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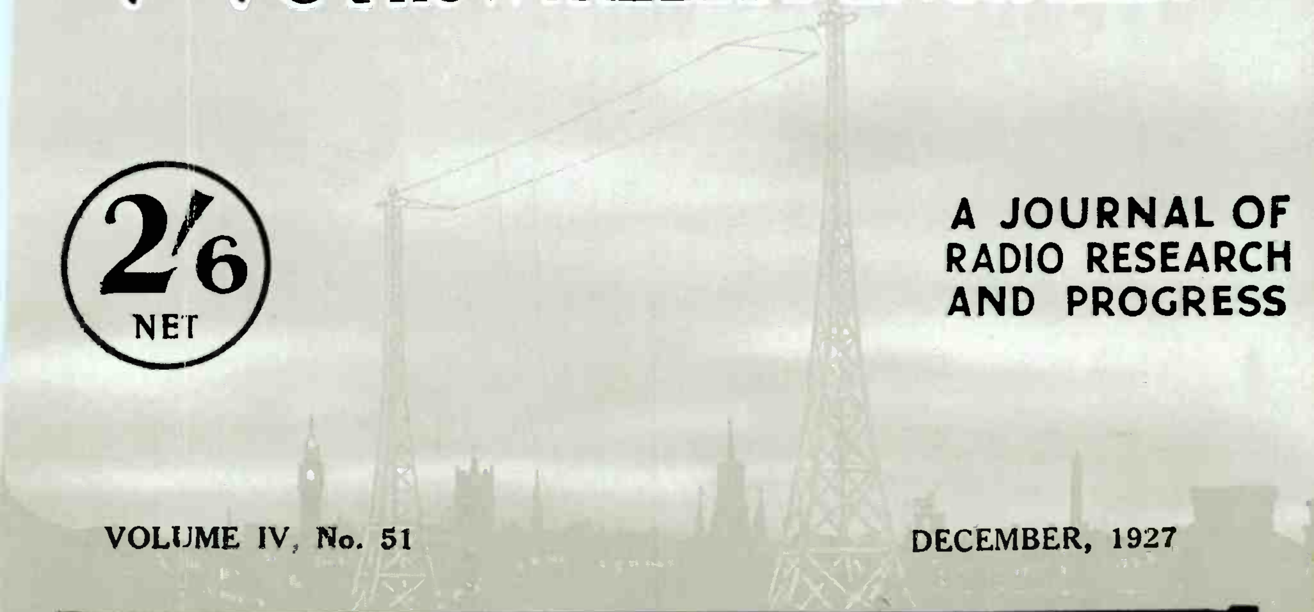

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VOLUME IV, No. 51 DECEMBER, 1927

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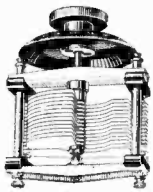

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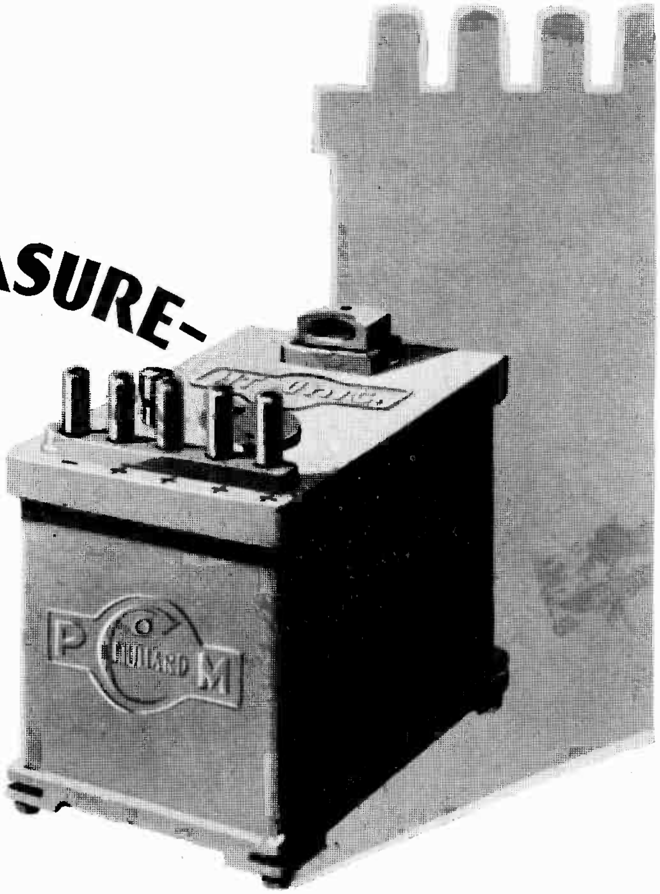

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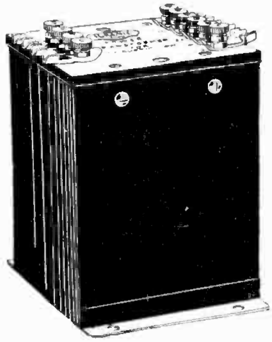

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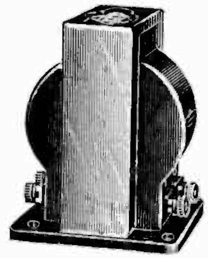

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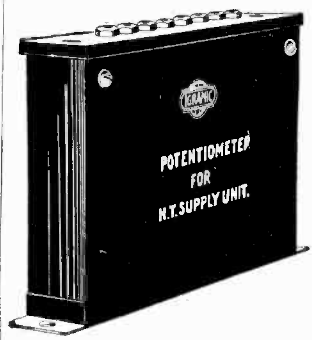

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EXPERIMENTAL WIRELESS

and The WIRELESS ENGINEER

A Journal of Radio Research and Progress

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CONTENTS OF THIS ISSUE.

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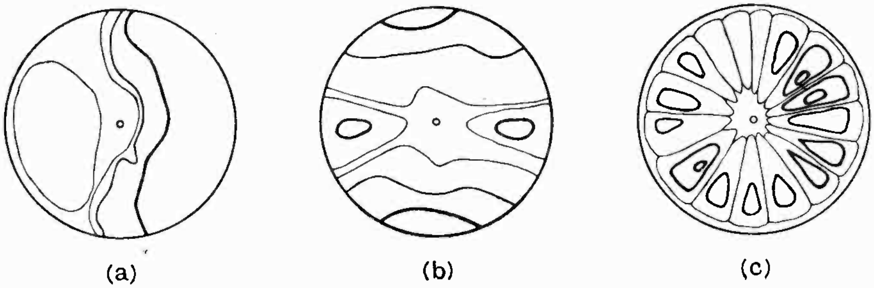
EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

Vol. IV. DECEMBER, 1927. No. 51.

Editorial.

The Vibrations of Loud-Speaker Diaphragms.

IN a loud-speaker of the cone type the mechanism moves the centre backwards and forwards at a frequency corresponding to the pitch of the note and with a complexity of movement depending on the character of the sound being reproduced. We feel sure that we are correct when we say that most people who use such a loud-speaker picture the whole diaphragm moving backwards and forwards with the central driving pin or coil, the extent of the movement naturally decreasing as one passes outwards from the centre to the periphery. Anyone holding such views will be very surprised at the results of some experiments made on a "Kone" loud-speaker by Mr. S. Hill of Standard Telephones and Cables, Ltd., and published in a recent number of *Electrical Communication*. The type of loud-speaker will be familiar to most readers. It consists of two cones of brown hand-made bookbinding paper about 18 inches diameter, cemented together at their bases; the back cone is truncated and clamped to a frame, whilst the apex of the front cone is clamped to the driving rod.



(a) *Sand figure obtained when the "Kone" rocks about a diameter;* (b) *Sand figure given by sector vibration of the "Kone" at a frequency of about 110 cycles per second;* (c) *Sand figure given by sector vibration of the "Kone" at a frequency of about 150 cycles per second.*

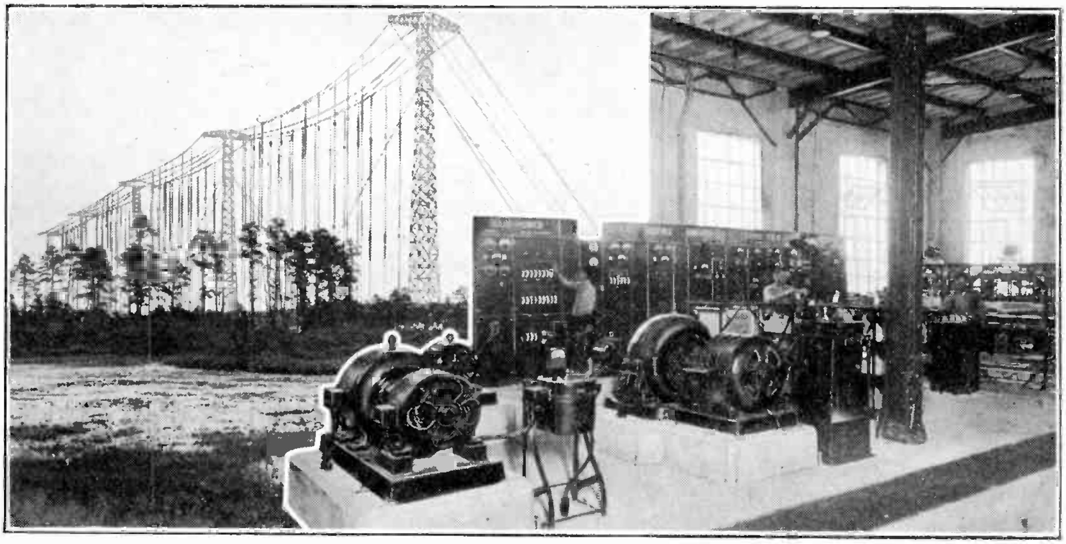
The modes of vibration were observed by placing the loud-speaker horizontally and sprinkling sand on it while it was energised by a steady alternating current of single frequency. The sand is thrown off the vibrating portions of the surface and accumulates along the nodal lines separating two portions of opposite phase. The experiments showed that there were four distinct types of vibration, depending on the frequency of the alternating current, and that none of them corresponded to the simple vibration of the diaphragm as a whole, although it is mentioned as a possibility at very low frequencies. The type that occurs at frequencies from these extremely low ones up to 100 cycles per second is shown in Fig. (*a*); it is mainly a rocking vibration about a diameter but by no means a simple rocking.

