})^{qs} = a^{ps} \times a^{rq}$

i.e., $(a^{\frac{p}{q}} \times a^{\frac{r}{s}})^{qs} = a^{(ps+rq)}$

This shows that $(a^{\frac{p}{q}} \times a^{\frac{r}{s}})$ is the qsth root of $a^{(ps+rq)}$, which we have agreed to write in the form $a^{\frac{ps+rq}{qs}}$, so that

$$(a^{\frac{p}{q}} \times a^{\frac{r}{s}}) = a^{\frac{ps+rq}{qs}} = a^{\left(\frac{p}{q}+\frac{r}{s}\right)}$$

The suggested form of notation therefore has the great advantage that the formula

$$a^m \times a^n = a^{m+n}$$

can be applied when m and n are fractions. A simple extension of the above proof will show that it will still apply even when m and n are negative fractions or when either is negative.

(C2) Full Generalisation of the Index Formulæ.

Assuming only that $a^{\frac{p}{q}}$ is a convenient way of writing the qth root of a^p, *i.e.*, on the basis of the definition

$$(a^{\frac{p}{q}})^q = a^p$$

it will be quite easy to show that the formulæ given in paras. (B), (B1), (B3) and (B4) can all be applied when the indices are fractional in form. For instance, to prove that

$$(a^m)^n = a^{mn}$$

where $m=p/q$ and $n=r/s$, p, q, r, and s being integers, we have, by definition

$$\{(a^{\frac{p}{q}})^{\frac{r}{s}}\}^s = (a^{\frac{p}{q}})^r$$

and

$$\{(a^{\frac{p}{q}})^{\frac{r}{s}}\}^{qs} = \{(a^{\frac{p}{q}})^r\}^q = \{(a^{\frac{p}{q}})^q\}^r = (a^p)^r = a^{pr}$$

so that by definition

$$\{(a^{\frac{p}{q}})^{\frac{r}{s}}\} = a^{\frac{pr}{qs}}$$

The proofs for the remaining formulæ will be omitted to save space. They will follow exactly similar lines to that given as an example. To resume, it may now be stated that for positive or negative integral or fractional values of m and n

$$a^m \times a^n = a^{m+n}$$

$$(a^m)^n = a^{mn}$$

$$(ab)^n = a^n b^n$$

$$(a/b)^n = a^n/b^n.$$

The reader should notice very carefully the logical sequence of the above demonstration of the generalisation of the index formulæ. This demonstration is put forward with all due deference as an alternative to the usual text-book treatment, in order to show that the full generalisation required can be obtained without bringing in any incomprehensible ideas or any purely formal symbolism.*

(D) An Example of the Index Notation.

The products considered in para. (D2) of Section 3 can now be written

$$(x-a)\ (x-b) = x^2 - (a+b)\ x + ab$$

and $(x-a)\ (x-a) = (x-a)^2 = x^2 - 2ax + a^2$

Further, $(x-a)\ (x+a) = x^2 - a^2$

These three formulæ, which are three special cases of the multiplication of number groups, will prove to be of great use in practical mathematics.

(E) Is $a^{\frac{1}{n}}$ always a Number?

The definition of $a^{\frac{1}{n}}$ is

$$(a^{\frac{1}{n}})^n = a.$$

We have so far taken it for granted that if a and n are numbers, there is some other number, written $a^{\frac{1}{n}}$, which fulfils the above definition; and so there is in most cases, but not in every case. Suppose a is 64 and n is 3. Then, by definition,

$$(64^{\frac{1}{3}})^3 = 64$$

and since $4^3 = 64$

we may say that $64^{\frac{1}{3}} = 4$

Again, since $5^3 = 125$, $125^{\frac{1}{3}}$ is the number 5. Moreover, since 100 lies between 64 and 125, 100 will presumably be some number greater than 4 and less than 5, what Barrie would call "four and a bittock," *i.e.*, four and a fraction. Actually there is no number between four and five the cube of which is *exactly* equal to 100, and 100 is for this reason called an "irrational" quantity. (This, by the way, does not mean "unreasonable" or in any other way feminine. It simply means a number which cannot be exactly expressed as the ratio of two whole numbers.) However, by methods to be described later, a number can be found which satisfies the condition to a very high degree of accuracy.

Thus $(4.6)^3 = 97.34$

$(4.64)^3 = 99.9$

$(4.642)^3 = 100.03$

and so on. Since in real life there is always a limit to the accuracy with which measurements of quantity can be carried out, the distinction between an irrational quantity and a rational quantity is, as far as the physicist or experimenter is concerned, purely academic. Thus for any work of an accuracy of a tenth of 1 per cent., $100^{\frac{1}{3}}$ *is* 4.64.

Consider now another case. What is $25^{\frac{1}{2}}$? By definition,

$(25^{\frac{1}{2}})^2 = 25$

Now $(+5)^2 = 25$

and also $(-5)^2 = 25$ (see para (D1) of Sec. 3)

so that $25^{\frac{1}{2}} = +5$

and $25^{\frac{1}{2}} = -5$

In other words, $25^{\frac{1}{2}}$ not only exists—it leads a double life—a sort of Dr. Jekyll and Mr. Hyde. This duality can be expressed

$$25^{\frac{1}{2}} = \pm 5 \text{ (plus or minus 5)}$$

Notice further that any even root can be expressed as a square root, for

$$a^{\frac{1}{2p}} = \left(a^{\frac{1}{p}}\right)^{\frac{1}{2}} \text{ (see para. (B3) above)}$$

so that the $2p$th root of a is the square root of the pth root of a. It is clear, therefore, that any even root, if it exists at all, will have at least two real values, differing only in sign. In practice this implicit ambiguity would be an inconvenience, since mathematics is, or should be, plain dealing *par excellence*, so it is generally agreed that $a^{\frac{1}{2}}$ shall mean the real positive number which satisfies the definition. The ambiguity can now be made explicit.

For instance, if $x^2 = b$

then $x = \pm b^{\frac{1}{2}}$ or $\pm\sqrt{b}$

Notice that this ambiguity will not occur in the case of odd roots.

Thus $-3 \times -3 \times -3 = -27$

and $3 \times 3 \times 3 = 27$

so that $(27)^{\frac{1}{3}} = 3$

* It is seriously stated in some text-books that the generalisation of the index formulæ depends on the Principle of the Permanence of Equivalent Forms, *i.e.*, "A law of algebra which admits of proof subject to certain limitations is true generally provided the removal of the limitations is not *incompatible* with the truth of the law." This principle appears to the writer to be modelled on the tactics of that sort of cuttle-fish which, when in difficulties, squirts out a cloud of sepia and escapes in the confusion.

and $(-27)^{\frac{1}{3}} = -3$

Similarly $32^{\frac{1}{5}} = 2$

and $(-32)^{\frac{1}{5}} = -2$

In words, the odd root of a negative number is a negative number or fraction, and the odd root of a positive number is a positive number or fraction.

One other important case remains. What is the square root of a negative number, $(-9)^{\frac{1}{2}}$ for instance? First let us simplify the matter a little. Since

$$-9 = -1 \times 9$$

$$(-9)^{\frac{1}{2}} = (-1)^{\frac{1}{2}} \times (9)^{\frac{1}{2}} \text{ (see para. (B 4) above)}$$

$$= (-1)^{\frac{1}{2}} \times 3 \text{ or } \sqrt{-1} \times 3$$

In a similar manner the square root of any negative number or fraction can be reduced to the form $\sqrt{-1} \times a$, and the feature common to all such cases is $\sqrt{-1}$. Also any even root of a negative number will depend on this same thing, for the $2p$th root of -1 is the pth root of the square root of -1. Now there is no number which, multiplied by itself, will give -1, so the symbol $\sqrt{-1}$ or $-1^{\frac{1}{2}}$ is, as far as pure number is concerned, meaningless. Later on an interpretation will be found for it in relation to quite a different set of ideas, and the symbol will prove to be of great service in connection with alternating current theory. For the present, however, it will be sufficient to say that the square root of a negative number is non-existent as a number, or, as the mathematicians have not very happily designated it, is an imaginary quantity.

Examples. Indices.

1. Show that $(x^{\frac{1}{2}} + a^{\frac{1}{2}})^2 = x + 2a^{\frac{1}{2}}x^{\frac{1}{2}} + a$

and $(x^{\frac{1}{2}} - a^{\frac{1}{2}})(x^{\frac{1}{2}} + a^{\frac{1}{2}}) = (x - a)$

2. Simplify $\dfrac{a^{\frac{5}{2}} b^{1\frac{1}{6}} c^{\frac{3}{2}}}{b^{\frac{3}{8}} c^{\frac{3}{8}}} - \dfrac{a^{\frac{3}{4}} b^{\frac{3}{2}} c}{a^{\frac{1}{4}} b^{\frac{1}{2}}}$

Show that it is equal to

$$abc(a^{\frac{3}{2}} b^{-1\frac{1}{6}} c^{\frac{1}{8}} - a^{-\frac{1}{2}})$$

3. If $a^x = \alpha$

$a^y = \beta$

$a^z = \gamma$

and $\alpha\beta = \gamma$

what is the relation between x, y, and z? Further, if $\gamma = \alpha/\beta$ what is the relation between x, y, and z?

4. Show that $(a + b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$

$(a - b)^3 = a^3 - 3a^2b + 3ab^2 - b^3$

$(a^3 - b^3) = (a - b)(a^2 + ab + b^2)$

$(a^3 + b^3) = (a + b)(a^2 - ab + b^2)$

5. What are the factors of $(a^4 - b^4)$ and of $(a^6 - b^6)$ and $(a^6 + b^6)$?

6. Show that

$$\left(\frac{x^a}{x^b}\right)^{(a+b)} \times \left(\frac{x^b}{x^c}\right)^{(b+c)} \times \left(\frac{x^c}{x^a}\right)^{(c+a)} = 1.$$

(*To be continued*).

Amateur Long-Distance Work.

By Hugh N. Ryan (5BV). **[R545.009.2**

FOR some time now, it seems, very little amateur long-distance work of great interest has been done. This is due, no doubt, to the fact that the summer weather has tempted most of the experimenters to other pursuits (though we do not think that this fact can legitimately be added to data collected on the "effect of weather upon wireless signals.")

Although there is so little activity to be noted, yet a short review of the present state of long distance work may be given.

The most noticeable feature of recent work is the greatly increased number of stations regularly using low power. Only a short time ago, useful low-power work, though quite often accomplished, was always regarded as something of a "stunt," and with a few exceptions the stations using it usually went back to fairly high power for ordinary serious work. Recently, however, not only have the stations habitually using low power increased their useful range very greatly, but many (if not most) have reduced power. It has been evident for a long time that this must happen, as the power used in many cases was certainly excessive in present-day circumstances. It is satisfactory to note that this reduction of power seems in all cases to have improved rather than prejudiced long-distance results. One imagines (with some relief) the number of valves which are no longer overloaded and the number of condensers which are now called upon to stand a voltage less in excess of that for which they were designed, and one wonders the less at the improvement in results, not to mention the improvement in note quality in some cases.

It is also to be noticed that more work is being done on Sunday mornings and afternoons, and less at night, than hitherto. Daylight work is gradually becoming more important than night work, with its accompanying disadvantages, now that daylight does not present so great a barrier. One of the greatest factors in the opening up of daylight work, and hence of growing importance nowadays, is the use of the waves of about 20 metres. It will be remembered that when these wavelengths were first explored, chiefly by 5LF on this side of the Atlantic, they were fairly widely used for a time, but results were found to be too uncertain for the patience of most amateurs, and they subsequently became almost neglected by the majority of stations.

There are signs now, however, of a reviving interest in these waves, with perhaps the promise of more patience in their investigation. Such signs take the form of good results by a very few stations rather than the presence of a lot of stations on this wave, but it is at any rate a good beginning, and it is hoped that more stations will soon be heard there. It should be emphasised that, whatever may be the disadvantages of 20 metres for ordinary winter night-time work, it is certainly a most useful wave for daylight DX in the summer, and perhaps the experience gained in this connection will help to overcome the difficulties of using it in the winter.

Judging by casual listening, the station now doing the most useful work on 20 metres is 2LZ, while a number of Northerners are also heard there, and 2SZ is between the two usual bands, on 32 metres, with crystal control. The chief difficulty at present on 20 metres is undoubtedly the lack of stations with which to work.

Some details of amateur long-distance work in Austria have been received, which will doubtless be of interest to the many amateurs who have heard or worked Austrian stations, now often heard in this country. They all use call-signs consisting of the letter Ö followed by two more letters. They appear to work on a variety of wavelengths, but most useful work is done on 45 metres or thereabouts. Very good results are obtained by these stations, especially on low power. The two best known stations are ÖAA and ÖAB, the former on 46 metres with 10 to 20 watts, and the latter on 58 metres with considerably less power.

Reports from this country for Austrian stations may be sent to ÖAA (Th. Mossig, Wien 1, Am Hof 13, Austria).

In the same way that interest among DX receivers centred, some years ago, round the "record" number of American stations received by any British amateur, a similar interest is now aroused by reception of Australian and New Zealand signals. While there is no scientific merit in "mass reception" there is undoubtedly a certain competitive interest attaching to it, and many have tentatively claimed the record. The best we have yet heard of is the record of a Birmingham receiver (Mr. T. S. Calder) who had, up to the beginning of June, heard 66 Australasians.

[Reports on interesting work carried out should be sent promptly to Mr. H. N. Ryan, c/o The Editor.]

D.C. Instruments in Wireless Receivers.

By J. F. Herd, A.M.I.E.E., M.I.R.E. [R251

THE need for an accurate knowledge of his D.C. values and adjustments (filament, anode, etc.), is one which frequently impresses itself on the wireless experimenter, and causes him to regret the insufficient use of D.C. measuring instruments in most wireless receivers. There is no doubt that for serious quantitative work such instruments are essential, and even for less accurate work they are very desirable in the interests of approximate constancy of performance. Expense is the only serious argument against them.

While it is readily possible to arrange by switching for one D.C. instrument to be transferred from one anode circuit to another, the arrangement is often somewhat complicated. If the instrument is desired also to be used for other circuits, *e.g.*, grid or filament, considerations of capacity may make such switching undesirable.

The use of ordinary pattern telephone jacks on the set, with the D.C. instrument joined to the corresponding two-point plug, provides perhaps the most complete solution for the application of one measuring instrument to different parts and circuits of the set.

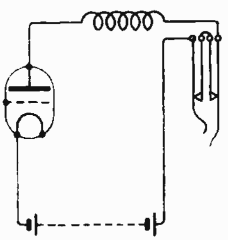


Fig. 1*a*.

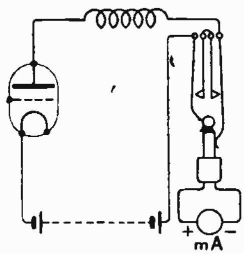


Fig. 1*b*.

Fig. 1*a* shows an arrangement which has been found convenient for providing access to anode circuits. The inner springs of the jack being shorted together, the connections of the anode circuit, when no plug is inserted, are completed through the outer springs and are perfectly normal. Insertion of the plug joins the milliammeter directly into the anode circuit for measurement of the steady current, as shown in Fig. 1*b*. A jack so wired into each anode circuit of any number of stages thus permits one instrument to be transferred quickly from one circuit to another, or to be left semi-permanently in one position for any particular purpose. If so left, especially in a H.F. circuit, the milliammeter should be by-passed by a condenser, which can, of course, be connected externally to the milliammeter itself.

The use of a suitable series resistance in conjunction with another jack readily enables

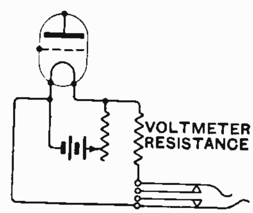


Fig. 2.

the same milliameter to be used as a voltmeter. For example, a milliammeter reading a scale maximum of 5mA can be used as a voltmeter, reading up to 5 volts, if used in series with a resistance making up a total resistance of 1 000 ohms.

Fig. 2 shows how this can be used for checking filament voltage. In this case the inner springs of the jack are *not* connected together, so that the jack circuit is open until the milliameter is plugged in. So used, the accuracy of the instrument becomes a function of the accuracy of the series resistance required to give the necessary conversion to volts. If, however, the measurement of absolute voltage is less important than the maintenance of an optimum working point or constant adjustment—as is often the case—some latitude becomes possible.

A similar arrangement can also be applied for use as a voltmeter on a potentiometer or other voltage measurement. In the case of a centre-tapped potentiometer two jacks, mutually reversed with respect to each other, can be used in conjunction with one series resistance to give the effect of a centre-reading voltmeter.

Such an arrangement is shown in Fig. 3. With a suitable series resistance for the scale of voltage required, the milliammeter in one jack can be used to read grid o to — max., and the other grid o to + max.

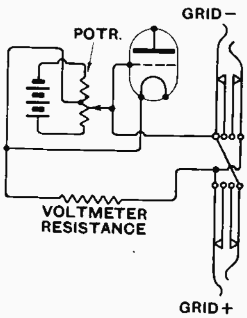


Fig. 3.

From the foregoing, the use of a jack with a suitable resistance also permits the instrument to be used as a voltmeter on the H.T. battery, a check of its voltage being frequently very desirable. Indeed, the extended use of the one instrument to many voltmeter applications is simply a matter of making and measuring with sufficient accuracy, the requisite series resistances for the scales of voltage desired.

The milliammeter can also be used as an ammeter measuring heavier currents, *e.g.*, that of the filament, a measurement which is sometines desirable with certain valves. This can be done by permanently shunting the *outer* springs of jack with a shunt such as will reduce the reading to amperes.

This arrangement is shown in Fig. 4, where *S* is the shunt, which permanently completes the circuit even when the plug is not inserted.

The adjustment of this shunt is a matter of experiment and must be done with some care. To convert the usual pattern of milliammeter to an ammeter reading up to a maximum of 2 or 3 amperes, a very short length of, say, No. 16 or 18 Eureka will usually be found suitable. The adjustment is best done by over shunting, subsequently increasing the resistance of the shunt by gradual filing. Final adjustment or re-check should be done after wiring the jack into the set, as there is often a tendency for the shunt to be moved by the softening of the solder in wiring into the apparatus. It should also be noted that the same shunt may not give consistently similar results if used with different instruments, each of the same nominal pattern.

One good instrument can thus be utilised to measure all the D.C. constants in which one is ever interested in a wireless receiver, and a system of telephone jacks—especially if purchased from ex-Government stock—is very much cheaper than a number of high-grade ammeters or voltmeters.

The instrument need not even be built into the set, but can be left on the bench with its plug attached, remaining available for other purposes.

The use of jacks also permits the ready introduction of, say, a more sensitive type of galvanometer if required for any particular measurement, while the jacks can also

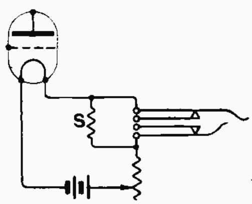


Fig. 4.

be used for the insertion of telephones into any anode of the L.F. system—a matter of considerable advantage in many experiments. It is, indeed, frequently desirable to be able to gain quick access to an anode circuit, and other uses may readily suggest themselves to the experimenter.

It is, of course, necessary to maintain some convention of wiring, so that the same instrument may be used throughout—*e.g.*, it can be arranged that the tip of the plug shall be joined to the + terminal of the instrument, and the jacks wired accordingly (as in the diagrams).

Abstracts and References.

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R000.—WIRELESS IN GENERAL.

R084.—MAPS AND WIRELESS WAVES.—R. Keen. (*Wireless World*, 21st July, 1926, pp. 73-76.)

An account of methods of indicating the track of wireless waves over the earth's surface.

R100.—GENERAL PRINCIPLES AND THEORY.

R112.—DAS GESETZ DES TIEFEMPFANGS IN DER DRÄHTLOSEN TECHNIK.—W. Schottky. (*Zeitschrift für Hochfrequenz*, 27, 5, pp. 131-141.)

Applying the classical reciprocal relation of oscillation theory to acoustics, Rayleigh (*Theory of Sound*, Vol. I., § 109) has formulated the "Law of low reception," which states that when receiving quasi-spherical waves, the ratio of the energy picked up from the sound field to that sent out increases with the square of the wavelength, and therefore efficiency reception becomes greater the lower the frequency. The author has attempted to formulate a corresponding law for electrodynamic radiators and in this article gives the results of his deliberations in so far as they bear on radio technique.

It is explained at the outset that in dealing with problems of wireless reception we have a choice of two methods: a direct and an indirect one. The direct method, by which most of the facts already known have been obtained, takes the field of the wave being received as given, and from it calculates the effective alternating E.M.F. in the antenna and the currents and tensions in the circuits connected to it. The other method does not study the receiving properties of the receiving antenna under investigation, but its transmitting properties instead, and the effect that its radiation would have on the transmitter that is being received. This indirect method is said to be of advantage when the receiving characteristics of the transmitter and the transmitting characteristics of the receiver can be more easily calculated than the receiving characteristics of the receiver under investigation. The conditions for which this method of reciprocal relation is applicable as well as some fundamental theorems for dipole antennæ that follow from it have already been given in this *Zeitschrift* (A. Sommerfeld, 26, 4, pp. 93-98.)

R113.—NOTES ON WIRELESS MATTERS.—L. B. Turner. (*Electrician*, 9th July, 1926, pp. 42.-43.)

Discussion of wave propagation, comparing the propagation that would occur in four ideal simple limiting cases:—

(*a*) With a flat perfectly conducting ground bounded by a perfect vacuum.

(*b*) The case (*a*) modified by the addition of a perfectly conducting upper layer parallel to the ground.

(*c*) The case (*b*) modified by making the ground spherical instead of flat.

(*d*) With the earth spherical and without an atmosphere.

R113 & 114.—MESURES DU CHAMP DES PRINCIPALES STATIONS EN AMÉRIQUE DU SUD.—P. Borias. (*L'Onde Electrique*, June, 1926, pp. 284-295.)

These observations were carried out during 1923 and 1924 for the Compagnie Générale de T.S.F., at the Transradio International receiving centre at Villa Elisa, near Buenos Ayres. They were made on the signals of the long-wave stations most easily received in the Argentine Republic, namely: New York, Sainte-Assise, Bordeaux and Honolulu. The method is described in detail. Though thought out independently, it is similar to that employed by Pickard and Englund, utilising ohmic coupling between a constant local transmitter and the aerial receiver. The results for the months of October, 1923, and February, 1924, are tabulated. It was found generally that waves from the north and north-east gave a figure pretty near that furnished by Austin's formula, sometimes less, with a characteristic absorption at seven o'clock local time, whatever the season. Waves coming from the west over the Pacific, on the other hand, were always much stronger than would be expected from the formula.

As concerns atmospherics in the Argentine, these came generally from a north-north-easterly direction, their nucleus appearing to be very distant. On to this background of directional disturbances, others more violent are sometimes superposed, due to local storms and atmospheric conflict.

R113.5.—RADIO WEATHER—"GOOD" AND "BAD." —E. van Cleef. (*Radio News*, August, 1926, pp. 113-184.)

In the absence of precise investigations of the subject, the following preliminary qualitative results are given by the author: Reception is clearest and strongest when the path of the waves is at right angles to the isobars. Reception is weaker when waves pass from one pressure area across another than when they are confined to a single area. Static is most frequent when the isobars are far apart, that is, when the waves travel across areas of little difference in air pressure.

As concerns the actual state of the weather, as good results may be obtained when it is very windy and raining or snowing as when the skies are clear: all that is necessary is the right distribution of pressure.

Another observation of interest is that when the waves travel in a path parallel to the isobars fading occurs.

R113.5.—WEATHER AND RADIO. (*Scientific American*, July, 1926, p. 70.)

Investigations of radio wave propagation by engineers at WGY show that signal strength falls off rapidly during the first 300 miles but becomes stronger at 600 miles and then gradually weakens. A study of the zones in which fading occurs shows that it is worst between 200 and 500 miles from the transmitting station. Therefore broadcast service is more reliable at 600 miles than at 300 miles because fading is less and the volume is somewhat increased. Reception reports indicate that the rate of fading increases steadily as the wavelength grows shorter. Temperature seems to have no effect upon the signals, although static increases as the temperature rises, especially in summer. The barometric pressure seems to make little difference in signal strength when both transmitter and receiver are at the same pressure. When transmission is from a high to a low pressure area, transmission is best at short and at long distances, but at a medium distance of 600 miles it is best from an area of low to an area of high pressure.

R113.6—DISCUSSION ON "POLARIZATION OF RADIO WAVES."—G. Pickard. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 391—393.)

Mr. Pickard's article appeared in *Proc. I.R.E.* for April (these abstracts, *E.W.& W.E.*, June, 1926, p. 381).

Systematic measurements on long-wave stations show great irregularities in direction-finder bearings during the hours of darkness, and it has always been assumed that these irregularities mean actual change in the direction of propagation.

Dr. Alexanderson states here that a number of facts have recently been brought out through work on polarisation of short waves which lead one to think that the evidence collected in the past may be given a different interpretation. We find now in dealing with short waves that such apparent changes in direction of wave propagation can be reproduced regardless of daylight by controlling the plane of polarisation of the radiated wave, and evidence is given here from which it can be inferred that the apparent changes in direction of long waves are also due to the presence of horizontally polarised wave components.

R113.6.—POLARISED TRANSMISSION.—R. Kruse. (*Q.S.T.*, June, 1926, pp. 9-16.)

A semi-popular discussion of the subject including Dr. Alexanderson's polarised wave model.

Direction tests carried out at different heights from the ground indicate the presence of a horizontal and a vertical wave component with different velocity of propagation and suggest that directional errors do not mean that the wave actually comes from unexpected directions, but characterise waves partially polarised in a horizontal plane.

R113.6.—REFRACTION OF SHORT RADIO WAVES IN THE UPPER ATMOSPHERE (Abridged).—W. G. Baker and C. W. Rice. (*Journ. Amer. Inst. Elect. Engineers*, June, 1926, pp. 535-539.)

The following synopsis is given :—

The paper shows that the striking phenomena of short-wave radio transmission (*i.e.*, below 60 m.) can be quantitatively accounted for on a simple electron refraction theory in which the effect of the earth's magnetic field and electron collisions may be neglected as a first approximation. The distribution and number of electrons per unit volume in the upper atmosphere required on this theory to account for the meagre experimental data, appear to be in general accord with the values required in the explanation of the diurnal variations of the earth's magnetic field, auroral and long-wave radio transmission.

The paths taken by the waves from an antenna to distant points on the surface of the earth are calculated. The path calculations give a definite picture of the now familiar skip distance effects. Ideal signal intensity curves (*i.e.*, neglecting absorption and scattering) are given, which show how the energy sent out by a transmitter is distributed over the surface of the earth. A focusing of energy just beyond the skip distance, and again just inside the point where the ray tangent to the ground at the transmitter comes back to earth, is clearly shown. The reflection of waves at the surface of the earth is also considered.

The results of these calculations make it possible to estimate the most suitable wavelengths for night and day communication between any two points on the earth's surface. It is also pointed out that there will be a minimum wavelength, in the vicinity of 10 metres, below which long distance communication becomes impossible. It is shown that from the point of view of long distance communication low angle radiation is most effective. The ray paths and energy flux density in the wave front of the sky waves are independent of the plane of polarisation of the transmitter. The effects of polarisation on the reception problem are not discussed.

The discussion after the reading of the paper is given on p. 571.

R113.7.—THE ATTENUATION OF WIRELESS WAVES DUE TO THE RESISTANCE OF THE EARTH.—Dr. Smith-Rose and R. H. Barfield. (*Journ. Inst. Elect. Engineers*, July, 1926, pp. 766-770.)