The second mode of vibration sets in just above 100 cycles per second; the diaphragm is split up into a number of sectors, the number increasing rapidly with the frequency. At a frequency of 110 there are four sectors as shown in Fig. (*b*) where, however, the diametral vibration still seems to predominate; at 150 cycles per second the number of sectors has increased to 16 as shown in Fig. (*c*). In this case, however, there is still considerable irregularity, some sectors showing single, some double and some well pronounced triple vibrations. It is a pity that no indication is given in the diagrams of the position of the cemented join in the paper, nor of the relation of this join to the position of the mechanism; these details would probably throw some light on the striking want of symmetry and regularity in the results.

Above about 150 cycles per second the radial sectors begin to break up into smaller patches; this goes on with decreasing size of the individual patches up to about 800 cycles per second, above which the diaphragm vibrates in a number of annular rings.

The fairly uniform response of this type of loud-speaker over a wide range of frequencies is due to the multiplicity of its modes of vibration, each having its own resonant frequency, but one mode merging into another as the frequency is varied. It is interesting to consider the complexity of the resulting vibration of the diaphragm when it is reproducing at a given moment every instrument in an orchestra and doing it so truthfully that one can pick out each instrument by its characteristic tone.

The Beam System in U.S.A.



Rocky Point Beam Station equipment. The aerial system for the beam transmitter is shown on the left, and on the right a general view of the generator room.

Some Experiments with Side-Band Telephony on Short Wavelengths.

By E. Howard Robinson.

A SIMPLE outline of the principles of side-band telephony was given in one of the first issues* of this journal, and has also appeared in various issues of the *Proceedings of the Institute of Radio Engineers*.† The essential feature of side-band radio telephony consists in removing the steady carrier component from the transmission and sending out either one or both of the side-bands. The carrier component, which is necessary for efficient and intelligible reception, is supplied at the receiver by a small local oscillator adjusted to the correct frequency. The chief advantages are great economy in power and size of transmitting valves at the transmitter for a given intensity at a distant receiver, and also the reduction of interference with receiving stations listening to some other transmission on a neighbouring wavelength.

The object of the experiments described here was to ascertain whether the advantages of side-band transmission could be realised on wavelengths of about 200 metres or less. From the start it was not even hoped that there would be any possibility in this particular series of experiments of isolating only one side-band. It was considered that useful work would have been done if satisfactory two-side-band transmission were accomplished; even the possibility of this was considered remote, as the only carrier-eliminating systems known at the time were virtually bridge methods, which are very difficult to balance at high frequencies.

The existing system, due to J. R. Carson,‡ was tried on the experimental bench, but it was very soon found that even with a carrier frequency corresponding to a wavelength of 450 metres it was a very tricky proceeding to balance out the carrier component completely. The Carson system employs two balanced modulator triodes, to the grids of which both H.F. drive and L.F. speech voltages are applied. If there is complete symmetry both in the valves themselves, and in the differential output circuit the carrier does not appear in the output, but the necessary symmetry is difficult to attain on frequencies of the order of 1.5×10^6, as it is essential not only to pick two valves of substantially identical characteristics, but to compensate for small differences in inter-electrode capacity and any residual differences in characteristics. Even then the carrier is apt to creep into the output again as the valves warm up and disturb the initial balance. Further, this system gives only a very limited side-band output for the size of valves used in the modulator. Operation must be limited strictly to the curved portion of the grid-voltage anode-current characteristic, otherwise the whole theory of the modulator falls to the ground.

Fortunately it was possible to devise a totally different and more efficient carrier-suppressing modulator. In order to understand clearly the principle on which the system works let us consider briefly the nature of two side-bands alone as compared with the usual two side-bands plus carrier. Suppose we start with an oscillator giving an H.F. carrier voltage $V_0 \sin \omega t$, and modulate its amplitude V_0 by $100 \times m$ per cent. with a low frequency $\omega_1 2\pi$; we obtain oscillations of the form:

$$(V_0 + mV_0 \sin \omega_1 t) \sin \omega t$$

$$= V_0 \sin \omega t + mV_0 \sin \omega_1 t \sin \omega t$$

$$= V_0 \sin \omega t + \frac{mV_0}{2} \cos (\omega - \omega_1)t - \frac{mV_0}{2} \text{sos}(\omega + \omega t)$$

(This is illustrated graphically in Fig. 1 (a).)

**E.W. & W.E.*, Vol. 1, No. 2. "Side-Band Telephony," by E. H. Robinson.

† *Proc. I.R.E.*, Vol. 11, No. 1. "Relations of Carrier and Side-Bands in Radio Transmission," by R. V. L. Hartley. *Proc. I.R.E.*, Vol. 13, No. 3. "Production of Single Side-Band for Trans-atlantic Radio Telephony," by R. A. Heising.

‡ See *E.W. & W.E.*, Vol. 1, No. 2.

B 4

The last two terms of the latter expression represent the two side-bands, and if we can eliminate the carrier component $V_0 \sin \omega t$, we are left with the two side-bands, which can be expressed by :—

$$mV_0 \sin \omega_1 t \sin \omega t \qquad \text{(See Fig. 1 (b).)}$$

This simply represents an H.F. oscillation whose amplitude is itself a simple harmonic

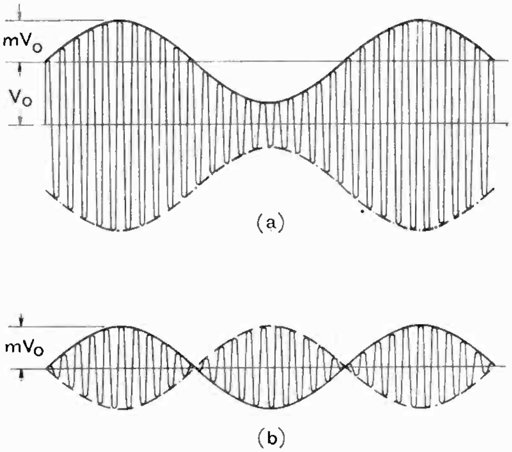


Fig. 1.

function at a low frequency. Now this means that if we can obtain a generator of H.F. oscillations whose amplitude is algebraically proportional to the instantaneous input, and if we supply such a generator with pure A.C. telephonic power input we shall get an H.F. output consisting entirely of two side-bands with no carrier component at all. An ordinary valve oscillator without any D.C. on the anode, but supplied from an audio-frequency transformer, would not be any use, of course, since it would only function on one-half of the cycle.

The system shown schematically in Fig. 2, and known among radio amateurs as the "self-rectifying" circuit, was tried. It will be seen that on either half cycle one of the valves must be operative. The system did not give the desired result ; it gave neither proper side-band output nor anything else of any use. The reason for this is an important and fairly obvious one. In the case of a normal pair of side-bands the H.F. amplitude, $mV_0 \sin \omega_1 t$, being a sine function, is alternately positive and negative ; when the modulation cycle passes through zero the H.F. oscillations undergo a phase change of 180 degrees. Figs. 1 (a) and (b) help to make this clear graphically : (a) represents ordinary modulation, *i.e.*, carrier plus two side-bands, while (b) represents two side-bands alone. The envelope of the positive half-cycles in (a) is shown by the full line, and that of the negative half-cycles by the dotted line. Now, to derive the graphical representation of two side-bands alone from (a) we must subtract the instantaneous carrier amplitude V_0 from every point of the H.F. cycles. This gives us directly Fig. 1 (b), in which the full positive envelope line alternately goes on the negative side of the zero line. The system in Fig. 2 does not give this 180 degree phase reversal, both valves giving the same phase of excitation in the output circuit with respect to the grid drive.

Fig. 3 shows the modified circuit giving the required phase reversal. The point of

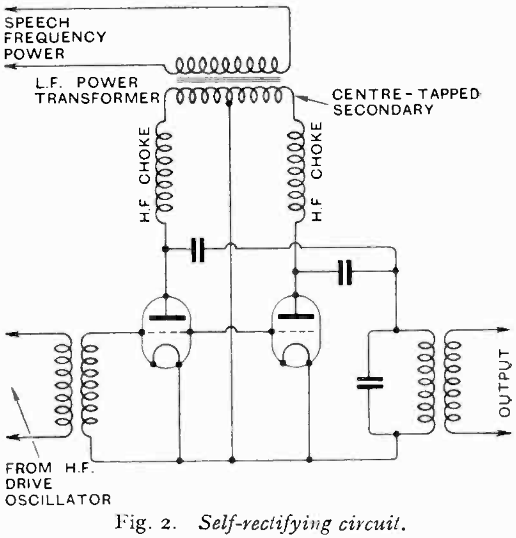


Fig. 2. *Self-rectifying circuit.*

difference from Fig. 2 is that there is a centre-tapped tuned anode circuit, the anodes of the two valves being connected to opposite extremities of this circuit. The grids of the valves are connected in parallel, and driven with a constant H.F. voltage of the required carrier frequency. It will be seen, therefore, that each time the speech frequency voltage across the L.F. power transformer passes through zero a different modulator valve comes into operation, and the H.F. phase in the output is reversed. An independent drive oscillator is used in preference to making the modulators a self-oscillating system, in order to avoid phase irregularities and threshold discontinuities each time the anode supply passes through zero.

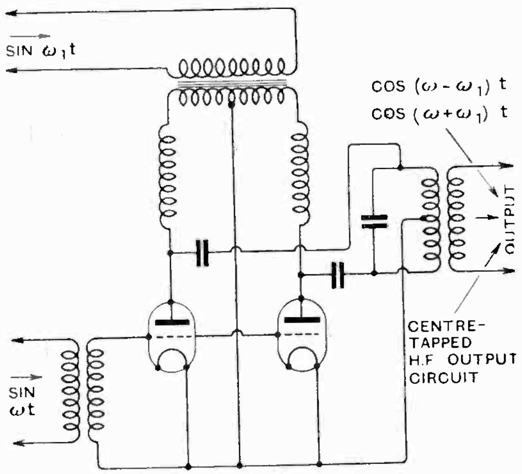


Fig. 3. *Modified circuit to give phase reversal.*

The system in Fig. 3 was found to be an immediate and complete success. It produces two side-bands minus carrier as easily and copiously as ordinary choke control produces "straight" telephony. Besides being a modulator system it is an H.F. power amplifying stage of reasonable efficiency. It is self-neutralised, and, therefore, quite stable. No trace of carrier wave appears in the output. Critical balancing is not necessary, but the two valves must be reasonably similar, and the centre-tapped L.F. and H.F. windings must be as symmetrical as conveniently possible. There would appear to be no lower limit to the wavelength upon which the system will work. The limit would be set rather by the difficulty of homodyne reception on very short wavelengths.