The following summary is given :—

The paper calls attention to the present condition of knowledge on the subject of the attenuation of wireless waves travelling over the earth's surface, due to energy absorption by the earth itself. The theories put forward on this problem by Sommerfeld and Zenneck are briefly outlined, and it is shown that the latter has taken account only of a special case of the more general theory of Sommerfeld. The results deduced from this theory have been worked out for some typical practical cases of both short- and long-wave transmissions, but, owing to the complete lack of experimental evidence, no practical test of the theory has yet been made. In view of the importance of a knowledge of ground absorption in connection with the complete study of the propagation of wireless waves of all lengths over the earth's surface, it is highly desirable that a systematic experimental investigation should be carried out in the near future.

R113.8.—Versuche über die Richtung der Höhenstrahlung im Meeresniveau.—L. Myssowsky and L. Tuwim. (*Zeitschrift für Physik*, 36, 8, pp. 615-622.)

From observations made at Leningrad on the intensity of the penetrating cosmic radiation in different directions, it was concluded that the intensity is uniform and independent of the azimuth, the rays all coming to the earth straight from above.

R113.8.—Les Grandes Perturbations Electromagnétiques des quatre Premiers mois de 1926, d'après les Enregistrements de l'Observatoire de l'Ebre, Tortosa (Espagne).—I. Puig. (*Comptes Rendus*, 14th June, 1926, pp. 1482-1483.)

R113.9.—Polarisation of Radio Waves.—Dr. Alexanderson. (*Jour. Amer. Inst. Elect. Engineers*, July, 1926, pp. 636-640.)

A paper presented at a regional meeting of the A.I.E.E., Niagara Falls, May, 1926. Evidence is given leading the author to believe that horizontal polarisation is not confined to short waves. Direct observations of horizontal polarisation with long waves could be made only at great heights, but indirect observation through the effect of ground currents can be made by ordinary direction finders on any wavelength. If the theory is correct it means that the irregularities of direction-finder indications recorded on long waves can be explained by the presence of horizontally-polarised wave components and are not due to the wave actually coming from unexpected directions.

R114.—On the Nature of Atmospherics, II. —Dr. Appleton, R. A. Watson Watt, and J. F. Herd. (*Roy. Soc. Proc., A.*, July, 1926, pp. 615-653.)

1. The paper describes the development of work, reported in an earlier communication (April, 1923), on the oscillographic examination of the characteristics of atmospheric electric disturbances of short duration. The method now involves the use of a cathode-ray oscillograph with a time-base which is both uniform in scale and unambiguous as to time-sense. The apparatus and methods described include a series of station tests for checking the performance of the assembly. The basis of the methods used is re-discussed.

2. Statistical analyses of approximately 8,000 individual drawings of atmospheric wave forms are tabulated and summarised. A more detailed sub-classification is based on the improved discrimination afforded by the unambiguous time-base. Sensibly aperiodic discharges were three times as numerous as were quasi-periodics; predominantly positive discharges were one and a-half times as numerous as were negatives. The mean quasi-periodic had a peak field strength of 0.156 v/m., the aperiodic 0.075 v/m. The negative discharges of both types were stronger by 20 per cent. to 30 per cent. than the positives. The mean quasi-periodic had a duration 3.125μs, 30 per cent. greater than that of the mean aperiodic. The most frequently occurring form of atmospheric was a symmetrical rounded positive aperiodic, forming 14 per cent. of the whole distribution. The most frequent quasi-periodic, forming 7½ per cent. of the distribution, had a peaked positive half-cycle followed by a single rounded negative half-cycle.

3. Examination of the fine structure of atmospherics shows a frequent "ripple period" of the order of 100μs. Typical oscillograms of fine structure as observed in dark hours in the Tropics are reproduced.

R114.—On the Nature of Atmospherics, III. —Dr. Appleton, R. A. Watson Watt, and J. F. Herd. (*Roy. Soc. Proc., A*, July, 1926, pp. 654-677.)

A paper, continuing the account of the investigation of atmospherics, summarised as follows :—

1. The experiments on atmospheric wave-forms recorded in preceding papers have been supplemented by observations in the nett changes of the earth's electric field, resulting from lightning discharges. These observations have been made at Aldershot, Cambridge, Helwan and Khartoum, and show that, at distances greater than 50km from the discharge channel, negative changes of field are at least 1.7 times as frequent as are positive changes. Since the field-changes at such distances may be taken as indicative of the sign of the thundercloud moment destroyed by the flash, it is concluded that lightning flashes resulting in the destruction of positive electric moments are at least 1.7 times as frequent as are those of opposite character.

2. A satisfactory reconciliation with Prof. Wilson's determination of the electric field changes produced by lightning discharges within 25km, in which an opposite preponderance of sign was obtained, is possible if thunderclouds are assumed to be bi-polar. Other evidence of such bi-polarity is cited.

3. It is shown that a frequently occurring type of thunderstorm mechanism is one which elevates the positive charge above the negative. This type of thundercloud polarity is that required by Prof. Wilson's theory of the maintenance of the earth's negative charge.

4. Lightning discharges are shown to be capable of producing radiation fields similar in wave-form and magnitude to those of atmospherics of distant origin.

5. An Appendix deals with the theory of the linear time-base used in the observations on wave-forms.

R114.—A Static Recorder.—H. T. Friis. (*The Bell System Technical Journal*, April, 1926, pp. 282-291.)

The following synopsis is given :—

This paper discusses different types of apparatus for recording static and also describes a new instrument in which the output of the set is kept constant by automatic control of the amplification, this amplification then being recorded as the relative measure of static. The set makes use of a flux-meter with zero restoring torque by means of which the rectified output current arising from static interference is integrated over a period of ten seconds. The following five seconds are required to adjust the gain of the amplifier and record the charge in gains from an arbitrary level. The gain is recorded in steps of 4 T.U. which correspond to a power amplification change by approximately a factor of 2.5. A record is shown during which the intensity of static changed by a factor of more than 10,000.

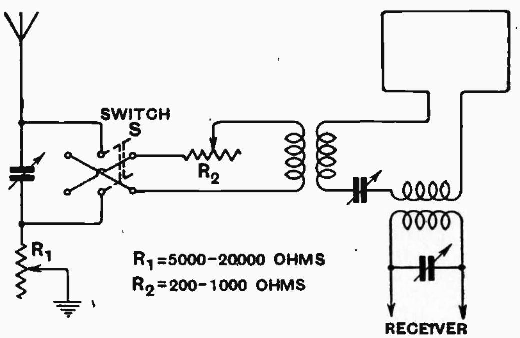
R114.—Sur des Enregistrements du Champ Electrique de l'Atmosphère jusqu'à 20,000 m. d'Altitude.—P. Idrac. (*Comptes Rendus*, 28th June, 1926, pp. 1634-1635.)

A brief account of measurements pointing to the conclusion that the electric field of the atmosphere can attain high values (exceeding 40 volts per metre) at about 10-12km, in the neighbourhood of the isothermal layer.

R114.—Direction Determinations of Atmospheric Disturbances on the Isthmus of Panama.—Dr. Austin. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 373—376.)

It has long been known that atmospheric disturbances in general originate over land rather than over the ocean and that the sources of tropical disturbances seem to follow the sun in its changing path between the northern and southern hemispheres.

Like this in Panama (10° north), the atmospheric disturbances would be expected to come chiefly from the mainland of South America in winter, and from the direction of Central America and Mexico in summer. During the rainy season, however, a considerable amount of local disturbance



could also be expected, generated in the low mountain chain which forms the backbone of the isthmus. The purpose of this investigation was to determine to what extent these local disturbances outweigh those coming from the larger land masses.

Directional observations were made on the atmospheric disturbances at the U.S. naval stations at Balboa and Colon at the two ends of the Panama Canal.

The apparatus used is shown diagrammatically above.

It consisted of an 8 ft. coil antenna with 48 turns and a small single-wire antenna forming a unidirectional receiving combination. It is explained how good readings can be obtained by this method when no direction at all can be observed on the coil antenna alone.

The results of the observations from February to November, 1925, are tabulated—the wavelengths employed were 14,000 and 20,000m.

From the data the following conclusions are drawn :—

1. During the dry season, from about January 15th to April 1st, the atmospheric disturbances both at Balboa and Colon come almost entirely from the South American continent, from the direction of the high Andes in Northern Colombia.

2. When the dry season comes to an end and local storms begin to appear, the local disturbances from the low mountains of the isthmus begin to be prominent. This displaces the prevailing direction at Balboa from the south-east to the north, at times, but has little effect on the direction at Colon since the mountains containing the local centres of disturbance here lie to the south and east, or roughly in the direction of the disturbance sources in Colombia.

3. In mid-summer, while there is probably much disturbance from Central America and Mexico, the local disturbances from the isthmus mask this to such an extent that the prevailing direction at Colon continues roughly south-east, while at Balboa the distant and local disturbances unite to give a northerly or north-westerly direction.

4. That from northern transmitting stations, Balboa and Colon should give nearly equally good unidirectional reception in the dry season, but during the rest of the year, when the disturbance conditions are more troublesome, Colon should have considerable advantage over Balboa.

R125.—Richtcharakteristiken von Antennenkombinationen.—Directional Characteristics of Combined Antennæ.—A. Esau. (*Zeitschrift für Hochfrequenz*, 27, 5, pp. 142-150.)

In this article a general formula is drawn up for the directional characteristic of the combination of two antennas, of which both can be either directional or undirectional or one only directional. Since errors have been observed in directional determinations which might in many cases be due to the waves arriving in a slanting direction, the equation for the characteristic has been developed for a ray incident at any angle, and not confined to the horizontal plane. The equation also takes into account the alteration of the plane of polarisation, which has been found to occur particularly with short waves, and its effect on the form of the characteristic.

Let the two antennæ A_1 and A_2 be a distance d apart, and their different characteristics, represented in polar co-ordinates, be

$$r_1=f(\alpha,\ \beta,\ \gamma) \quad \text{and} \quad r_2=g(\alpha,\ \beta,\ \gamma),$$

where α is the angle that the incident wave makes with the line joining the feet of the antennæ in the horizontal plane, β is the angle of inclination to this plane, and γ the angle through which the plane of polarisation has been turned from its normal position.

Denoting the wavelength by λ corresponding to a circular frequency ω and the phase difference by

ϕ, we obtain for the characteristic of the combination of the two :—

$$r = r_1 + r_2 = f(a, \beta, \gamma) \sin \omega t + g(a, \beta, \gamma) . \sin (\omega t + \phi)$$

or on simplifying

$$r = \sqrt{(f - g)^2 + 4fg \cos^2 \phi/2}$$

where $f(a, \beta, \gamma)$ and $g(a, \beta, \gamma)$

are abbreviated to f and g.

The two special cases are discussed of the combination of

(1) Two undirectional antennæ, and
(2) Two directional (frame) antennæ.

Undirectional antennæ can be combined either so that the principal direction of incidence coincides with the line joining the feet of the antennæ (series arrangement) or is perpendicular thereto (parallel arrangement). The sharpness of the characteristic for waves incident horizontally is considerably greater with the parallel arrangement than the series. For inclined waves ($\beta \gtrless 0$), on the other hand, the directivity of the characteristic is in general sharper for the series arrangement than for the parallel.

Two frames can also be combined either in series or in parallel. The characteristic is sharper with the combination than with a single frame and also with the parallel arrangement than the series. For waves incident at an angle, the sharpness of the characteristic decreases with increasing angle of inclination.

R132.—Small-Shot Effect and Flicker Effect. —W. Schottky. (*Physical Review*, July, 1926, pp. 74-103.)

J. B. Johnson observed, under certain conditions (oxide coated and tungsten filaments, low frequencies, electron currents high but not high enough for space charge effects), voltage fluctuations across connected resonant circuits which were much larger than the theory of the small-shot effect would lead one to expect. Analysing Johnson's curves, it is found that this effect increases as the square of the electron current instead of as the first power as in the case of the small-shot effect. This fact supports Johnson's hypothesis that the effect is independent of the shot effect and that it should be attributed to fluctuations in the properties of the surface (flickering) resulting in fluctuations in the electron current. The trend with the natural frequency of the connected circuit is likewise different from that observed in the shot effect. The elementary atomic process underlying the flicker effect is the appearance of an individual foreign atom or molecule in the surface of the cathode, changing the ability of the surface to emit electrons so long as the foreign atom remains. The influence exerted upon the current by foreign atoms in the surface may be calculated with sufficient approximation from the electrical image theory and Langmuir's doublet theory. A value is given for the mean square voltage fluctuation produced by the effect in terms of the impedance of the connected circuit, and formulæ are given for circuits of various kinds. Measurements with two circuits, one being resonant and the other a pure resistance, should provide a definite check of the calculated length of stay of the foreign atoms.

R132.—Uber die Kompensation der Anode-Rückwirkung (On compensating back coupling in a valve).—L. Müller. *Archiv. für Elektrotechnik*, June 14th, 1926, pp. 251—260.

Certain theoretical deductions are made which agree qualitatively with the results of experimental tests.

R132.—Beiträge zur Untersuchung der Verstäkertransformatoren. (Contributions to the Investigations of Amplifier Transformers.—L. Müller (*Archiv. für Elektrotechnik*, June 14th, 1926, pp. 219—250.

Detailed theoretical and experimental consideration of the grid transformer.

R134.—Les différentes Détections par Lampe et l'Amelioration de la Détection.—Stéphane Lwoff. (*Radio Revue*, July, 1926, pp. 91-98.)

An instructional article on valve rectification. After first considering energy in an alternating or oscillating circuit, and the general action of rectification, the author deals with the theory of rectification and considerations of power and maximum efficiency. Various methods of valve detection are then discussed, *e.g.*, with two-electrode valves, with three-electrode valves using grid or anode rectification, autodyne, etc.