Practical Details of Experiments.

A transmitter was set up at a location in N.W. London. Details of the circuit arrangements are shown in Fig. 4. The master oscillator V_1 was an ordinary high impedance receiving valve (μ=35), namely, a "Cosmos" SP55B, with an anode supply of about 100 volts. The quartz plate Q lay on a flat copper plate A, and on the upper face of the crystal a brass disc B $\frac{5}{8}$ in. diameter was allowed to rest. The .25 megohm Varley wire-wound resistance R_1 served to maintain the normal grid potential of V_1 about equal to that of the negative filament lead. The crystal Q had a main natural frequency corresponding to a wavelength of 194 metres, this being the wavelength used throughout the experiments. The anode circuit $L_1 C_1$ was tuned to this frequency, no further reaction coupling being needed to maintain oscillations. A coil L_2 was just sufficiently coupled to L_1 to give the required drive on the grids of V_2 and V_3. Both L_1 and L_2 were ordinary plug-in receiving coils, L_1 having thirty turns, and L_2 having sixty turns. The coupling between L_1 and L_2 requires a certain amount of care in adjustment. This coupling must be sufficiently great to ensure adequate voltage drive on the grids of V_2 and V_3 to deal with the highest probable L.F. anode voltages, but at the same time it was found that if the coupling is too tight the frequency of V_1 is wobbled slightly during modulation, in spite of the crystal control.

The modulators V_2 and V_3 were two Marconi DE5's, with their anodes shunt-fed through chokes L_7 and L_8 from the centre tapped transformer T_2. The anodes were connected through 0.001μF mica stopping condensers C_7 and C_8 to the ends of an inductance L_3 tuned to the carrier frequency with a 0.0005μF variable air condenser C_3. L_3 was a single-layer winding of 20 D.C.C. copper wire on a cylindrical cardboard tube four inches in diameter. The middle turn of this coil was connected to the common negative filament lead as shown. The grids of V_2 and V_3 were connected in parallel and given about 6 volts negative bias by means of some dry cells B_1 through the coupling coil L_2. The coupling coil L_4 for transferring the two-side-band output from L_3 to the grid of the power amplifier V_4 had about the same number of turns as L_3, but on a former of smaller diameter which would slip inside L_3 for coupling purposes. The coupling was made quite tight, L_4 being right inside L_3 and symmetrical with respect to its centre point. The main H.F. power valve V_4 was a Mullard 0/150C, with 700 volts D.C. anode supply and a negative grid bias of about 35 volts from a battery B_2. The filament was heated with A.C. from a suitable transformer working off the 50 cycle mains. The anode of V_4 was series fed through the centre point of the tuned anode circuit L_5 C_5, tuned to the carrier frequency (λ=194 metres). This circuit was centre-tapped to provide the necessary circuit calls for no comment, as it was quite conventional. The aerial current meter H only registers, of course, during modulation.

The low frequency side of the transmitter was straightforward enough. The microphone M was of the ordinary commercial inset type, which gave quite good enough speech quality for the purposes of the experiments. The microphone transformer T_1 had a step-up ratio of about 50 : 1. Since

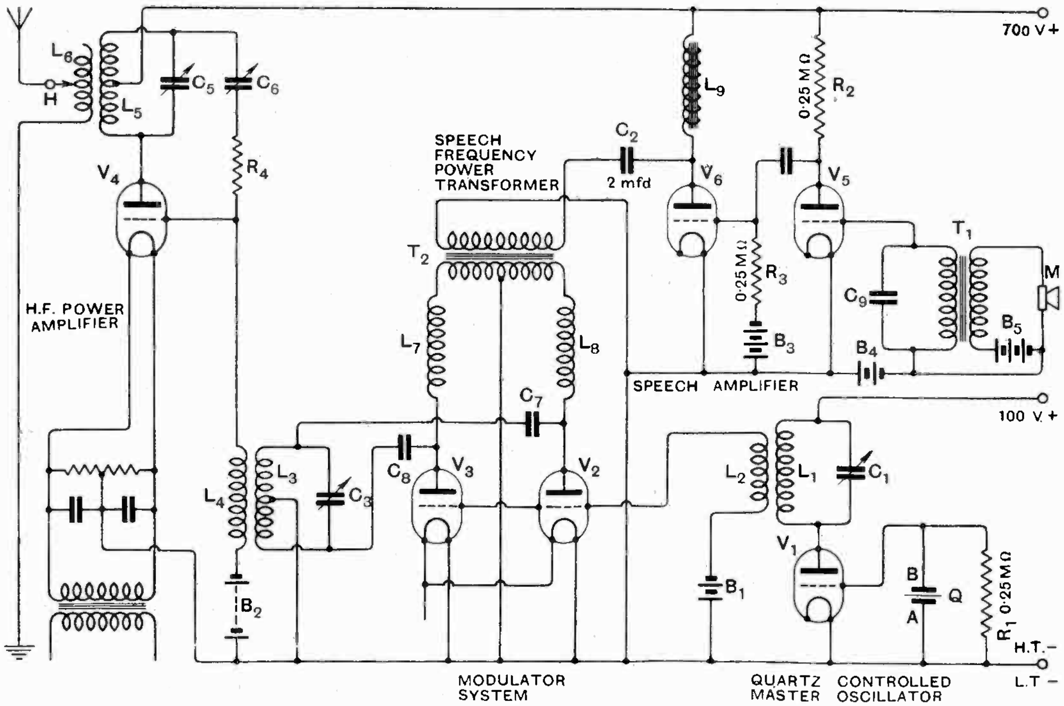


Fig. 4. *Details of transmitter circuit set up in N.W. London.*

neutralisation through the condenser C_6. This neutralisation is most essential as V_4 must, of course, have no tendency to oscillate on its own. C_6 need have only a very small capacity (about that of the inter-electrode capacity of V_4), but requires very careful adjustment. It was found that even when the system was neutralised with respect to the working frequency there was a strong tendency for oscillations at about 5 metres to be set up round the short path via C_5 C_6, grid and anode of V_4. This was stopped by insertion of a resistance R_4 in series with C_6; R_4 was about 100 ohms and took the form of an old carbon filament lamp. The aerial the main H.T. supply of 700 volts was used also for the L.F. amplifier it was convenient to use resistance coupling for the first stage V_5, which was a DE5B with a .25 megohm wire-wound anode resistance R_2. The final audio-frequency stage has, however, to produce several watts of audio-frequency power, since it is this power alone which feeds the anode circuits of the modulators V_2 and V_3. For this reason the second L.F. amplifier V_6 was an Osram DET1 with the full 700 volts on its anode and about 60 volts negative grid bias. The speech-frequency power transformer T_2 was virtually a 1 : 1 inter-valve transformer, with

2,000 turns on the primary and 2,000 turns on each half of the secondary. The core was closed, and had a cross-sectional area of one square inch; the design is not claimed as ideal, but it served its purpose. It will be noticed that a condenser C_2 and choke L_9 are used to keep the D.C. out of the primary of T_2. This is not absolutely essential, but seems to assist in obtaining a symmetrical output from T_2. The writer has noticed that when the primary of a small inter-valve transformer is connected directly in the anode circuit of the last power stage of a speech amplifier an asymmetrical voltage may be produced across the secondary, *i.e.*, the alternate half-cycles have different peak potentials. A more symmetrical output for the secondary of T_2 seems to be obtained with the arrangement shown.

It is rather difficult to rate the power of such a transmitter on the ordinary basis, as H.F. power is only generated as demanded by the modulation. If the main valve V_4 were allowed to oscillate on its own the H.F. power produced would be about 20 to 30 watts. The power dissipated on the anode in the absence of modulation was about 50 watts, but since the whole of the useful part of the characteristic could be used in accommodating the side-band components the transmission was equivalent to that from an ordinary system employing about 120 watts.

Too much emphasis cannot be laid upon the necessity for absolute constancy in the frequency of the oscillations generated by the master oscillator. One or two cycles frequency shift on the part of the master is quite enough to produce objectionable beats at the receiver in the case of a two-side-band transmission. On the wavelengths tried a quartz-controlled master oscillator valve was found to be practically a complete solution, and to all intents a necessity. Passably good results have, however, been obtained with a self-driven master, but very special precautions were necessary, chief of which were very loose coupling to the master oscillator, and the interposition of a carefully neutralised stage of H.F. amplification between the master oscillator and the modulator grids.

The correct H.F. drive for the grids of the modulators V_2 and V_3 was found by trial, the coupling between L_2 and L_1 being varied until best all-round results were obtained. With ample drive on these grids there appeared to be no trouble from "threshold effect." The smallest background noises were transmitted in due proportion in spite of the absence of carrier.

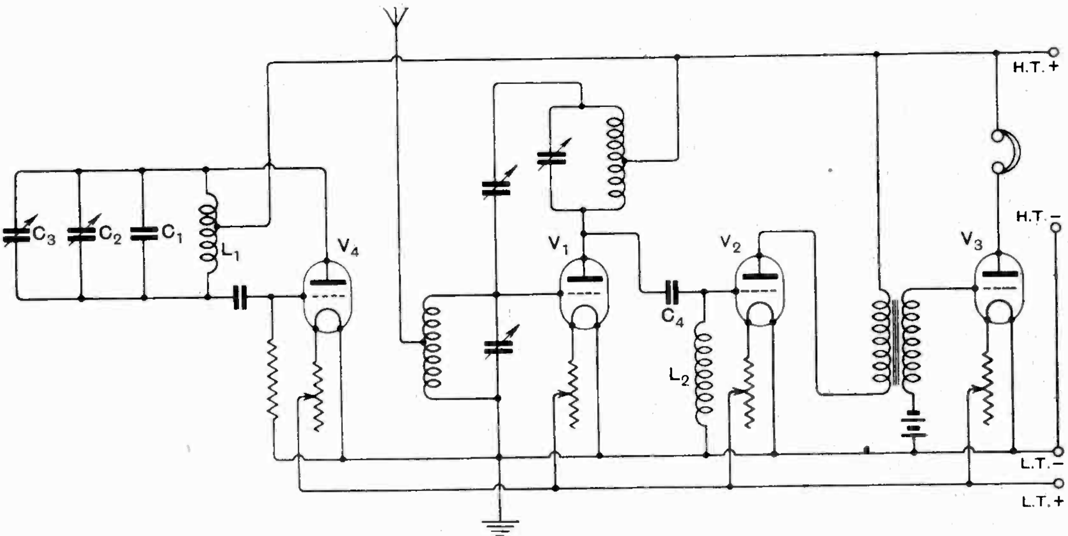


Fig. 5. *Circuit of receiver used.*

The circuit of the receiver used is shown in Fig. 5. The receiver itself calls for little comment, as it is quite conventional. There is one stage of neutralised tuned anode H.F. amplification using a DE5B (V_1) followed by an anode-bend detector V_2 and one stage of transformer-coupled L.F. amplification. V_2 was an SP55B, and V_3 a DE5, the untuned H.F. choke L_2 is simply for the purpose of biasing the grid of V_2 for anode-bend rectification. Incidentally, it may be noted that neutralised H.F. amplification is very effective for the reception of telephony between 150 and 200 metres, and its ability to amplify to a really useful extent is beyond question. The homodyne oscillator V_4 was a simple Hartley circuit oscillator, V_4 being a DE5. The condenser C_1 was comparatively large, having a capacity of 0.0035μF, and correspondingly small inductance L_1 of copper strip was used. L was, in fact, a small transmitting helix. The object of using a large C to L ratio is to minimise the effects of variable stray capacities upon frequency, and also to reduce to a negligible magnitude variations due to changes in internal resistance of the valve. C_1 and L_1 together nearly tune to the carrier frequency of the transmitter. ($\lambda = 194$ metres.) The 0.0005μF variable condenser C_2 parallel with C_1 brought the homodyne within about a kilocycle of the carrier frequency, while the 0.00005μF condenser C_3, fitted with a long extension handle, allowed final adjustment to zero beat frequency between homodyne and carrier. The homodyne adjustment was the most troublesome feature in the whole system. Even when stray capacity effects have been eliminated troubles due to self and mutual inductance variations are apt to make their appearance. L_1 must be so loosely coupled to the receiver that "pulling" effects are substantially absent.

The arrangements described above gave such promising results on first tests that another similarly equipped transmitter and receiver were set up near Rickmansworth about twenty miles away from the first station.

Observations on Effects noticed in Working.

Two-way side-band was accomplished quite readily on a wavelength of 194 metres, but no true duplex working was attempted. When a two-side-band transmission is received with a non-oscillating receiver and no local heterodyne, it is mostly unintelligible, although familiar phrases are sometimes recognised. Something is heard, of course, but the intensity without the homodyne is relatively weak, and the sounds heard have a mumbling, scratchy quality. When the homodyne is brought into action, however, and is properly adjusted, the strength of the received speech is greatly increased, and the quality is as good as with any normal transmission.

It is not safe to consider the side-band transmission as a system of "secret telephony." A good deal is heard on a non-oscillating receiver which allows the meaning of some of the transmitted phrases to be understood. The rhythm and part of the intonation are, for instance, largely preserved. Further, although all fundamental tones are in theory absent until the heterodyne is used, it is often found that the fundamentals are heard to some extent without the heterodyne. One of the reasons for this would appear to be that in practice any note or tone contains harmonics as well as the fundamental and the side-bands due to these harmonics heterodyne mutually at the receiver to reproduce the fundamental. Also, any departure from symmetry in the modulator system appears to introduce some element of intelligibility, although the system is still a quiescent one. During one transmission the writer found that his speech was being read and understood quite well by several receiving stations using perfectly ordinary receivers. This was traced to asymmetry in the speech transformer T_2 (Fig. 4) and when this matter was rectified the speech became normally unintelligible on an ordinary receiver. The reason for this is at present a little obscure.

There is some difficulty in tuning in a side-band transmission for the first time; since no carrier is emitted, and the operator at the receiver finds it puzzling to decide when his homodyne is adjusted to zero beat frequency with respect to the master oscillator at the transmitter. When the homodyne is within a few cycles of the correct frequency, speech is received fairly clearly, but with a superimposed ripple equal to the discrepancy between carrier and homodyne frequencies. Once this stage has been reached by trial the discrepancy can be brought practically to zero by use of the fine adjustment. (C_3 in Fig. 5.)

These experiments showed quite unmistakably that on a wavelength of 194 metres the carrying power of a given wattage is greatly increased by the use of a two-side-band transmission instead of an ordinary one. When the valve V_4 in Fig. 4 was made to self-oscillate on the same anode voltage and was choke-controlled in the ordinary manner the signals received at a distance of twenty miles were considerably weaker than those obtained with the two-side-band system.

It is concluded from these experiments that there are considerable possibilities in side-band systems for short-wave telephony transmission. The great difficulty is the homodyne adjustment; it must be accurate to less than one cycle in a million, but this is not quite so impossible as it may sound. A one-side-band transmission would be much easier to receive, since it does not matter in this case if the homodyne is a few cycles out as far as speech is concerned. Unfortunately, it is much more difficult to isolate a single side-band and radiate it at a short wavelength. From the point of view of efficiency it is better to radiate two side-bands than one. (See Appendix.)

The side-band system certainly allows a very great saving of transmitting power and local interference. The subject is well worth the attention of amateur experimenters.

APPENDIX.

It is of great interest to decide upon the relative usefulness from the power-saving point of view of a single-side-band transmission and a two-side-band transmission. Let us consider both from the standpoint of the resulting effect at the receiver.

Two-side-band transmission.

Let the transmission produce at the receiver a wave represented by

$$\frac{A}{2} \cos(\omega - \omega_1)t - \frac{A}{2} \cos(\omega + \omega_1)t$$

Let the local homodyne add $B \sin \omega t$ where $B > A$. Resultant in receiver is :—

$$\frac{A}{2} \cos(\omega - \omega_1)t - \frac{A}{2} \cos(\omega + \omega_1)t + B \sin \omega t$$

$$= A \sin \quad \sin \omega_1 t + B \sin \omega t$$

$$= (B + A \sin \omega_1 t) \sin \omega t \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Single-side-band transmission.

Let wave coming in from transmitter be represented by

$$A \cos(\omega - \omega_1)t$$

Let local homodyne add $B \sin \omega t$ where B is large compared with A.

Resultant in receiver is :—

$$A \cos(\omega - \omega_1)t + B \sin \omega t$$

$$= A \cos\left\{\left(\omega - \frac{\omega_1}{2}\right) - \frac{\omega_1}{2}\right\}t + B \sin\left\{\left(\omega - \frac{\omega_1}{2}\right) + \frac{\omega_1}{2}\right\}t$$

$$= \left(A \cos \frac{\omega_1}{2} t + B \sin \frac{\omega_1}{2} t\right) . \cos\left(\omega - \frac{\omega^2}{2}\right)t$$

$$+ \left(A \sin \frac{\omega_1}{2} t + B \cos \frac{\omega_1}{2} t\right) \sin\left(\omega - \frac{\omega_1}{2}\right)t$$

By adding vectorially we can condense these two terms into one involving

$$\sin\left\{\left(\omega - \frac{\omega_1}{2}\right) t + \phi\right\}$$

and expression becomes

$$\left\{\sqrt{\left(A \cos \frac{\omega_1}{2} t + B \sin \frac{\omega_1}{2} t\right)^2 + \left(A \sin \frac{\omega_1}{2} t + B \cos \frac{\omega_1}{2} t\right)^2}\right\} \sin\left\{\left(\omega - \frac{\omega_1}{2}\right)t + \phi\right\}$$

$$= \left\{\sqrt{A^2 + B^2 + 2AB \sin \omega_1 t}\right\} \sin\left\{\left(\omega - \frac{\omega_1}{2}\right)t + \phi\right\}$$

Now,

$$B + A \sin \omega_1 t = \sqrt{A^2 \sin^2 \omega_1 t + B^2 + 2AB \sin \omega_1 t}$$

and if B is large compared with A we can neglect terms in A^2 and we may say

$$\sqrt{A^2 + B^2 + 2AB \sin \omega_1 t} = B + A \sin \omega_1 t$$

to a close approximation.

Hence the expression for the resultant wave becomes

$$(B + A \sin \omega_1 t) \sin\left\{\left(\omega - \frac{\omega_1}{2}\right) t + \phi\right\} \qquad (2)$$

It will be seen that both expressions (1) and (2) represent the same amplitudes and modulation envelopes and therefore equivalent effects on a receiver. (1) however is derived from two waves each of amplitude $A/2$ representing a power proportional to $2(A/2)^2 = A^2/2$, while (2) is derived from one wave of amplitude A and power proportional to A^2. Thus when a strong enough homodyne is used the same effect is produced at the receiver by a two-side-band transmission using half the power which would be necessary with a single-side-band transmission.

Description of a Valve Wavemeter with a Range of 10 metres to 20,000 metres

(30,000 kilocycles to 15 kilocycles per second).

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

(*Of the National Physical Laboratory.*)

Summary.

THE paper describes a valve oscillator wavemeter, which is an improvement on the previous design described in the *Wireless World*, 6th October, 1926. The operating range of wavelengths has been considerably extended and a separate valve modulator has been incorporated in the instrument. The frequency calibration is constant to about one part in a thousand over a wide range of variation of anode and filament voltage, and is not affected to more than one part in a thousand by changing the valve for another of the same type. This accuracy is considered sufficient to make the oscillator a valuable instrument in connection with many radio measurements.

Description.

1. The oscillator wavemeter has the following characteristics :—

(*a*) Wide range of operation (10 metres to 20,000 metres) obtained by means of separate coils, without any other change in the circuit.