R138.—Austrittsarbeit bei Oxydkathoden.—H. Rothe. (*Zeitschrift für Physik*, 36, 9/10, pp. 737-758.)

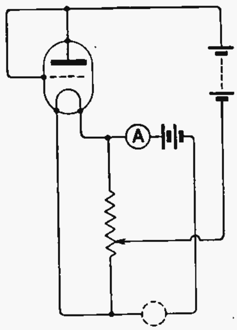
The electron emission energy was determined for several valves with oxide cathodes and found to be extremely small, both when using Richardson's equation and the cooling effect produced by the emission. It was observed that when the emission current was below the saturation value the cooling effect was considerably greater than that corresponding to the energy of emission. With regard to the relation between the emission from these cathodes and the amount of gas removed from them, it appears that it is not possible entirely to free them from gas, owing to the emission current passing radially through the oxide layer decomposing the oxide and thus constantly producing new gas. It is thought that the high emission of these cathodes is due to the metal particles produced by this decomposition which remain embedded in the oxide. Study was made of a fatigue effect which was observed in nearly all the valves, producing a rapid falling off of the emission current with the time.

R138.—Maintaining a Constant Reading on an Ammeter in the Filament Battery Circuit of a Thermionic Triode.—E. Banner. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 325—331.)

The trouble experienced in determining what is a constant filament current is stated at length in a paper read before the Wireless Section of the Institution of Electrical Engineers on March 16th, 1921 : "The Effect of Electron Emission on the

Temperature of the Filament Anode of a Thermionic Valve," by G. Stead (Vol. 59, p. 427). Most of the speakers in the discussion emphasised the point and no satisfactory solution was arrived at. The present research was undertaken with the idea of supplying a solution to the problem.

The writer first states the case as generally accepted, that the switching on of the anode battery makes it impossible to maintain the filament current constant, showing that, for accurate work, a statement that the filament current was constant during any particular test is void, unless the method of connection and the position of the ammeter are given. He then describes his investigation to find whether any position of the ammeter and a method of connecting the anode battery were possible, so that the ammeter reading would be unaffected by any variation in the anode current. He succeeded in devising such a circuit, which is shown in the diagram.



One ammeter only is used, which may be in either the positive or the negative lead, as shown.

R138.—ANLAUFSTROM UND GESCHWINDIGKEITSVERTEILUNG BEI OXYDKATHODEN.—H. Rothe. (*Zeitschrift für Physik*, 37, 6, pp. 414-418.)

The velocity distribution of electrons emitted from industrial triodes with oxide cathodes was determined by measurement of the initial current. Maxwell's law of distribution was found obeyed, although the average velocity of the electrons was 1.5 to 2.2 times as large as required by the cathode temperature according to the kinetic theory of gases.

R138.—A TEMPERATURE SCALE FOR TUNGSTEN.—H. A. Jones. (*Physical Review*, July, 1926, pp. 202-207.)

Account is given of the measurement of the temperature variation of the resistance of tungsten from 273°k to 3655°k, and the temperature variation of the rate of radiation from tungsten filaments. The results are tabulated and compared with those of other investigators.

R139.—WARUM KEHREN SICH DIE FÜR DEN LICHTBOGEN GÜLTIGEN STABILITÄTSBEDINGUNGEN BEI ELEKTRONENRÖHREN UM? (Why are the conditions of stability that hold for the arc reversed in the case of valves?)—H. Barkhausen. (*Zeitschrift für Hochfrequenz*, 27, 5, pp. 150-153.)

Arcs and valves behave exactly oppositely as concerns their stability regarding direct current (sudden changes) and alternating current (self-excitation of oscillations). All that increases stability with the arc (prevents sudden changes or oscillations) diminishes it in the case of the valve (favours these sudden changes or oscillations, and *vice versa*).

The difference physically lies in the fact that, in the arc, tension changes are caused by current changes, while in the valve current changes are caused by tension changes. Mathematically the succession of changes conditioned submits to calculation by assigning inductivity to the arc and capacity to the valve.

R.148.1.—COMMENT EVITER LES DÉFORMATIONS DE LA VOIX EN TÉLÉPHONIE SANS FIL (How to avoid speech distortion in wireless telephony.)—(*Radio Electricité*, June 10th, 1926, pp. 219-220.)

Continuation of an article begun in *Radio Electricité* for May 10th (these abstracts, p. 457, July, 1926), when deformation due to the tuning system and reaction was discussed. This instalment considers the distortion arising from detection.

R200.—MEASUREMENTS AND STANDARDS.

R210.—NEW RADIO DEVICES OF FIXED PRECISION. (*Radio News*, July, 1926, pp. 32 and 91.)

An account of the tiny apparatus, hermetically sealed and thus invariable, constructed by Dr. Loewe for measuring wave-frequencies with an error of less than a hundredth of 1 per cent.

R213.—ESTABLISHMENT OF RADIO STANDARDS OF FREQUENCY BY THE USE OF A HARMONIC AMPLIFIER.—C. Jolliffe and G. Hazen. (*Physical Review*, June, 1926, p. 815.)

Abstract of paper presented at April meeting of American Physical Society.

One method used by the Bureau of Standards in establishing radio standards of frequency consists in the "stepping up" from a known standard audio frequency to a radio frequency by the use of harmonics. The low-frequency output is carried through an amplifier arranged to distort and so produce harmonics. By means of tuned circuits a harmonic is selected which in turn serves as a fundamental for further distortion and amplification to give the desired frequency with sufficient power to operate the frequency meter under standardisation.

A fixed radio-frequency generator, such as a piezo oscillator, or a fixed audio-frequency generator, such as an electrically driven tuning fork, can likewise be standardised by the use of the harmonic amplifier with the addition of a sonometer for measuring an audio-frequency beat note produced by a harmonic from the standard audio-frequency source and the fundamental or harmonic from the fixed-frequency generator. The frequency of the beat note is impressed on the steel wire of the sonometer by means of a telephone receiver magnet. The vibration frequency of the wire is calculated by means of the constants of the wire and the tension applied.

R225.—WAVE FORM OF FREE ELECTRICAL OSCILLATIONS: SELF-CAPACITY EFFECT IN MULTILAYER COILS.—A. Astin. (*Physical Review*, June, 1926, p. 815.)

Abstract of paper presented at April meeting of American Physical Society.

Observations are made of the wave form of the free oscillations of a section or sections of a multi-layer coil, by itself and with added capacities, using the drop chronograph method developed by J. C. Hubbard (*Physical Review*, 9, 529, 1917). The results are used to determine the periods, self capacities and damping factors of the coil.

R240.—RÉSISTANCE DES CONDENSATEURS.—F. Flaud. *L'Onde Electrique*, June, 1926, pp. 263—275.

It is stated that the resistance of a condenser giving rise to losses of energy should be defined as the quotient of the loss of power corresponding to the current through it and the square of the effective intensity of this current; that it is a mistake that this definition has not always been adopted and has resulted in some confusion.

Starting from this definition the author finds expressions for these resistances in different cases and shows how they vary with the frequency. He states that the methods employed to measure these resistances are generally at fault and indicates what modifications they should undergo to render them correct.

Following the article there is a reply from M. Mesny to certain objections the author has made to what he has written on the subject.

R261.—VALVE VOLTMETERS AND THEIR APPLICATION TO HIGH FREQUENCY MEASUREMENT.—S. Chiba and S. Kitta. (*Journ. Inst. Elect. Engineers of Japan*, June, 1926, pp. 612-621.)

Three types of valve voltmeter are described :—

1. The Moullin A type, utilising the plate current-grid voltage characteristic.
2. The Moullin B type, utilising the grid current-grid voltage characteristic.
3. A third type utilising both these characteristics (to which Siemen's audio-frequency voltmeter belongs).

The authors' tests result in their recommending the third type, used with a blocking condenser and leak resistance in the grid circuit.

R281.—DIELECTRIC ABSORPTION AND THEORIES OF DIELECTRIC BEHAVIOUR.—Prof. Whitehead. (*Journ. Amer. Inst. Elect. Engineers*, June, 1926, pp. 515-524.)

Abridgement of a paper presented at the February Convention of the A.I.E.E., New York, from whom copies of the complete paper are available, including an extensive bibliography of the subject.

A brief summary of the paper is given below :—

1. Dielectric absorption is a conspicuous but little understood phenomenon: its general character is well known as shown by the decay, with time, of the changing current, residual change, etc.; however, exact and definite forms of even the empirical laws are still lacking.

2. Only solids show the complete absorption phenomena of charge and discharge. Liquids often show an apparent absorption in charging but no residual phenomena. Nearly all solid dielectrics show some absorption, though in some substances in a very pure state, *e.g.*, sulphur, quartz, paraffin, it is very small if not negligible.

3. Large changes in the absorption of solids may be caused by extremely small changes in composition. Impurities and moisture in very small amounts may cause large changes in absorption.

4. The charging absorption current merges into a final steady conduction current; both are strongly increased by increase of temperature, the absorption finally disappearing or changing into conduction.

5. The alternating losses in solid dielectrics are due almost entirely to absorption, shown by theoretical analysis and confirmed by experiment. The losses due to conductivity are usually very small compared with those due to absorption, and there is no evidence of losses of other types. There is nothing to indicate a hysteresis loss of the character pertaining to magnetic materials.

6. Theories of the ultimate nature of the phenomenon of absorption are :—

(*a*) That it arises in the mixture of two or more dielectrics, and depends only on the known quantities, conductivity and specific inductive capacity. This is Maxwell's theory.

(*b*) That it is due to anomalous relation between electric displacement and electric force, the seat of which is within the molecule or atom. (Pellat.)

(*c*) That it may be explained by Lorenz's theory of electron motion within the structure of the atom. (Décombe.)

(*d*) That it is due to water in capillaries or interstices in the body of the dielectric.

Finally, the phenomenon of absorption is in great need of further investigation.

R300.—APPARATUS AND EQUIPMENT.

R334.—THE DOUBLE-GRID TUBE.—H. Gernsback. (*Radio News*, August, 1926, p. 103.)

An enumeration of the advantages of the four-electrode valve over the triode, the chief being :—

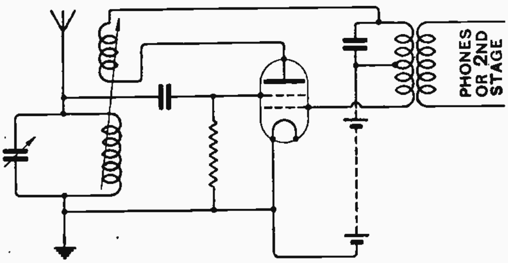
1. An amplification factor almost three times as great without any increase in the internal output impedance.
2. The elimination of capacity effect between plate and grid.
3. Circuits of greater sensitivity and efficiency.

R334.—THE FOUR-ELECTRODE VALVE.—A. Castellain. (*Wireless World*, 21st July, 1926, pp. 90-91.)

R334.—LE "CRYPTADYNE"—UNE NOUVELLE UTILISATION DE LA BIGRILLE. (The "Cryptadyne"—A new use of the four-electrode valve).—G. Thébault. (*Radio Revue*, July, 1926, pp. 89-91.)

It is shown that when the outer grid of a four-electrode valve is at zero potential, the currents in the anode circuit and in the inner grid circuit are of nearly equal value, with characteristics, and of opposite slopes, the former increasing and the latter decreasing as a positive potential is applied to the outer grid. If an alternating voltage be applied to the outer grid with telephones in the inner grid and anode circuits, sensibly equal sounds are heard in each telephone.

The arrangement of the figure below is shown as utilising the principle, the currents in the split primary of the transformer being additive in their magnetic effects on the secondary. Reaction is obtained in the usual manner as shown. The application of the arrangement to an additional stage is



also illustrated, the transformer secondary in this case working to the outer grid of the succeeding valve, with arrangements similar to those shown in its inner grid and anode circuits. Only the usual four-electrode valve H.T. of about 12 volts is required and it is stated that excellent results have been obtained on both near and distant transmissions.

R.337.351.—MECHANICAL AND ELECTRICAL VIBRATIONS.—Dr. Eccles and Dr. Leyshon. (*Electrician*, 16th July, 1926, pp. 65 and 72.)

The authors have investigated some direct methods of linking a tuning fork, piezo-electric crystal, or other mechanical vibrator, with harmonic producing circuits such as the neon lamp flashing circuit, the multivibrator, or generally with conductors possessing so-called "negative resistance."

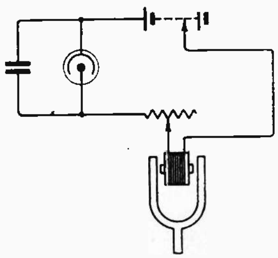


Fig. 1.

The new method is explained here as it is carried out in co-operation with a modified form of the well-known flashing circuit of the neon lamp described by Pearson and Anson (*Proc. Phys. Soc.*, p. 204, 1922).

The method consists in adding an electromagnet to the neon lamp circuit and adjusting the rate of flashing until it is approximately equal to the frequency of the given tuning fork; the fork can then be driven by means of the electromagnet. When this is done, the motion of the fork induces an electromotive force in the windings of the magnet which is sufficient to compel the rate of flashing to synchronise exactly with the frequency of the fork. Fig. 1 is a diagram of the simplest circuit, but for convenience of manipulation, the apparatus is best arranged as indicated in Fig. 2.

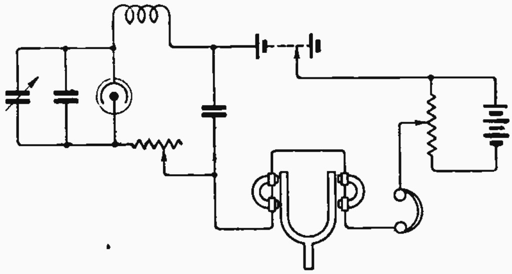


Fig. 2.