(*b*) Continuous waves modulated at an audible frequency can be generated if desired over the whole range of operation. This is a very useful feature in connection with the tuning and testing of receiving circuits.

(*c*) Constancy of calibration (to one part in a thousand) with respect to changes in anode and filament voltage and changes of the valve.

(*d*) Portability. The batteries required are incorporated in the case of the instrument.

2. The circuit is shown in Fig. 1. The details of the components are as follows :—

A. *Coils.*—Three-plug centre-tapped coils are used. The construction of the coils calls for no special feature beyond the centre tapping and sufficient robustness of framework to ensure constancy of form. Low self-capacity is a desirable feature but the resistance does not seem to be a matter of great importance, except at the very short wavelengths. A pattern which has been

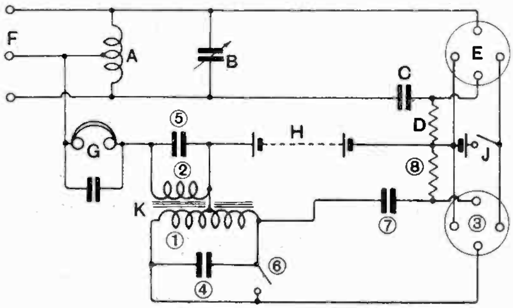


Fig. 1.

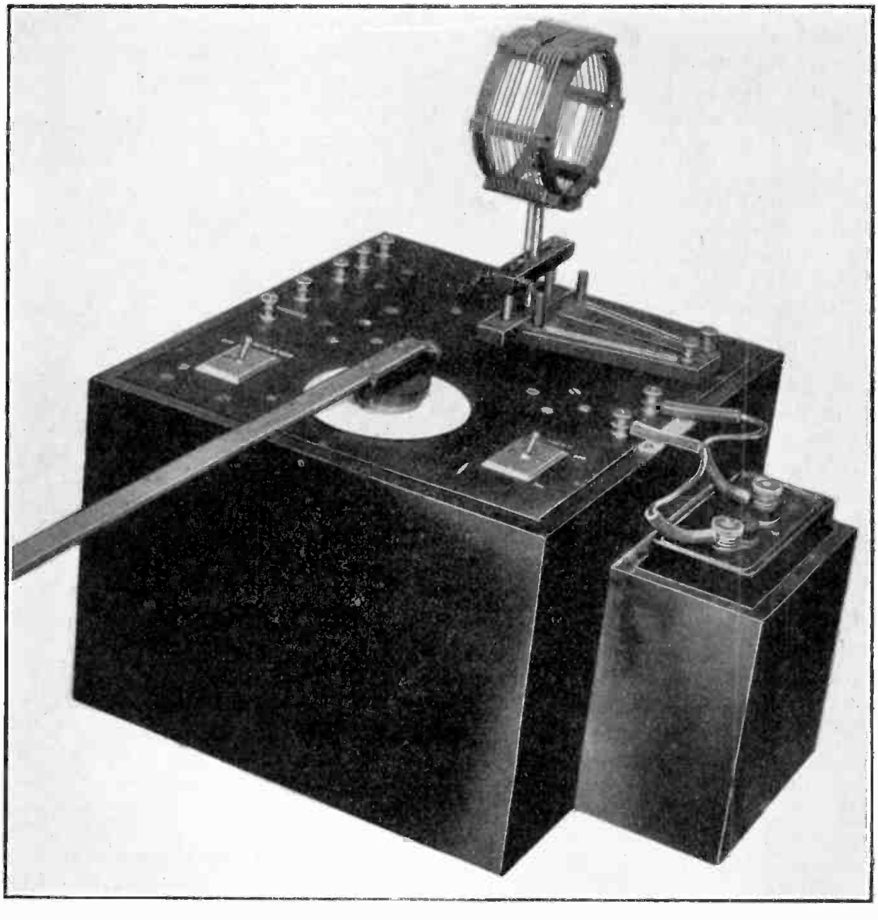
found suitable for the lower wavelength range (10-100 metres) is illustrated in the photograph. For the shortest wavelengths (down to 10 metres) the coil consists of two turns of about 7 cm. diameter of bare No. 18 tinned copper wire.

B. *Tuning Condenser.*—In the existing model the tuning condenser is a "low loss" 500$\mu\mu$F straight line capacity condenser. The square law pattern can be used with advantage unless it is desired to extend the range of each coil by means of an additional small fixed condenser. The principal requirement is low power factor and rigid construction. A remote control handle and a vernier drive are very desirable. It has been found that this is a simpler method of reducing body capacity effects than any arrangement of screening, to which the circuit is not very well adapted.

C. *Small Coupling Capacity.*—This is a small air or mica dielectric condenser having a capacity of about 30-50$\mu\mu$F. In the existing model it consists of two brass discs about 4 cms. in diameter, the distance between which can be varied and then fixed. The chief requirement is that the capacity shall be variable up to about 100$\mu\mu$F or so, with a rigid locking arrangement. When the instrument has been assembled this capacity is adjusted to the smallest value consistent with oscillation over the whole range required, and is then fixed.

D. *Grid-Leak.*—A grid-leak of the metallic film vacuum pattern should be used, as this is likely to be more constant than the carbon filament type, and will have a smaller self-capacity. Its resistance should not exceed about 1 megohm, or else the oscillations may suffer from intermittent interruption, or "squegging."

E. *Valve.*—A valve of the short-path low impedance pattern has been used, as this appears to facilitate oscillation at the extreme low wavelengths. If the very short wave-length range is not required any ordinary dull emitter valve can be used.



General view of the complete wavemeter

F. *Coupling Terminals.*—These have been added to enable any suitable three terminal coil to be driven by the set, and also to permit of capacity coupling to any other circuit. It must be remembered, however, that any form of coupling to another circuit will necessarily affect the calibration to some extent.

G. *Telephone Terminals.*—These are inserted in the high tension supply lead, and are shunted by a fixed mica condenser of about 0.001μF capacity. If preferred, a telephone transformer can be inserted at this point instead. The insertion of telephones does not affect the calibration within the limits stated.

H. *High Tension Battery.*—Four 15-volt dry battery units are used, and are housed in the base of the case. Forty to fifty volts would be sufficient, but it is well to have a margin for the deterioration of the cells. A by-pass condenser of about 1μF (paper) is desirable if dry cells are used.

I. *Low Tension Battery.*—A 2-volt accumulator is housed in the case attached to the side of the main box. It is better not to have an accumulator contained in the box itself, as this might increase the humidity of the interior of the box and lower the insulation resistances.

K. *Modulating System.*—Essentially this consists of a low frequency oscillating circuit driven by a separate valve with the same batteries, and coupled magnetically to the high frequency circuit so that a small low frequency E.M.F. is added to the anode voltage of the high frequency circuit.

The low frequency oscillating circuit was made by rewinding an ordinary intervalve low frequency transformer with two windings—one (1) of about 4,000 turns, approximately centre tapped, and one (2) of about 100 turns, or preferably of say 200 turns tapped at 50 and 100, so that the best output winding can be chosen from 50, 100, 150 and 200 turns. The low frequency oscillations are tuned to any desired note by means of a fixed condenser (paper dielectric will do for this) of capacity 0.01 to 0.02μF. It may be necessary to shunt the output winding with a fixed condenser (5) (about 0.001μF) to prevent any radio frequency choke effect. A short circuiting switch across the modulator main winding enables the modulator to be put in or out of action as required.

The grid coupling condenser (7) is about 0.005μF and the grid-leak (8) about 1 megohm.

3. Action of the Circuit and Constancy of Calibration.

The circuit will be recognised as a variation of the well-known Hartley circuit. Its special suitability for the present purpose appears to lie in the fact that the oscillations are accompanied by rectification in the grid circuit, producing a considerable fall of mean grid potential and correspondingly low anode current. This has the effect of restricting the amplitude of the oscillations generated. The grid coupling capacity is reduced to as low a value as possible for the same purpose. Under these conditions the frequency of the oscillations is very little affected by changes in the supply voltage. The circuit seems to be quite remarkable in this respect. A very thorough test of the constancy of the calibration was carried out, and showed that over the whole range of frequency covered by the wavemeter a variation of from 30 to 70 volts in the high tension supply and of from 1.5 to 2 volts in the filament voltage affected the frequency calibration to less than one part in a thousand. Changing the valve for another of the same pattern, picked at random, also did not affect the calibration to one part in a thousand. The important practical consideration is that the changes of anode and filament voltage likely to occur in practice will not cause any appreciable change in the frequency of the oscillations.

The incorporated separate valve modulator has proved to be a very useful feature. It does not affect the mean radio frequency and greatly facilitates the adjustment and testing of receiving apparatus. Compared with the grid-leak interrupter arrangement adopted for the previous design, it is certainly not so simple and requires more auxiliary apparatus. On the other hand it has the advantage of greater certainty and uniformity in action, with a much less disturbing effect on the mean frequency and general character of the radiation.

[This work was carried out for the Radio Research Board and is published by permission of the Department of Scientific and Industrial Research.]

The Suppression of Parasitic Oscillations in Valve Circuits.

By M. Reed, M.Sc., A.C.G.I., D.I.C.

Summary.

THIS article considers the conditions that must be satisfied for oscillations to be maintained in the case of a "tuned-anode," a "tuned-grid," and a Hartley oscillator, respectively.

Methods are given that can be used to stop an oscillation in any one of the above cases.

The treatment is quite general; no attempt being made to apply the methods to any particular detector, amplifier, or oscillator that may be encountered in radio practice.

Introduction.

Parasitic oscillations are of great importance in radio engineering. They form a constant source of trouble in all types of receiving and transmitting apparatus.

In receiving sets they lower the efficiency of reception owing to the "howling" which sometimes arises from their presence, and also to the energy which they absorb.

In transmitting apparatus the parasitic oscillations may sometimes be sufficiently strong to prevent the propagation of the legitimate oscillation. In any case they will spoil the wave-form of the oscillation propagated, and in addition they will lower the efficiency of the oscillator, since their presence will result in the absorption of power which would normally go to the maintenance of the legitimate oscillation.

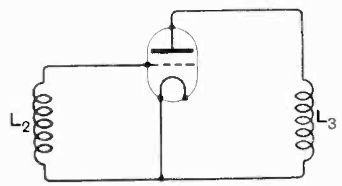


Fig. 1.

Undesirable oscillations cannot always be wholly eliminated by the careful design of the apparatus, because they are generally confined to circuits which have as one of their components the stray capacity which may exist between the electrodes of a valve, between coils, or between other parts of the apparatus. These stray capacities, in addition to forming a component for the parasitic oscillatory circuit, are generally such that they form the electrostatic coupling necessary for the maintenance of the oscillation.

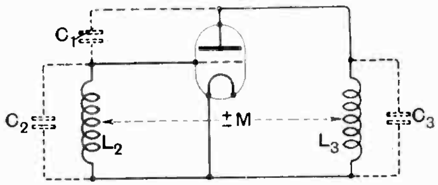


Fig. 2.

In some cases electromagnetic coupling is provided owing to the proximity of coils, transformer windings, or similar components.

Where a common H.T. battery is used for a number of valves, it is possible for this battery to act as a resistance coupling.

To eliminate undesirable oscillations completely in any given piece of apparatus, it is not sufficient always to rely solely on careful design. In any case it would not be very convenient to redesign and rebuild the apparatus continually until parasitic oscillations are completely eliminated.

It is therefore essential that these oscillations should be eliminated by some simple alteration in the apparatus, such as the addition of a suitable resistance or condenser.

The Possible Parasitic Oscillatory Circuits.

Fig. 1 shows a simple circuit consisting of an anode and grid coil. Now it is possible for both the coils L_3 and L_2 to have self capacity, and also that there should be stray magnetic and electrostatic coupling between the grid and anode circuits.

Fig. 2 shows Fig. 1 redrawn with these quantities taken into account.

From Fig. 2 it is seen that there are three possible oscillatory circuits; they are :—

1. The Hartley circuit, comprising C_1, L_2, and L_3.
2. The anode circuit, comprising L_3 and C_3.
3. The grid circuit, comprising L_2 and C_2.

Each of these circuits will now be considered in detail.

The Hartley Circuit.

The Hartley circuit is shown in Fig. 3. It is made up of C_1, L_2 and L_3. The self-capacities of L_2 and L_3 have been neglected for the moment.

For this circuit to be maintained in oscillation, the following expression must be satisfied :—

$$C_1 R R_a (L_3 + L_2 \pm 2M) < (L_3 \pm M) [m(L_2 \pm M) - (L_1 \pm M)]^*$$

where R=resistance of the oscillatory circuit;

R_a=internal resistance of the valve;

m=amplification factor of the valve.

The maintenance of this oscillation does not depend on the sign of the mutual induction so long as it has not got a negative value

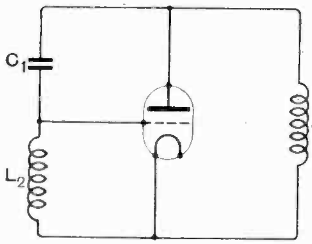


Fig. 3.

which is equal to or greater than the inductance of either the grid or the anode coil. If the mutual inductance has a greater negative value, then the condition for the maintenance of the oscillation, namely, that the grid and anode voltages should be 180 degrees out of phase, will be impossible.

To prevent the Hartley circuit from oscillating, the following methods can be employed :—

* Van der Bijl. *Thermionic Vacuum Tube*, p. 283.

1. From the formula it is seen that for a given valve and a given L_2, L_3 and M, the oscillation can be prevented by increasing C_1, R, or their product. It is usually found most convenient to increase the product. Fig. 4 shows how the resistance and capacity of the Hartley circuit can be increased. C is a condenser placed across the grid and anode terminals and R_2 is a non-inductive resistance connected in the grid circuit.

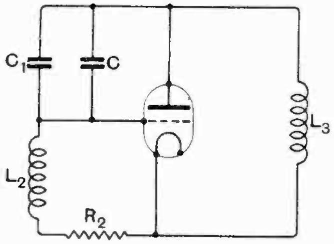


Fig. 4.

In the case of oscillators it can be seen that R_2 will not interfere with a normal oscillation existing in the anode or the grid circuit. C must be so chosen that the normal oscillation is not affected.

If the legitimate oscillation is of low frequency then there will be no difficulty in stopping an undesirable oscillation in the Hartley circuit.

Example.

An anode-tuned oscillator had the following dimensions :—

Tuning capacity=0.0567μF.

L_3=0.48 henries.

L_2=0.08 ,,

Frequency of anode circuit=965 cycles/sec.

C_1=90$\mu\mu$F.

Frequency of Hartley oscillation=40,000 cycles/sec.

It was found that if

C = 1,530$\mu\mu$F

and R_2 = 10,000 ohms,

the Hartley oscillation was completely stopped.

If the legitimate oscillation is of high frequency, then it will be found that C must be made very small and R_2 must be increased so as to obtain the necessary product.

2. From Fig. 5 it is seen that if L_2C_R was tuned to the frequency of the Hartley oscillation it would act as a rejector circuit to that oscillation (indicated by the arrow).

Under these conditions the circuit L_2C_R would offer a very high impedance to the Hartley oscillation, and it would make it impossible for that oscillation to persist.

A similar condition could be obtained by connecting a suitable condenser across L_3.

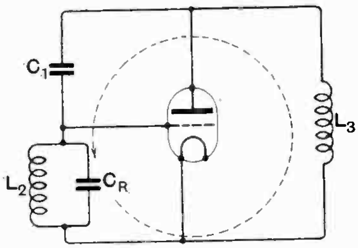


Fig. 5.

Thus the Hartley oscillation can be prevented by connecting a suitable condenser across the anode or grid coil. This method can be used so long as the grid (or anode) circuit does not tend to oscillate because of the added capacity.

In the case of oscillators the condenser must be connected across the coil which does not form part of the normal oscillatory circuit.

The Grid Circuit.

This circuit consists of L_2 and C_2 (see Fig. 2).

There are two cases to be considered here :—

(*a*) When the natural frequency of the grid circuit is less than that of the anode circuit;

(*b*) When the natural frequency of the grid circuit is greater.

Case (*a*).

Here we are, in effect, dealing with a simple "tuned-grid" oscillator. For such an oscillation, if the coupling is magnetic, it is well known that the sign of the mutual induction must be negative.*

One of two methods can be employed to prevent the oscillation :—

1. In Fig. 6 is shown a vector diagram for a "tuned-grid" oscillator with electrostatic coupling. To obtain this diagram it is assumed there is a current I_2 in the grid coil, and that the coupling is provided by the condenser C. It is assumed that there is no magnetic coupling between the anode and grid coils. This assumption is used only for the purpose of drawing the vector diagram. Further on the effect of the magnetic coupling is considered.

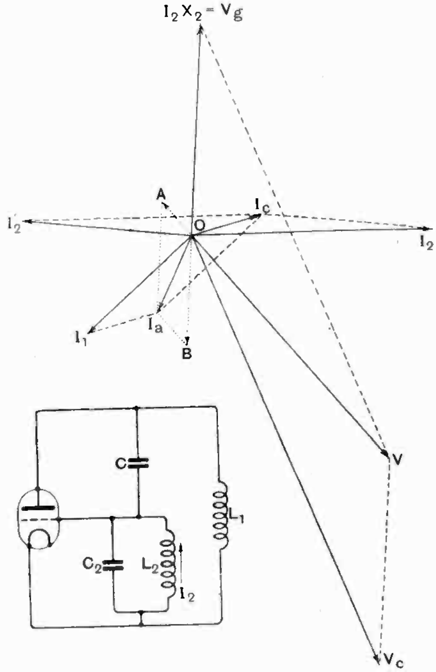


Fig. 6.

The symbols employed are as follows :—

OI_2=current in grid coil=I_2.

OI_2X_2=E.M.F. induced in the grid coil=$-V_g$.

OI_2'=current through C_2 $= -V_g \times j\omega C_2 = -j\omega C_2 V_g$.

OI_c=current through C $= OI_2 + I_2'O$.

OV_c=resulting voltage across C $= -jI_c/\omega C$.

OV=voltage across L_1 $= OV_c - V_g = -V_a$.

$OA = V_a/R_a$.

$OB = gV_g$.

OI_a=anode current $= OA + OB = I_a$.

OI_1=current through $L_1 = OI_a - OI_c$.

* Turner's *Outline of Wireless*, p. 125.

The condition that must be satisfied in this vector diagram is that the angle I_1OV must not be greater than 90 degrees, *i.e.*, the current through L_1 must not lag by more than 90 degrees on the voltage OV.

This condition can only be satisfied if OV_c is longer than OI_2X_2, *i.e.*, if the voltage across C is greater than the voltage across C_2. If this is not the case it will be found impossible to construct the vector diagram, which means that it will not be possible for an oscillation to be maintained in the grid circuit. Thus to prevent an oscillation in this circuit we must reduce the voltage across the condenser C, *i.e.*, the value of the capacity of this condenser must be increased.

If in addition to the electrostatic coupling there is also a magnetic coupling, then we have the following conditions. Under normal circumstances the electrostatic coupling will help the magnetic coupling to maintain the oscillation, since the capacity between the anode and the grid is generally not sufficient to make OV_c less than V_g (see Fig. 6). If this capacity is increased, then as OV_c becomes less than V_g, the capacity coupling will tend to neutralise the magnetic coupling until finally it will become impossible for the valve to maintain the oscillation any longer.

When using this method to stop a parasitic oscillation in the grid circuit, a suitable resistance must be inserted in the Hartley circuit, if that circuit tends to oscillate. In all the methods which follow, it is tacitly assumed that this precaution is taken if the Hartley circuit tends to oscillate.

The anode circuit cannot oscillate as the mutual induction is of the wrong sign, since the natural frequency of the anode circuit is above that of the grid circuit (see Appendix 1). In any case the condenser across the anode and grid will prevent the anode circuit from oscillating (see below).

(2) Another method that can be used to prevent an oscillation in the grid circuit is to connect across the anode coil a condenser of such a value that the natural frequency of the anode circuit is now less than that of the grid circuit. In this case the grid circuit will not be able to oscillate because the mutual induction will be of the wrong sign, this case demanding that the sign of the mutual induction should be positive. (This follows from the corresponding case of the anode circuit which is considered in Appendix 1.)