The method may be used for generating electrical oscillations of exceedingly constant frequency or for receiving wireless signals by the heterodyne method or for calibrating wavemeters.

Compared with the triode and fork, the neon lamp and fork combination is more difficult to adjust and keep in adjustment, due partly to the variation of the gas content of the lamp as time goes on. Thus the triode arrangement is generally the more reliable, while the neon arrangement is the more fertile in harmonics.

R341.—LA DÉTECTION PAR LAMPE CHAUFFÉE EN ALTERNATIF (Detection by valve, heated with alternating current).—R. Barthelemy. (*Radio Revue*, July, 1926, pp. 99-101.)

An analysis is given of the conditions of a rectifying valve in a receiver, when the filament is heated by A.C. The causes of noise are fully discussed, and a remedial filter circuit shown. Criticism is made of the vacuum of certain valves, and it is suggested that there is a need for a valve specially constructed for use with alternating current.

R342.1.—INTERVALVE TRANSFORMER CORES.—Dr. McLachlan. (*Wireless World*, 14th July, 1926, pp. 45-47.)

Discussion of the permeability of iron under speech amplifying conditions.

R342-7.—DESCRIPTION D'UN AMPLIFICATEUR BASSE FRÉQUENCE À GRANDE SÉLECTION (Description of a low-frequency amplifier of high selectivity).—A. Pagès. *L'Onde Electrique*, June, 1926, pp. 276—283.)

A paper presented at a meeting of the Société des Amis de la T.S.T., March 17th, 1926.

Description of a circuit-arrangement, for which patent rights have been applied, permitting very sharp and controllable resonance effects to be obtained. Retroactive coupling is employed in phase opposition to the tensions to be amplified. This coupling is obtained by transformers, as perfect as possible, and the resonance effects by shunting each coupling transformer with a system of impedances presenting at least one frequency of counter-resonance ; the investigation here is limited to the case where this system consists simply of one inductance and one capacity.

R343.—SHORT-WAVE RECEIVING SETS.—L. Hatry. (*Q.S.T.*, July, 1926, pp. 20-26.)

Certain points are considered in the design of sets limited to a regenerative detector with audio amplification that are said to receive little attention.

R343-8.—DISCUSSION ON "THE SHIELDED NEUTRODYNE RECEIVER" BY DREYER AND MANSON.—L. A. Hazeltine. (*Proc. Inst. Radio Engineers*, June, 1926, pp. 395—412.)

The above paper (*Proc. Inst. Radio Engineers*, April, 1926, pp. 217—247) was largely a descriptive one, giving the final results of an engineering development for which the authors were mainly responsible. It is here supplemented by a theoretical discussion of some of the considerations that enter into the electrical design of a receiver employing tuned radio-frequency amplification. The most basic theoretical considerations are those of sensitivity, selectivity and fidelity, all of which are best illustrated graphically on a resonance curve, in which amplification is plotted against frequency: sensitivity is represented by the amplification at the resonant frequency ; selectivity, by the falling off in amplification as we depart considerably from the resonant frequency ; and fidelity, by the uniformity of amplification in the immediate neighbourhood of the resonant frequency. The equation of the resonance curve is derived and plotted for various values of the ratio of transformation with given values of the circuit constants. The effect of varying the number of stages of amplification is also considered. With regard to the question of strays, the conclusion is drawn that the only effective way of minimising strays over the range of a receiver is to so design the audio-frequency amplifier and loud-speaker as to pass only the useful audio-frequencies and to attenuate all higher audible frequencies.

Lastly, the effects on the resonance curve of an amplifier of slight lack of resonance in the different stages are considered, due in particular to accidental misalignment of the condensers when a common control is employed.

R346.—LE MEILLEUR EXPOSÉ POUR EXPLIQUER LE FONCTIONNEMENT DE LA TELEPHONIE SANS FIL (The best discussion on the operation of wireless telephony).—J. Jammet. (*Radio Revue*, July, 1926, pp. 102-106.)

The final part of the paper which was awarded first prize in a competition by the Radio Club of France. Receiving apparatus with crystal (galena) detection is first illustrated and discussed, followed by the use of one or two stages of H.F. amplification with final crystal detection. Low frequency amplification and valve detection (by cumulative grid) are then discussed. Reaction is then explained, leading up to the oscillating circuits of a transmitter.

R351.—LUMINOUS PIEZO-ELECTRIC RESONATOR. (*Electrical World*, 12th June, 1926, p. 1307.)

Abstract of a paper by E. Giebe, appearing in *E.T.Z.*, 47, 13, 1926, pp. 380-385.

In an article published in 1922 in the *Proc. Inst. Radio Engineers*, W. G. Cady described the peculiar effect of small pieces of quartz, cut in a certain way, when subjected to an alternating current field. A combination of mechanical and electrical oscillations sets in which may lead to resonance and to vibrations of very pronounced amplitude. As the logarithmic decrement of these is very small, only about 7×10^{-4}, resonance occurs very sharply, for which reason Cady recommended the use of such crystals as resonators. The author discovered that if such a quartz rod is enclosed in a partly evacuated glass bulb, full resonance will cause a uniform glow of the rod. Partial resonance and higher harmonic oscillations manifest themselves as a partial luminosity of the rod. It is thus possible to determine by night the nature of the electric characteristics of a circuit by merely observing the quartz rod in the dark. Beautiful configurations can be produced by high harmonics, the paper containing photographs of the appearance of the quartz rod with up to the twenty-first harmonic. The use of these simple resonators is recommended for the regulation of a broadcasting station to proper wavelength.

A brief account of piezo-electric wavemeters is given in the *Wireless World* for 14th July, 1926, pp. 65-66.

R351.—QUARTZ CRYSTAL MOUNTINGS.—J. Clayton. (*Q.S.T.*, July, 1926, pp. 15-16.)

R376.3.—CAN PERFECT LOUD-SPEAKER REPRODUCTION EVER BE ATTAINED ?—C. Balbi. (*Electrical Review*, 9th July, 1926, pp. 50-52.)

The reply is in the affirmative, but not by eliminating the causes that produce the irregularities in reproduction, since this proves too difficult, but by compensating for the irregularities by changing the character of the electrical input so as to neutralise their effect. This is done by dividing up the frequency range into a number of small bands by means of electric filters and bringing the response in each band to the required strength by an increase or decrease of amplification.

R380.—LA STANDARDISATION DES PIÈCES DETACHÉES (The standardisation of components).—(*Radio Revue*, July, 1926, pp. 108-109.)

A note, from Le Syndicat Professionel des Industries Radio-Electrique, on the need for standardisation. Inductance coils and mounts are particularly dealt with, with notes on the dimensions and nomenclature recommended.

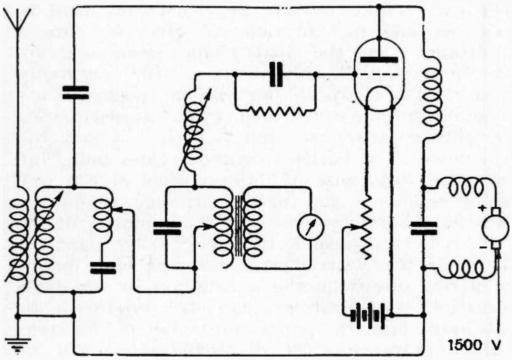
R382.—TRANSMITTING COILS.—F. E. Handy. (*Q.S.T.*, July, 1926, pp. 29-30.)

R500.—APPLICATIONS AND USES.

R510.—Les Nouveaux Radiophares Français (The new French radio beacons).—A. Blondel. (*Annales des Postes Télégraphes et Téléphones* June, 1926, pp. 478—491.)

Three types are distinguished :—

1. Land-fall beacons, of long range, working for five minutes at the beginning of every hour, whatever the weather. Such are being erected at La Hague, Belle-Ile, La Coubre, Porquerolles and Ouessant. A circuit diagram of this latter beacon is shown below :—



2. Fog beacons of shorter range which are to number twenty-five—Sandettié and Gris-Nez being already in operation.

3. Beacons at the entry to ports, of which there will be nine (Boulogne, Havre, etc.).

All three types will work automatically and employ in general modulated continuous waves.

R542.—Methods of High Quality Recording and Reproducing of Music and Speech Based on Telephone Research.—(Maxfield and Harrison). (*Journ. Amer. Inst. Elect. Engineers*, July, 1926, pp. 676-679.)

Discussion of the paper that was published in *Journ. A.I.E.E.* for March, 1926.

R545.—Feeding the Antenna.—R. Kruse. (*Q.S.T.*, July, 1926, pp. 8-14.)

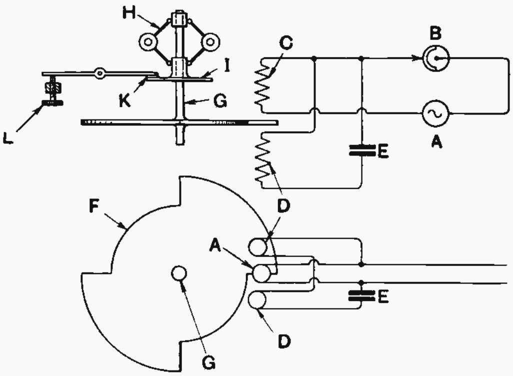
R545.—Progress and Plans at Five Meters—and Below.—R. Kruse. (*Q.S.T.*, July, 1926, pp. 34-37.)

R550.—Irish Free State—New Stations. (*Electrical Review*, 9th July, 1926, p. 104.)

The Minister of Posts and Telegraphs has announced that the Government proposes to build a high-power station in the Midlands of the Free State, and three smaller stations at Cork, Galway and Bundivar, County Donegal. Thus, with the Dublin station, there will be five stations in the 26 counties. It is estimated that the four new stations will cost £29,000, that the smaller ones will be completed during the next 12 months, and the high-power station within two years.

R570.—Sur un Nouveau Moteur Synchrone à Induction Demarrant Automatiquement, et pouvant être actionné par Ondes Hertziennes Modulées en vue de Résoudre les Problèmes de Téléindication et de Télévision (On a new synchronous induction motor starting automatically, capable of being set in motion by modulated Hertzian waves, for solving problems in connection with signal transmission and television.)—J. L. Rontin. (*Comptes Rendus*, May 17th, 1926, pp. 1207—1209.)

The motor is shown diagrammatically in the figure, where *A* is a source of alternating current of frequency *f*; *B* is a rotating interrupter worked at a speed of *N* turns per sec. (*N* being a sub-multiple of *f*), adjusted so that the duration of the emissions is equal to that of the interruptions; *C* is a first inductor supplied by *A* each time that *B* is closed ; *D* is a second inductor, out of phase with A, connected up in parallel with *A* through the condenser *E* ; *F* is a metal disc mounted on the shaft *G* ; the disc *F* is cut so as to have *n* teeth separated by *n* notches of equal width (in the figure $n=2$).



R594.—L'Organisation Radiophonique en Allemagne. (*Radio Revue*, July, 1926, p. 107.)

A short note on wireless telephony stations, working or imminent, in Germany, and on maritime radio telephony.

R600.—STATIONS : DESIGN, OPERATION, AND MANAGEMENT.

R611.—Radio-Telegraphy in Brazil. (*Electrical Review*, 16th July, 1926, p. 93.)

A brief account of the new high-power station recently opened at Rio de Janeiro, for communication between Brazil and other South American countries, as well as with the North American Continent, Australia, South Africa, and the countries of Europe. The equipment includes a 20,000-metre-ampere valve transmitter, an aerial carried by 800 ft. high steel masts, and an earth-screen supported by short masts.

R612.—TRANSMISSION EN ONDES COURTES (Short wave transmission).—H. Chireix. (*L'Onde Electrique*, June, 1926, pp. 237—262.)

A paper presented at a meeting of La Société des Amis de la T.S.F., April 21st, 1926.)

Among short-wave commercial communications mention is made of : Issy-les-Moulineaux—Djibonti, Sainte-Assise—Buenos Ayres, Nauen—Buenos Ayres, and New York—Buenos Ayres. The chief technical problems to be solved in the production of transmitters of considerable power are the following :—

1. The development of oscillating valves able to resist the high tensions and intense high-frequency currents passing through them.

2. The elimination of alien capacities and the reduction of losses by suitable circuit arrangements, with a view to increasing the frequency emitted and securing good efficiency for the installation.

3. Obtaining as stable a frequency as possible so as to profit to the fullest extent by the phenomena of resonance and to permit heterodyne reception.

These questions are discussed here in detail, together with the solutions that have been adopted by La Société Française Radio-electrique, particularly as concerns the attainment of stable frequency.

Lastly, considerable attention is directed to antennæ that are specially suitable for short waves.

R612.—UNDER 50 METRES. (*Scientific American*, July, 1926, p. 68.)

A list of the world's stations (50) operating on waves of less than 50 metres.

R616.—WIRELESS AND POLAR EXPLORATION.—(*Electrician*, 9th July, 1926, pp. 43-44.)

Details are given of the equipment on the airship *Norge I.*, including the direction-finding system.

R800.—NON-RADIO SUBJECTS.

538.—THE GENERATION OF VERY INTENSE MAGNETIC FIELDS.—Dr. Wall. (*Journ. Inst. Elect. Engineers*, July, 1926, pp. 745-757.)

A method for generating magnetic fields of the order of magnitude of one million gauss is described, also the means used to measure the value and frequency of the heavy transient currents producing these fields.

538.—THE LOSS OF ENERGY IN METAL PLATES OF FINITE THICKNESS, DUE TO EDDY CURRENTS PRODUCED BY ALTERNATING MAGNETIC FIELDS.—Dr. Marchant and J. Miller. (*Roy. Soc. Proc. A*, July, 1926, pp. 604-614.)

539.—ZUR THEORIE DES THERMIONENEFFEKTES, I.—N. v. Raschevsky. (*Zeitschrift für Physik*, 36, 8, pp. 628-637.)

539.1.—THE MECHANICS OF THE ELECTRIC FIELD.—Sir J. J. Thomson. (*Journ. Inst. Elect. Engineers*, July, 1926, pp. 721-726.)

The seventeenth Kelvin lecture. The lecturer puts forward considerations which suggest that electrons and protons are not the ultimate constituents of matter, but are capable of further sub-division.

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto - Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

R000.—RADIO ĜENERALE.

R050.—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.

R100.—ĜENERALAJ PRINCIPOJ KAJ TEORIO.

R131.—UZADO DE PLAT-KURENTAJ—PLAT-TENSIAJ KARAKTERIZOJ DUM STUDADO PRI LA FUNKCIADO DE VALVAJ CIRKVITOJ.—E. Green.

Daŭrigo de artikolo el la antaŭa numero, pritraktanta la uzadon de anodkurentaj—anodvoltaj karakterizoj ĉe amplifaj cirkvitoj. Unue pritraktitaj estas rezistance kuplitaj amplifikatoroj, poste agorditaj anodaj kaj transformatore kuplitaj amplifikatoroj. La apliko de ĉi tiuj kurvoj al oscilaj cirkvitoj kaj al grandpotencaj amplifikatoroj estas poste konsiderita, kaj sekve ilia uzado en la problemo de sendistorda grandpotenca amplifado. Apartaj ekzemploj estas cititaj, unue pri la valvo LS5, poste pri la valvo LS5A, kaj fine pri grandpotenca amplifikatoro por la modula amplifado de telefona sendilo, ekz., 6-Kilovata Brodkasta sendilo uzanta ŝokbobenan reguligadon.

Aldonita noto pritraktas la metodon ricevi la Ip—Ep karakterizojn el grupo de la plikutimaj Ip—Eg karakterizoj (kiel tiuj ordinare donitaj de la fabrikistoj).

R144.—EFEKTIVA REZISTECO DE INDUKTANCAJ BOBENOJ JE RADIO-FREKVENCO.—PARTO IVa.—S. Butterworth.

La daŭrigo de artikoloj el antaŭaj numeroj (resumitaj en ĉi tiu Sekcio en la Aŭgusta numero.)

La nombro da turnoj en bobeno estas diskutita, kaj la decido pri la plej taŭga fadena diametro, por kiu celo estas presita kurvo. La apliko de teorio estas ilustrita aparte pri desegno de 2,000μH bobeno (t.e., por agordo de proksimume 1,600 metroj).

Poste sekcio pritraktas la uzadon de dividitaj fadenoj. Oni citas esprimojn por la efektiva rezisteco de dividitaj konduktoroj, kaj tabelo montras komparojn pri la provado de formuloj kun observado. Poste diskutita estas la desegno de bobeno el dividita fadeno, kaj aparta ekzemplo donita. Oni komparas solidan kaj dividita-fadenan bobenojn, la komparo estante esprimita laŭ terminoj de " pligrandigo " jam sugestita de la aŭtoro kiel specifo de bobena funkciado. Aldono diskutas la kalkuladon de la meza elektra kampo super la vinda parto de induktancaj bobenoj.

R200.—MEZUROJ KAJ NORMOJ.

R230.—ANSTATAŬAĴOJ.—G. H. Watson.

La artikolo priskribas metodon fari mezuron (de ferkerna induktanco) laŭ neordinara maniero per utiligo de disponeblaj instrumentoj. La cirkvito estis energiita pere de transformatoro, kies primaria kurento kaj sekundaria tensio estis mezuritaj per disponeblaj instrumentoj. La kurento tra la prova cirkvito povus esti kalkulita kaj ĝia indukteco ricevita laŭ la impedanco.

R300.—APARATO KAJ EKIPAĴO.

R343.—PROBLEMOJ PRI DESEGNADO DE BRODKASTAJ RICEVILOJ.—Lekcio farita de S-ro. P. P. Eckersley, Ĉef-Inĝeniero de la Brita Brodkasta Kompanio, antaŭ la Radio-Societo de Granda Britujo, je la 26a Majo, 1926a.

La lekcianto unue diskutis aparatojn por la ricevado de longdistanca brodkastado, sub la rubrikoj Neŭtrodinaj kaj Supersonaj. Koncerne ĉi tiun lastan, metodo estas montrita por apliki la batantan osciladon post neŭtraligita altfrekvenca ŝtupo, por ke ĝi estu neradianta.

Poste li pritraktis ricevilojn por la loka stacio, diskutante unue rektifadon, kun speciala aludo al la produkto de distordo. Traktante amplifadon, oni montris cirkviton por uzi kristalan rektifikatoron kun unu neŭtraligita altfrekvenca ŝtupo, kaj sekvita de malaltfrekvencaj ŝtupoj, dum alia interesa cirkvito estis montrita por minimumigi la altfrekvencajn reakciojn, kiuj ofte okazas kiam rezistanca kapacita kuplo estas uzita por altfrekvenca amplifado. Fine la lekcianto montris kompletan ricevilon enkorpigantan ĉi tiujn kaj aliajn apartajn sugestojn pritraktitajn en la lekcio.

Raporto pri la diskutado, kiu sekvis la lekcion, estas ankaŭ presita.

R384.—ONDOMETRO POR MALLONGAJ ONDOJ.—A. E. Tubbs.

Priskribo pri ondometro uzanta la cirkviton " Colpitts." La instrumento estas uzebla por skalo de 15 ĝis 80 metroj, kaj la priskribo estas ĝenerala, por ebligi al konstruantoj utiligi disponeblajn konstruerojn. La skrenaj metodoj uzitaj de l'aŭtoro estas priskribitaj, kaj estas ankaŭ noto pri la metodo normigi la ondometron.

R500.—APLIKOJ KAJ UZOJ.

R545.1.—" DX " SENDADO PER RICEVA VALVO.—A. D. Gay.

Raportoj pri la spertoj de l'aŭtoro je uzado de ricevaj valvoj ĉe malgranda ricevilo, kun kelkaj ĝeneralaj notoj pri DX (longdistanca) sendado.

R800.—NE-RADIAJ TEMOJ.

621.355.01.—NOVA TEORIO PRI LA PLUMBA AKUMULATORO.—Prof. G. W. O. Howe.

Post komentado pri la nesufiĉeco de la malplinova teorio pri la kemia efiko de akumulatoroj, raporto sekvas pri nova teorio evoluigita de S-roj. Fery kaj Cheveneau. La ĉefa punkto interesa estas, ke la plene ŝargita pozitiva plato ne estas plumba dioksido (PbO_2), sed plialta oksido (Pb_2O_5). La agoj necesigitaj en la nova teorio estas priskribitaj, kaj eksperimentaj rezultoj estas cititaj por subteni ĝin. La apliko de la teorio al sulfado kondukis al desegno de malgranda pilo nesulfadebla.

510.—MATEMATIKOJ POR SENFADENAJ AMATOROJ.—F. M. Colebrook.

Daŭrigo de la serio el antaŭaj numeroj. La nuna numero traktas pri Divido en Algebro, enhavante la Negativan Signon en Divido, diversajn farojn per Frakcioj, Dividon de Nulo, kaj noton pri la ĝeneralaj konkludoj de la fundamentaj reguloj pri Algebro jam pritraktitaj.

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.

j, the Heaviside Operator, and $\sqrt{-1}$.

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

SIR,—Since it is admitted that D is an operator to which the usual laws of algebra do not apply, the point of your comment on my last letter does not seem very clear. The correct method of obtaining the equation $D^2 = -\omega^2$ is, as pointed out by Mr. Riley and myself, by a repetition of the operator. Although, as you observe, it can also be obtained by algebraical multiplication, this derivation cannot be regarded as legitimate. Indeed, had the order of one of the equations been reversed, an inconsistent result would have been obtained by the same process.

The correspondence has brought out the "operational" character of D and of $j\omega$ when used in place of D, for to j also, when used in this "operational" sense, the laws of algebra do not apply. But as j is used algebraically for $\sqrt{-1}$, the precise meaning of this symbol in any instance is not clear, while its mode of treatment is also in doubt. Using D for the operator, no trouble need arise.

The confusion caused by an illegitimate use of D is, in my view, already created by the dual use of j for both vectorial operator and $\sqrt{-1}$. This dualism, as you, Sir, acknowledge, has been in the past a stumbling block to many wise men; is it fair to our students to let it continue?

Murtle, Aberdeenshire. W. A. BARCLAY.

A New Theory.

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

SIR,—The interesting experiments described by Mr. Derek Shannon in the current issue of *E.W. & W.E.* seem to prove beyond doubt that the moon has an effect upon the propagation of radio waves, but the explanation suggested by him does not appear to be feasible. The gravitational deflexion of a ray of light grazing the sun's surface is only of the order of 1 second of arc, so that the effect of a much smaller body such as the moon at a distance of a quarter of a million miles, could not possibly be appreciable.

It seems far more probable that the sun and moon set up tidal motions in the atmosphere, which change the disposition of the Heaviside layer. Professor Balfour Stewart, and more recently Professor Chapman, have used such a theory to explain the diurnal variations in the earth's magnetic field. There is also some barometric evidence of the existence of such atmospheric tides.

In any case, it is highly desirable to obtain further observations, at different distances and on different wavelengths, and it is to be hoped that those who have the necessary facilities will give some attention to this problem.

Reading. N. L. YATES-FISH (G5CA).

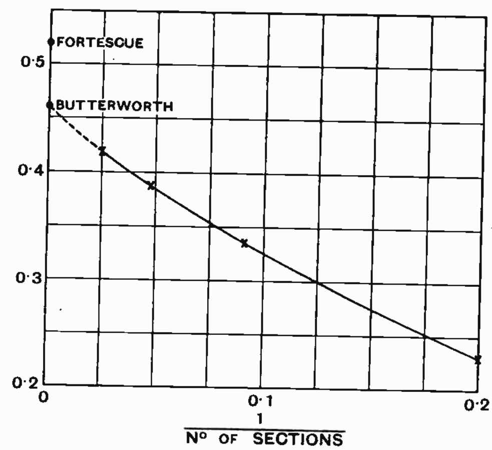
Effective Resistance of Inductance Coils at Radio Frequency.

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

SIR,—In Part III. of Mr. Butterworth's paper on the effective resistance of coils, which appeared in the June number of the *E.W. & W.E.*, reference was made to a factor K which was used by Professor Fortescue in his paper (*J.I.E.E.*, Vol. 61, p. 933, 1923).

Mr. Butterworth obtained values by his method, which were very appreciably different to those of Professor Fortescue.

The factor K^2 represents the average of the square of the magnetic field at the wires of the coils. Professor Fortescue calculated the value of K by dividing the coil into sections, working out the value of the square of the magnetic field due to the rest of the coil at the centre of each section and taking the mean of the values for all the sections. Obviously the method represents a great deal of heavy arithmetic, especially as the accuracy depends very greatly on the number of sections taken.



In support of Mr. Butterworth's calculations I would like to give some results I obtained in calculating the value of K. I started this work to check Professor Fortescue's values but gave it up when Mr. Butterworth kindly made me acquainted with his work.

I took a single layer coil having a length equal to its diameter, calculated the value K obtained by dividing the coil into various numbers of sections. The results are given in the following table:—

No. of Sections.	5	11	21	41
K	0.231	0.336	0.39	0.42

I have plotted this value of K against the reciprocal of the number of sections as shown in the accompanying figure.

The value obtained by Mr. Butterworth, who considers an infinite number of sections, is 0.460,* and by Professor Fortescue is 0.52. If these two points are added to the curve it will be seen that Mr. Butterworth's result shows no discontinuity with the curve I calculated, while Professor Fortescue's does.

Thus the two methods of computing K are in agreement, but Professor Fortescue probably made an error in the special case I considered. It would not be fair to suggest from this isolated case that all Professor Fortescue's values of K were incorrect, but greater reliance can probably be placed on Mr. Butterworth's results whose method for calculating K represents much less arithmetic and consequently fewer opportunities for errors of computation.

National Physical Laboratory.

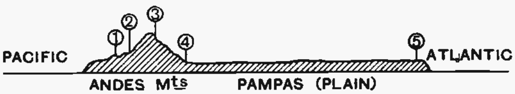
RAYMOND M. WILMOTTE.

[If six sections are taken—a very likely number—the value obtained is 0.26, which is exactly half the 0.52 which is given as the value actually found by Prof. Fortescue. This strongly suggests that a 2 has been overlooked somewhere.—ED.]

Fading and Mountains.

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

SIR,—The following facts may be of use to experimenters studying this subject. They refer to the broadcast waves (250-550) and no striking seasonal variations are recorded.



In sketch, 1 is Santiago de Chile, 2 Los Andes Chile, 3 Puente del Inca just across the boundary in Argentina, 4 Mendoza, 5 Buenos Aires.

At 1, 4 is received with strong fading and 5 with nominal fading, or often with slight. At 2, 1 is received without fading, 4 with strong fading, and 5 with normal or strong fading. At 3, the fading of 1 is incredibly strong (from absolute inaudibility in loud-speaker to unpleasant volume in same, within two minutes, and practically continuous): 4 is received with little fading, and 5 with average to heavy fading. At 4 (incidentally one of the worst places for atmospherics that I have ever found), 1 is received with heavy fading, 5 with slight. At 5, 1 is received with fair fading, 4 with slight. All the above are from personal experience.

At a point about half-way between 3 and 4, 1 is received with very strong gfadin, though not as bad as at 3, 4 with practically no fading, 5 with slight to fair: at a point about half-way between 4 and 5, 1, 4 and 5 are all received with fair fading. These are from information given me by other amateurs.

R. RAVEN-HART.

Caletta, Livozno, Italy.

* *Phil. Trans. A.*, Vol. 222, p. 59, 1921.

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

SIR,—Mr. A. Woodmansey states that the resistance of a cloud would be very high on account of its non-homogeneous character. May I point out that the resistance he considers is to direct current and not high frequency alternating currents with which we are here concerned.