This method can only be used if the anode circuit itself does not tend to oscillate.

If the coupling is electrostatic, then the method (1) is the only one which can be employed.

Case (b).

In this case if the coupling is magnetic, the sign of the mutual induction must be positive. This corresponds to the anode circuit case given in Appendix 1.

Three methods can be employed:—

1. Connect a condenser across the anode and the grid in the manner indicated on page 2. Here again the anode circuit cannot oscillate because the mutual induction is of the wrong sign.

2. Connect a condenser across the anode coil, thus decreasing the natural frequency of the anode circuit, and make this condenser of such a value that the mutual induction will not be large enough to maintain the oscillation in the grid circuit.

The reason for this will be seen from Appendix 2, where the corresponding case for the anode circuit is considered.

3. Connect a condenser across the grid coil so that the natural frequency of the grid circuit is now less than that of the anode circuit, thus making the mutual induction of the wrong sign for the maintenance of the oscillation.

As before, this method can only be used if the anode coil does not tend to oscillate.

For electrostatic coupling, or combined electrostatic and magnetic coupling, see the remarks below.

The Anode Circuit.

This circuit consists of L_3 and C_3 (see Fig. 2).

As in the case of the grid circuit, there are two cases to be considered.

Case (a) When the N.F. of the Anode Circuit < N.F. of Grid Circuit.

In this case we have, in effect, a simple "tuned-anode" oscillator.

For magnetic coupling, the sign of the mutual induction must be negative (see Appendix 1).

Two methods can be employed to stop an oscillation in this circuit:—

1. By connecting a suitable condenser across the anode and grid. The vector

diagram in Fig. 7 shows that this case is similar to the one considered for the grid circuit.

OI_1'=current through $C_1=j\omega C_1\times OV$.

$OP=OI_2+OI_1'$.

OI_1=current through $L=I_a-OP$.

As before, the condition to be satisfied is that OI_1 must not lag more than 90 degrees on OV. This condition can only be satisfied if OV_c is greater than V_g, and hence the anode circuit can be prevented from oscillating by having a suitable value for C.

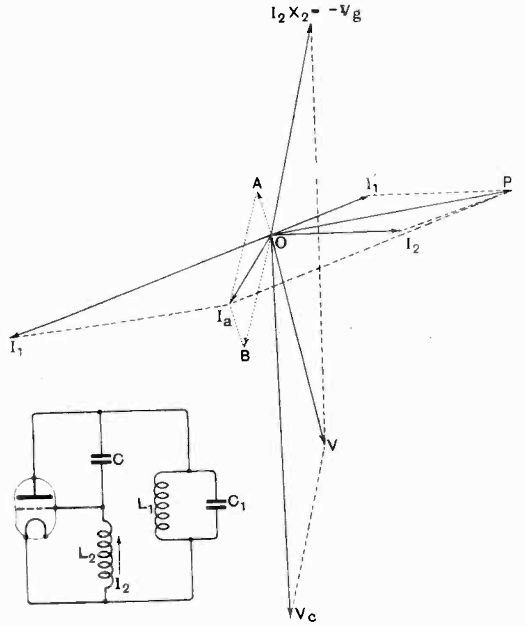


Fig. 7.

2. Connect a condenser across the grid coil so that the frequency of the anode circuit is now greater than that of the grid circuit. The sign of the mutual induction will then prevent the anode circuit from oscillating. This method can only be used if the grid circuit does not intend to oscillate.

Case (b) N.F. of Anode Circuit > N.F. of Grid Circuit.

In this case, if the coupling is magnetic, the sign of the mutual induction must be positive (see Appendix 1).

Three methods can be used to stop the oscillation :—

1. Connect a suitable condenser across the anode and grid. The electrostatic coupling thus obtained neutralises the magnetic coupling (see below).

2. Connect a condenser across the grid coil, thus reducing the natural frequency of the grid circuit so that the value of the mutual induction becomes insufficient to maintain the anode circuit in oscillation. The reason for this is given in Appendix 2, where it is shown that when the natural frequency of the anode circuit is greater than that of the grid circuit, the value of the mutual induction required is greater when the difference between these two frequencies is increased.

In this method the grid circuit cannot oscillate because the sign of the mutual induction is positive.

3. Connect a condenser across the anode coil so that the frequency of the anode circuit becomes less than that of the grid circuit. It will then be impossible for the anode circuit to oscillate since the mutual induction is positive.

This method can only be used if the grid circuit does not tend to oscillate.

If in Case (*a*) the coupling is electrostatic, then only method (1) can be used. For combined coupling the remarks made for the corresponding case in connection with the grid circuit apply equally well here.

Case (b) with Electrostatic or Combined Coupling.

For the sake of clearness the grid circuit oscillations are considered.

In Case (*b*) if the coupling is solely electrostatic it will be impossible for an oscillation to be maintained in the grid circuit. The reason for this is as follows :—

If the grid circuit oscillates at a frequency which is above the natural frequency of the anode circuit, then at that frequency the reactance of the anode circuit will be positive. That is, the current through the anode circuit must lead on the applied voltage. From Fig. 6 it is seen that if the grid circuit oscillates, it is impossible for the current through the anode circuit to lead on the applied voltage V. Thus it is impossible for the grid circuit to oscillate if the frequency of the oscillation is above the natural frequency of the anode circuit and the coupling is solely electrostatic.

It is probable that if the coupling is sufficient, the anode circuit will oscillate, *i.e.*, with electrostatic coupling the circuit which has the lower natural frequency can only oscillate.

If the coupling is both electrostatic and magnetic then it is only possible for the grid circuit to oscillate if the latter is the greater. The electrostatic coupling tends to neutralise the magnetic coupling, and hence in this case a smaller capacity will be required to stop the grid circuit from oscillating than in the corresponding example of Case (*a*).

The above remarks apply equally well for corresponding case in connection with oscillations in the anode circuit.

Conclusions.

When applying the methods given in this article to particular cases, care must be taken that the added capacities do not prevent the proper functioning of the apparatus in question. The choice of the method to be employed will be governed by this consideration.

The methods given can be applied most efficiently to "tuned-anode" or "tuned-grid" oscillators giving an oscillation at audio-frequency. In such cases the added capacities necessary to prevent an undesired oscillation will be too small to affect the normal oscillation.

For oscillators of higher frequency there is a danger that the added capacities will interfere with the legitimate oscillation, and where it is necessary to place a condenser across the anode and grid terminals, it is possible that the production of the proper oscillation may be prevented.

In the case of amplifiers when a condenser is placed across the anode and grid, care must be taken that it has not got a sufficiently high value to interfere with the amplifying efficiency of the valve.*

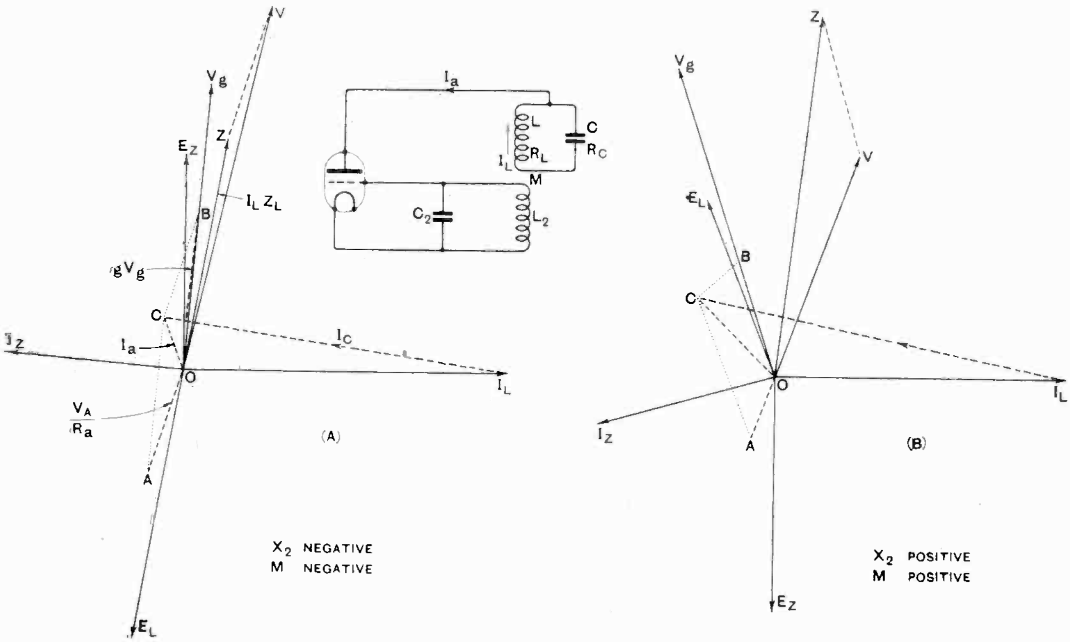


Fig. 8.

* See H. W. Nichols. *Physical Review*, June 1919.

SUMMARY OF THE METHODS USED IN THIS ARTICLE.

Oscillator.	Case.	Coupling possible.	Necessary sign of Mutual Induction.	Method employed to stop the Oscillation.	Remarks.
Hartley		Magnetic coupling may be present in addition to the permanent electrostatic coupling	Positive or negative	1. Insert suitable resistance, capacity, or both in the Hartley circuit	In the case of H.F. oscillators and amplifiers it is usually possible to insert resistance only
				2. Connect a suitable condenser across grid coil	Only possible if the grid or anode circuit does not tend to oscillate
Tuned Grid	N.F. of anode circuit above N.F. of grid circuit	1. Magnetic 2. Electrostatic	Negative	1. Connect a suitable condenser across the anode and grid	If necessary prevent the Hartley circuit from oscillating by adding suitable resistance
				2. Connect a suitable condenser across the anode coil	1. Can only be used in the case of magnetic coupling 2. Only possible if anode circuit does not tend to oscillate
	N.F. of anode circuit below N.F. of grid circuit	Magnetic	Positive	1. Connect suitable condenser across anode and grid	Prevent Hartley oscillation if necessary
				2. Connect a suitable condenser across anode coil	Prevent Hartley oscillation if necessary
				3. Connect a suitable condenser across grid coil	Only possible if the anode circuit does not tend to oscillate
Tuned Anode	N.F. of grid circuit above N.F. of anode circuit	1. Magnetic 2. Electrostatic	Negative	1. Connect a suitable condenser across anode and grid	Prevent Hartley oscillation if necessary
				2. Connect a suitable condenser across grid coil	1. Can only be used in the case of magnetic coupling. 2. Only possible if grid circuit does not tend to oscillate
	N.F. of grid circuit below N.F. of anode circuit	Magnetic	Positive	1. Connect a suitable condenser across anode and grid	Prevent Hartley oscillations if necessary
				2. Connect a suitable condenser across grid coil	Prevent Hartley oscillation if necessary
				3. Connect a suitable condenser across the anode coil	Only possible if the grid circuit does not tend to oscillate

N.F.=Natural frequency.