Compared with an ion a water particle in a cloud is large, and it is quite conceivable for conduction to occur from one side to the other of the globule. Under the action of alternating potentials the conduction would be periodically reversed. Ionic movement in liquids is comparatively slow, and in many cases would never reach the other side, but would return to their original position in phase with the inducing potential. The only result is an ether strain of the driving frequency with consequent emission of radio waves. Thus an effect of reflection is obtained and Mr. Woodmansey's argument is futile The case he quotes is not parallel, and the homogeneity of the cloud makes little difference.

In addition I have conceived a further possible cloud action. All clouds normally possess an electric charge. (A positive charge is obtained in the process of vaporisation). When two equal spheres combine the radius of the new sphere is only 26 per cent. more than that of each original sphere. Now the capacity of a sphere is proportional to the radius. Therefore when two equal charged spheres combine there is an excess of charge of 37 per cent. In consequence the potential rises. The only limiting factor of this rise in pressure is the rate at which the charge will leak owing to the ionisation of the surrounding gas. Such leakages may be the cause of atmospherics. The air around the cloud will be very highly ionised as the area of this cloud is small compared with the total area of bodies of different potential, such as the earth and other clouds, forming the opposite electrode. The extent of this ionisation can rise far higher than in the Heaviside layer for this reason. In a cloud the potential forces ionisation until the surrounding air becomes an almost indefinitely good conductor with a limit provided only by the leakage rate of the charge. On the other hand, the Heaviside layer is only ionised by electronic bombardment from the sun. These electrons are driven off from their source by the light pressure and will continue to move away from the sun until a force in opposition forms an equilibrium. These electrons rapidly come to rest in the earth's atmosphere ionising the air in doing so. An excess of electrons always exists here and a high negative potential results. This introduces an opposing force to the light pressure and further electrons are deflected forming the zodiacal light according to accepted theory. Thus it is seen that the limit of ionisation is provided by the light-pressure of the sun.

Dr. Eccles has observed results similar to those reported by Mr. H. Piraux and attributed this to refraction. (See *Journal, R.S.G.B.*, March, and *E.W. & W.E.*, May.)

I regret that I have no tabulated data, all my previous observations being quite casual though perfectly definite. I propose, however, in the forthcoming winter to make a complete record.

Further, I propose, with assistance, to attempt to reflect waves of the order of 5 metres from clouds. This will present many practical difficulties, first and foremost being the P.M.G.

I appeal to all observers, especially those with barometric records, to look through them and anything in support or direct opposition to this theory will they please report them, as I feel sure that many of the mysteries of variable reception will be interpreted thereby.

N.16. W. H. MADDISON (2BOX).

Makeshifts.

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

SIR,—Having recently made numerous A.C. measurements of coils of the type referred to by Mr. H. G. Watson in the August issue, I was interested to read of the method employed by him. I was rather surprised, however, that he did not turn his good fortune in possessing an electrostatic voltmeter to better profit by eliminating his rather doubtful assumptions regarding the current ratio of the transformer.

It is extremely unlikely that a small high ratio transformer would have an efficiency so near 100 per cent. as to justify neglecting the difference. It was mentioned that the no-load current was not readable on a 2 amp instrument, but owing to the cramped scale usual with A.C. meters, such a current might easily be a very appreciable fraction of 0.75 amp, and in this case, owing to the highly reactive load, would be nearly in phase with the load current.

A sounder method is to put a known non-reactive resistance in series with the coil, and to measure the voltage across each in turn with an electrostatic or other non-disturbing voltmeter. It is comparatively easy to get a reasonably non-reactive resistance at 50 cycles. The current may then be known accurately.

It was only by using this method that I was able to avoid a much more serious error than that referred to above. Mr. Watson calculates the inductance from a knowledge of the impedance and the D.C. resistance in the usual manner. Unfortunately, for coils of this type, the results obtained thus are quite erroneous. In order to get a check on calculation I measured the voltage across coil and resistance in series in addition to each separately. It is then quite a simple matter to obtain the phase angle as well as the magnitude of the voltage across the coil, and hence the inductance and *effective A.C. resistance*. The latter was in some cases enormously greater than the D.C. resistance, as much as 20 times as great, depending on the A.C. current passing, on superimposed D.C., if any, and on the past history of the iron (*e.g.*, previous passage of several milliamps of D.C. through the coil).

This result was so surprising at first sight that measurements were repeated using a different method of voltage measurement and very elaborate precautions against error. The results were substantially the same, and were afterwards verified in other ways.

In passing, it may be mentioned that the inductance of such a coil shows wide variations quite apart from the well-known saturation effect, and the value obtained depends upon a large number of variables, some of which cannot be specified with any degree of certainty.

The measurement of iron-core coils is beset with many pitfalls, and the results when obtained are practically valueless unless the full circumstances are also indicated, which is a matter of more difficulty than appears at first sight.

S.E.12. MARCUS G. SCROGGIE.

Inductance Coils Quantitatively Compared.

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

SIR,—I have to thank Mr. A. L. M. Sowerby for the very full rejoinder he has made in your issue of August to my criticism in that of July. But his rejoinder has still not convinced me.

He claims that my suggested procedure has the failing of which I accused him—the simultaneous change of several variables. Well, that resolves itself into the definition of "variable" for the present argument. If, for example, diameter of wire and spacing between turns are regarded as two separate variables, then his test given in Table II., p. 365, June issue, is conducted on right lines, and I am wrong. (It will be remembered that he wound a series of coils, all of one gauge, but with increasing spacing.) If, on the other hand, the ratio d/c (where d is wire diameter and c the spacing between centres of neighbouring turns) is regarded as one variable, then my procedure (July, p. 462) is reasonable and his is not.

I based my suggestion on the fact that the whole theory of eddy current losses due to proximity of wires is based on the ration d/c, considered as one variable.

My anxiety as to the accuracy of his method of test seems to be justified from the research point of view, though perhaps not from the purely practical standpoint. He gives a difference of .1 ohm as "certainly unnoticed," and .5 ohm as certainly noticeable in his tests.

Now the inductance of all his coils is in the neighbourhood of 250μH, and the tests were carried out at about 380 metres. The reactance of the coils is, therefore, about 1,250 ohms. The power factor of a reasonably good coil of the type indicated should most certainly not exceed .005, so that their resistance should be in the neighbourhood of 6 ohms. Putting .25 ohm as his limit of observation, we have an accuracy of 4 per cent.

Certainly I am pleased to admit that his method has given very fair practical accuracy—in my previous letter I described it as "open to question," and the question has been answered. But I am still of the opinion that his selection and arrangement of coils is such that his tabulated results are not of as much use as they might have been.

Detailed reasons for this would occupy too much space. If Mr. Sowerby would care to meet me to discuss the matter verbally, with a view to concluding this correspondence by a joint final letter, I should be delighted to do so.

Blackheath. P. K. TURNER.

Some Recent Patents.

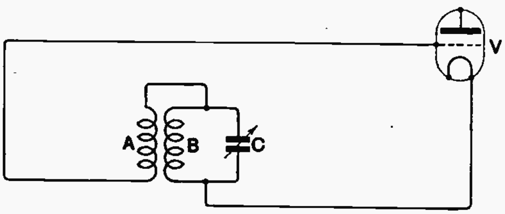
[R008

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.

AN INTERESTING FRAME AERIAL.

(*Application date, 7th April*, 1925. No. 254,036.)

A very interesting frame aerial circuit particularly suitable for use with superheterodyne receivers is described by P. W. Willans in the above British Patent. Interference is frequently experienced when using superheterodyne receivers owing to the intermediate amplifier becoming directly energised by long wave signals. It is found that the presence of an inductance of appreciable area connected between the grid and filament of the first valve causes sufficient potential to be set up across it from longer wave stations to energise the intermediate amplifier, thereby causing interference. This difficulty is overcome according to this invention by so arranging the aerial that it is substantially non-inductive at intermediate frequencies. The accompanying illustration should make the invention quite clear, in which a valve *V* has connected between the grid and filament a frame aerial consisting of two portions *A* and *B*. The two windings *A* and *B* are electrically equal, and are arranged so that they are coupled together and are wound in opposite directions. Neglecting the presence of the variable condenser *C* it will be obvious that since the two halves of the aerial are in opposition, the voltage existing between the

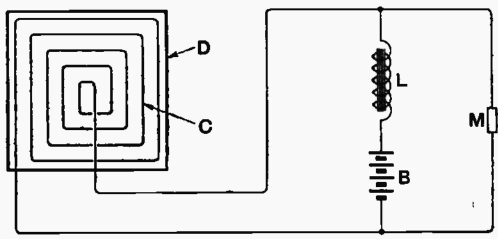


grid and the filament, that is across the ends of the complete frame, will be substantially zero since the whole arrangement is non-inductive. One portion of the aerial *B*, however, is tuned by a variable condenser *C*, and thus the potential difference existing across the ends of the halves *A* and *B* respectively will be different. In other words, tuning the section *B* will cause a potential difference to be communicated to the grid and filament, thereby causing the valve to become operative. The section *B* is tuned to the desired frequency of reception by means of the condenser, and thus the valve will respond to signals at the desired frequency, while potential differences set up by longer wave wave stations will cause no interference effect.

AN EDDY CURRENT LOUD-SPEAKER.

(*Convention date* (*U.S.A.*), *21st April*, 1924. *No.* 232,600.)

A very novel form of loud-speaker functioning by virtue of eddy currents is described by the Westinghouse Electric and Manufacturing Company, and J. Slepian in the above British Patent. The invention can best be understood by reference to accompanying illustration, which represents one form of the acoustic reproducer, or loud-speaker, connected to a source of energisation. The energisation source comprises a battery *B* connected to a microphone *M* through a choke *L*. In shunt with the battery and choke is a coil *C* having an appreciable area. Upon the coil is supported a membrane or diaphragm *D* consisting of a flat sheet of foil, such as gold leaf, or gold leaf reinforced with cardboard, or other sheet material cemented to it. The battery *B* will cause a steady current flowing through the windings of the coil *C*, thereby setting up a magnetic field. Sound waves impinging upon

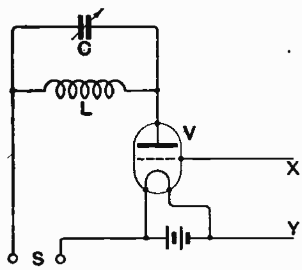


the diaphragm of the microphone will cause its resistance to alter, thereby causing an alteration of current flowing through it, this alteration being proportional to the sound waves. Since the microphone circuit contains a choke *L*, potential variations will be set up across it, thereby producing a change in current flowing through the windings *C*. Fluctuating currents in the winding *C* will thereby cause a variation in eddy currents and the foil diaphragm will be alternately attracted and repelled by opposite half cycles of the microphone currents. In other words, the diaphragm will vibrate in sympathy with the microphone currents, thereby obtaining an ordinary loud-speaker effect.

AN IMPULSE EXCITATION GENERATOR.

(*Convention date* (*Germany*), *25th. July* 1924. *No.* 237,585.)

The Telefunken Gesellschaft für Drahtlose Telegraphie M.B.H. describe in the above British Patent a method of generating very short waves by means of impulse excitation, in which a thermionic valve is used as an interruptor. Thus in the accompanying illustration it will be seen that a circuit *LC* is tuned to the desired frequency of generation, and supplied through a source *S*. In series with the source of power is a valve *V*, the grid potential of which is controlled at *XY* from a source of high frequency current. The frequency of the exciting current is an integral fraction of the circuit *LC*, such as a half, a third, or a quarter. In addition, the voltage or current curve of the exciting valve is so arranged that the time during which the interruptor valve is conductive only lasts until the high frequency circuit has passed a quarter of its oscillation phase; the exciting voltage must therefore rise rapidly, and then retain for a short time its maximum value, and finally remain quite low for at least three times as long. The working circuit thus receives the charging impulse during the first quarter of its oscillation phase, and oscillates for

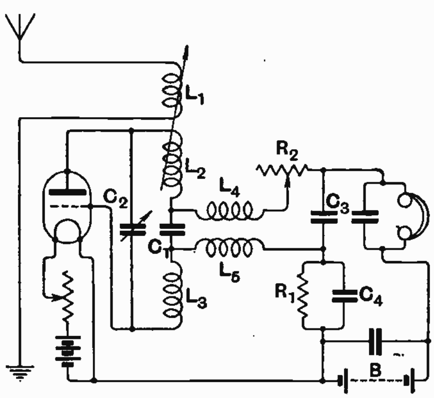


the remaining part of its period without supply of energy. The specification states that various means may be employed for obtaining the asymmetry of the control current, and mentions the use of coils containing iron which may be employed with or without auxiliary magnetisation.

A SUPER-REGENERATIVE CIRCUIT.

(*Application date*, 10*th March*, 1925. *No.* 253,192.)

A super-regenerative circuit is described by C. Seymour, D.S.O. and J. C. W. Drabble in the above British Patent. The advantage of the receiver, according to the invention, is the simplicity of control, which utilises one tuning adjustment, and one variation of the quenching frequency strength. The invention will be clearly understood by reference to the accompanying illustration. The aerial

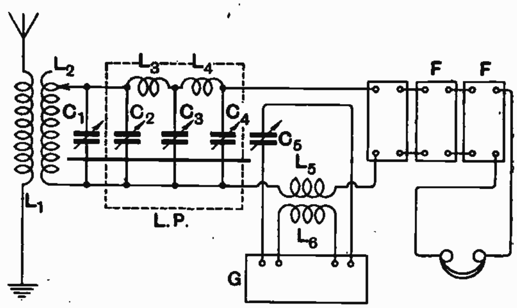


circuit contains an inductance L_1, tightly coupled to a split inductance L_2 L_3, tuned by a variable condenser C_2, the split inductance being connected by a fixed condenser C_1. Inductance L_4 and L_5 constituting the inductance of the quenching circuit, are associated with a condenser C_3. The lower end of the grid circuit contains a resistance R_1 shunted by a blocking condenser C_4, telephones T and H.T. battery B being shunted by the usual condensers. The anode circuit, in addition to containing half the split inductance L_2, and one of the quenching inductances L_4, contains a variable resistance R_2. The specification gives alternate considerations of the principle by means of which the invention functions. It has been mentioned that the chief feature of the invention is the simplicity of control. The variable condenser C_2 is simply used to tune the receiver to the desired frequency, and the strength of the quenching oscillations, which is a critical factor in a super-regenerative circuit, is controlled by a variable resistance R_1, which, of course, varies the anode potential.

HETERODYNE RECEPTION.

(*Convention data* (*U.S.A.*), 20*th November*, 1924. *No.* 243,371.)

Marconi's Wireless Telegraph Company, Limited, A. N. Goldsmith, and A. F. van Dyck, describe in the above British Patent a system of heterodyne



reception employing a low pass filter. The specification mentions that with ordinary heterodyne reception it is possible to obtain more than one adjustment of the local oscillator for any desired beat note, thereby resulting in confusion.

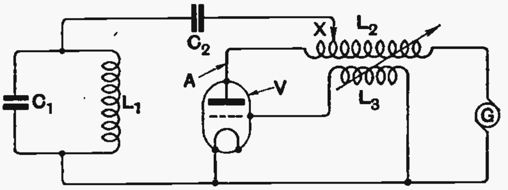
Again, one particular adjustment of the local oscillator results in the production of the desired beat frequency not only from desired signals, but from undesired signals as well, thereby introducing interference. Essentially, the invention consists in providing a low pass filter through which the received signals are passed before the local oscillations are super-imposed, so that beat frequencies can be obtained only with the desired signals. Several modifications of the invention are described, and one is shown in the accompanying illustration. Thus, in the accompanying illustration, the aerial circuit comprises an inductance L_1 coupled to an inductance L_2 tuned by a variable condenser C_1. The tuned circuit L_2 C_1, tuned to the desired frequency of reception, is connected to a low pass filter LP, comprising variable condensers C_2, C_3, C_4, and inductances L_3 and L_4. A local oscillator G is coupled by inductances L_5 and L_6, the frequency being varied by the variable condenser

C_5. Further selectivity in this particular case is obtained by the introduction of two audio-frequency filters for the desired beat, which are shown, and *F* and *F*.

A VALVE GENERATOR CIRCUIT.

(*Application date, 18th April,* 1925. *No.* 254,424.)

A valve generator circuit is described in the above British Patent by C. R. Burch, N. R. Davis and Metropolitan-Vickers Electrical Company, Limited, of the shunt supply type, that is, in which the valve is fed through a choke. Referring to the accompanying illustration, which shows one modification of the invention, a valve *V* is provided with an oscillatory circuit L_1 C_1, connected through a stopping condenser *C* to the anode *A* in the normal manner. The valve is supplied from a generator *G* through an inductance L_2. The effective resistance of the circuit L_1 C_1, or any load coupled to it, is a minimum, that is, the loading on the valve *V* is a maximum when the circuit L_1 C_1 is connected directly to the anode. When connection of the circuit L_1 C_1 is made to a point, such as at *X* on the inductance L_2, the effective resistance of the circuit L_1 C_1 is increased, this increase being

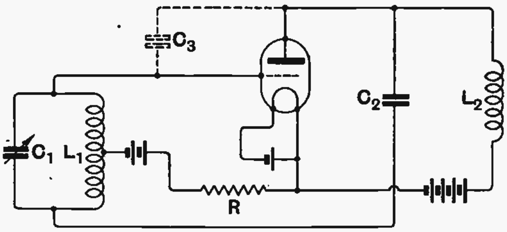


proportional to the number of turns of the inductance L_2 between the anode and the connection *X*. In other words, the choke or inductance L_2 functions in the manner of a step-down auto-transformer. In order that the system shall generate oscillations an inductance L_3 is connected between the grid and filament of the valve, and is coupled to the inductance L_2. The specification is fairly detailed and contains several modifications of the scheme.

SUPPRESSING PARASITIC OSCILLATIONS.

(*Application date, 28th May,* 1925. *No.* 254,472.)

An interesting circuit is described by The Western Electric Company, Limited, in the above British Patent, and deals with the suppression of oscillations in a valve amplifier. The invention relates to a circuit of the balanced or neutralised type, and particularly to a modification containing a number of stages of amplification, and also to one containing valves of high magnification. The accompanying illustration shows one modification, and will no doubt be familiar to readers. The arrangement consists of an inductance L_1 tuned by a variable condenser C_1, the mid point of the inductance being connected to the filament, one end to the grid of the valve, and the other end through a balancing capacity C_2 to the anode. The anode circuit contains an inductance L_2, which is used to pass on the output of this valve to the next. The balancing capacity C_2 is substantially equal to the capacity existing between the grid and the filament, which may be considered as C_3, and is shown dotted. This portion of the circuit is perfectly normal. The capacity C_3, representing the inter-electrode capacity of the valve, actually provides a path from the anode to the grid, which permits the

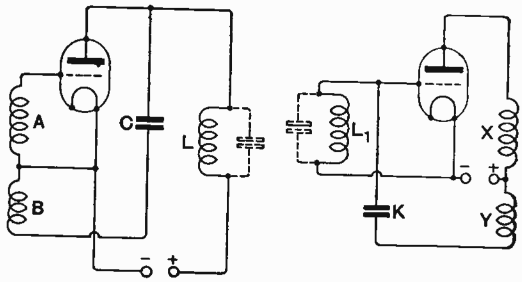


transference of waves from the output to the anode circuit, and may produce undesirable oscillations. In order to neutralise this effect a capacity C_2 is connected as indicated, and is actually in parallel with the inter-electrode valve capacity. Varying currents therefore flow through two parallel paths, through the respective halves of the inductance L_1, with the result that substantially no potential variations are imposed upon the grid of the valve. The invention states that in practice, however, it has been found that the balancing capacity C_2 in parallel with the electrode capacity C_3 provides new paths in which oscillations may be generated. It is stated that this is due to the fact that the input circuit of the valve contains an inductance represented by the difference between the self inductance of L_1 and the mutual inductance between its two halves, and also that the anode circuit contains an inductance L_2. It is well known that if inductances are contained in the anode and grid circuits of a valve, and there is no coupling between them, oscillations will be generated. Therefore, in order to prevent these oscillations a resistance *R* is inserted in the common filament lead, which tends to prevent the potentials reaching sufficient value to cause the valve to oscillate. We should imagine that this circuit would be of particular interest and value to amateurs who experience difficulty in stabilising multi-stage neutralised amplifiers.

AN INTERESTING NEUTRALISED CIRCUIT.

(*Application date, 7th April,* 1925. *No.* 253,277.)

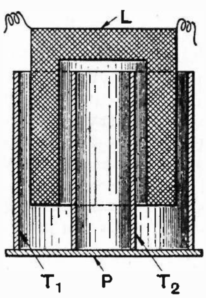
An interesting form of neutralised circuit is described by P. W. Willans in the above British Patent, the specification of which contains details of several modifications, one being shown in the accompanying illustration. The invention really consists in the use of a transformer comprising two portions *A* and *B*, one winding being connected between the grid and the filament, and the other winding being connected in series with a condenser *C*, which, in turn, is connected to the anode of the valve. The anode circuit consists of an impedance *L* in the form of a radio-frequency choke, or the winding of a transformer. A further feature of the invention is that the capacity C constitutes the major portion of the capacity in shunt to the inductance L. The figure also shows another modification in which a transformer of this type is used in the anode circuit. Here, one winding X is connected directly between the anode and the H.T., and the other winding Y is connected to the grid through a capacity. Here, again, the capacity K forms the major portion of the capacity in shunt with an inductance L_1, connected, of course, this time in the grid circuit. This circuit should prove of interest to experimenters, and it is found to be very satisfactory in practice.



A TUNING SYSTEM.

(*Application date, 5th October*, 1925. *No.* 254,568.)

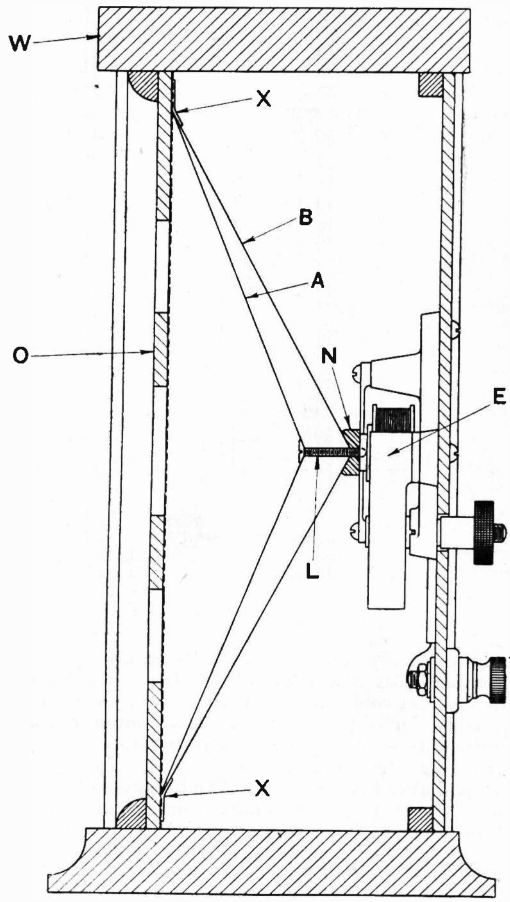
L. Bonnet describes in the above British Patent a method of tuning which consists in short-circuiting the magnetic field of an inductance. The short-circuiting device consists of two concentric tubes T_1 and T_2 joined by a plate P, the tubes and the plate preferably being of copper. The inductance L is arranged so that its windings are between the two tubes, and means are provided for varying the tubes in relation to the inductance. It is stated that the two tubes act in the manner of a Faraday cage.



A DOUBLE CONE.

(*Application date, 14th May*, 1925. *No.* 253,687.)

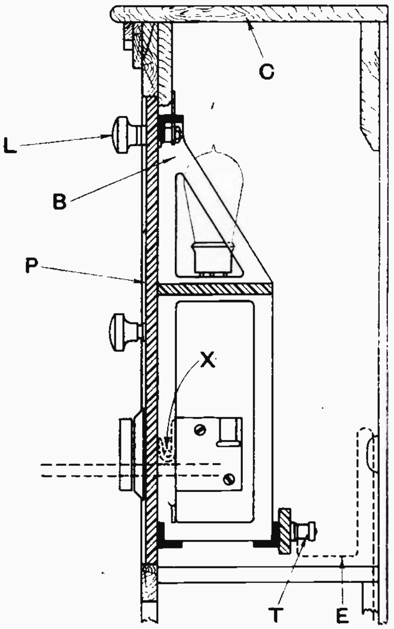
Another form of loud-speaker employing two cones is described by P. J. Mullaly in the above British Patent, and the form of construction should be quite clear by reference to the accompanying illustration. The loud-speaker is contained within a cabinet W provided with an open-work front O. Two cones A and B constitute the diaphragm, and are fixed at their peripheries to the front of the cabinet, as shown at X. The inner cone A has a more obtuse angle than the outer cone B, and the apices of the two cones are connected to a wooden plug N to which they are joined by a screw L. This screw communicates with an ordinary electro-magnetic system E, such as a telephone receiver, which is used to energise the cones. It is stated that the cones may be made of paper, parchment, thin wood, or metallic foil.



A PIVOTED PANEL.

(*Application date, 29th May*, 1925. *No.* 253,348.)

Another system of set construction is described in the above British Patent by T. E. Haywood, T. A. E. Haywood, and A. Haywood, the object of the invention again being to facilitate access to the components of the receiver. The invention will be clearly understood by reference to the accompanying illustration, in which it will be seen that the cabinet *C* is provided with a panel *P* carrying a bracket framework *B*, which supports the components of the receiver. The panel *P* is pivoted at its base at *X*, and is maintained normally

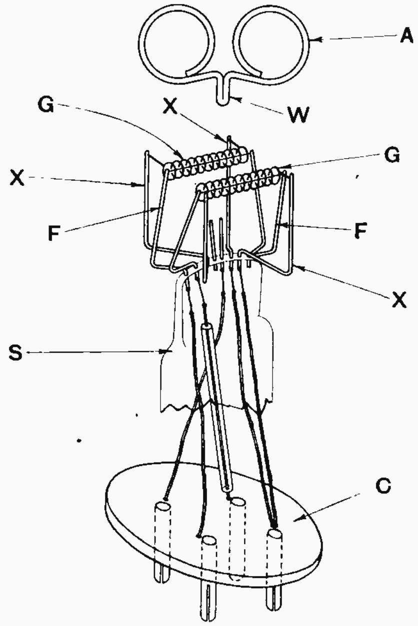


in position by means of a knob-operated lock *L*. Flexible leads *E* are provided between the back of the cabinet and the terminals *T* and the receiver proper. In order to expose the contents of the cabinet, it is merely necessary to rotate the knob operating the lock *L*, and tilt the front panel forward about the point *X*. The pivot is so arranged that, if desired, the whole front panel can be withdrawn.

VALVE CONSTRUCTION.

(*Application date*, 26*th November*, 1925. *No*. 253,426.)

Several types of valves have recently been devised in which the electrodes are duplicated, and are contained within one envelope. The accompanying illustration shows an arrangement of one which is claimed by W. Frudenthal and L. Kremner in the



above British Patent. The anode *A* will be seen to be in the form of two cylinders, which are welded together at *W*, or fixed in any other convenient manner. Supports *X* carry two grids *G*, which are centrally disposed within the two anodes, the filaments *F*, of course, being arranged along the common axis of the two sets of grids and anodes. All the supports are sealed into a glass foot *S*, and the valve is provided with the usual four-pin cap *C*.