APPENDIX 1.

The "Tuned-Grid," "Tuned-Anode" Oscillator.

Generally, both the grid and anode coils have self-capacity. In this appendix, the condition for the anode circuit to oscillate under such circumstances will be determined.

The condition to be satisfied can be best determined by means of a vector diagram. To obtain this diagram, it is assumed that there is a current I_L in the anode coil, and that there is a mutual induction M between the anode and grid coils.

The capacity between the grid and the anode is neglected since it unnecessarily complicates the diagram.

The vector diagram is shown in Fig. 8.

OI_L = current in anode coil $= I_L$.
OE_2 = E.M.F. induced in the grid coil $= -j\omega MI_L$.
OI_2 = resulting current in the grid coil $= j\omega MI_L/Z_2$.
OV_g = grid voltage $= jI_2/\omega C_2 = V_g$.
OE_L = E.M.F. induced into anode coil $= -j\omega MI_2$.
$OZ = I_L Z_L$.
OV = anode volts $= OZ - OE = -V_a$.
$OB = gV$.
$OA = V_a/R_a$.
OC = anode current $= OB + OA = I_a$.
CI_L = current through $C_1 = I_L - I_a = OI_L - OC$.

In these vector diagrams the condition that must be satisfied is that the angle between CI_L and OV must be less than 90 degrees—that is, the current through the condenser C_1 must not lead by more than 90 degrees on the anode voltage. In Fig. 8 two vector diagrams are shown.*

In Case (*b*) it is assumed that the frequency of the anode circuit is above that of the grid circuit, *i.e.*, X_2, the reactance of the latter circuit, is positive. It is found that in this case it is only possible to make the angle between CI_L and OV less than 90 degrees, if the sign of the mutual is positive.

In Case (*a*) it is assumed that the frequency of the anode circuit is less than that of the grid circuit. From the vector diagram it is seen that in this case the sign of the mutual induction must be negative. The condition that must be satisfied for the simple "tuned-anode" oscillator.

We are interested in the Case (*b*). Thus it is seen that when the natural frequency of the anode circuit is above that of the grid circuit, it is possible for the former to oscillate only when the sign of the mutual induction is positive.

* These diagrams were given by Prof. C. L. Fortescue during the course of a lecture at the City and Guilds College, South Kensington.

APPENDIX 2.

In this appendix the effect of the difference between the values of the natural frequency of the anode and grid circuits on the value of the mutual induction required to maintain an oscillation in the anode circuit, is shown.

For a simple "tuned-anode" oscillator where the natural frequency of the grid coil is much above that of the anode circuit, the sign of the mutual induction necessary to maintain the oscillation is negative. As the frequency of the anode circuit is raised (by reducing the value of the anode capacity), *i.e.*, as the anode circuit is brought nearer to the natural frequency of the grid coil, the value of the mutual induction required is seen from the formula—

$$M = \frac{RR_aC}{m} - \frac{L}{m}\,*$$

to be reduced. If the capacity of the oscillatory circuit is still further reduced so that the natural frequency of the grid coil is now less than that of the anode circuit, the sign of the mutual induction required to maintain the oscillation is now positive (see above). Further reduction of the capacity must therefore require an increased value for the mutual induction in order that the expression $M = f(C)$ may be continuous. [$f(C)$ denotes "function C."]

Hence when the natural frequency of the grid coil is below that of the anode circuit, the lower the frequency of the latter the less the value of the mutual induction required to maintain that circuit in oscillation.

* In the above formula—

M = Mutual induction between the anode and grid circuits.
R = Resistance of the anode circuit.
C = Capacity of the anode circuit.
L = Inductance of the anode circuit.
R_a = Resistance of the valve.
m = Amplification factor of the valve.

The expression gives the condition necessary for a "tuned-anode" oscillator to be just about to oscillate.

Van der Bijl. *Thermionic Vacuum Tube*, p. 275.

A Graphical Method of Amplifier Coupling Design.

By Marcus G. Scroggie, B.Sc.

(Research Department, Burndept Ltd.)

IN considering the correct coupling condenser and grid-leak to use in order to meet any given conditions in a resistance or choke coupled amplifier Fig. 1(a), the accompanying graph is probably the most useful form in which to present the quantities

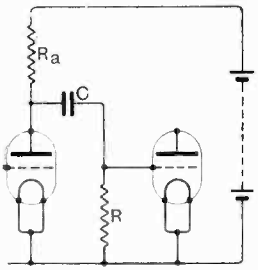


Fig. 1(a).

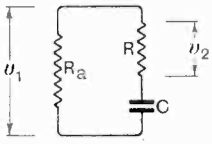


Fig. 1(b).

in question. There are three main points to bear in mind :—

(1) The drop in amplification due to the impedance of the condenser as compared with that of the leak.

(2) The drop in amplification due to the shunting effect of the leak.

(3) The time constant of discharge of the condenser.

(1) is important at the lowest frequencies, while (2) need not be considered at low frequencies, nor at any frequency provided that the leak resistance is large compared with the anode resistance; (3) should not enter into the matter at all were one to keep strictly within the limits of the amplifier, so that the greatest peak voltage of signal or atmospheric never makes the grid positive. In practice such is seldom the case as the output would then be surprisingly low; a few peaks do occasionally overstep the normal limits and produce momentary grid current, and if the charge on the coupling condenser can leak off very rapidly the quality of reproduction suffers only slightly. The time constant of the condenser-leak combination should, then, be as low as possible consistent with (1).

The proportion of signal E.M.F. across the anode resistance (or choke) which is applied to the next grid is, say, p :—

$$p = \frac{v_2}{v_1} = \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$$

where R is the resistance of the grid-leak,
C is the capacity of the coupling condenser,
ω is $2\pi \times$ frequency. (See Fig. 1 (b).)

so $$p = \frac{\omega RC}{\sqrt{\omega^2 C^2 R^2 + 1}}$$

but $CR = T$, the time constant, which is the

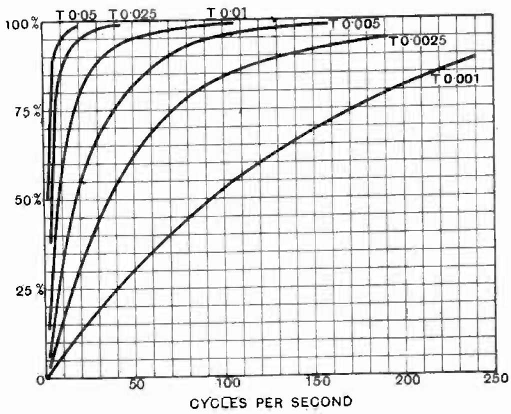


Fig. 2.

time in seconds for the condenser to discharge through R to about 36 per cent. of its original potential, so

$$p = \frac{\omega T}{\sqrt{\omega^2 T^2 + 1}}$$

It is clear that T can be made up of C

and R in any proportion without affecting p, so all that is required is to decide on how small p can be made for some frequency, and read T off from the curve-sheet, Fig. 2, R cannot be made small without conflicting with (2) nor must it be made very large, or the shunting capacity of the grid circuit of the valve, which may be quite large with high magnification valves, will take charge. About 0.5—5 megohms covers most cases; then dividing T by R in megohms gives C in microfarads.

It is extremely doubtful whether even a trained ear can detect less than a 30 per cent. drop in strength of any restricted band of frequencies when mixed with others, and as 32 cycles may be said to constitute the lower limit, a value of T which may be considered satisfactory for a single stage, with the best loud-speakers available, is 0.005, say a 1 megohm leak and an 0.005 microfarad condenser. With two stages of amplification the values of p are, of course, squared, making it necessary to increase T.

The curves give a very clear picture of what is happening to the lower frequencies, and enable one to judge the cut-off effect of any particular coupling without difficulty.

Radio Patent Litigation in America.

By A. H. Morse, A.M.I.E.E., Mem.I.R.E.

ALTHOUGH American patent law was founded on the British, there is now a wide difference between them; and it is characteristic of this difference that it militates against the stability of American trade. The radio trade has furnished a number of proofs of this contention; and the latest is of particular interest.

In the evolution of broadcasting one of the most important factors was the application to valve circuits of the principle of regeneration. In England, this application was patented to C. S. Franklin in 1913; and E. H. Armstrong successfully applied for an American patent on the same invention in the same year. In 1924, however, the U.S. patent office issued another patent on this invention to Lee de Forest, who successfully claimed 6th August, 1912, as his date "of conception." The Armstrong interests have naturally availed themselves of recourse to the Courts in an endeavour to maintain their position; but now it is reported that they will fight no more. In view of the fact that for years the Armstrong invention was used in almost every radio receiver made in America, and that enormous sums were paid in royalties therefor, it will be seen that a very complicated situation has now arisen; and the complications are so numerous and involved, that the parties most interested can hardly know where they stand.

Had the Armstrong patent stood, "regeneration" would have come into the "public domain" in America in October, 1931; whereas, in the ordinary course, the proprietors of the De Forest patent will now have a legal monopoly of regeneration until September, 1941. By virtue of the patent-pooling agreement which is the basis of the Radio Corporation of America, that Corporation seems unlikely to be seriously affected by the changed situation; in fact, it may derive great benefit from the ten years' extension of its monopoly of regeneration. On the other hand, it may find itself confronted in all its fields of activity by a competitor very much strengthened by the ascendancy of De Forest over Armstrong; for at the aforesaid "date of conception" De Forest was in the employ of the Federal Telegraph Company of California, who, therefore, under a provision of American patent law, have what are known as "shop rights" to the invention in question. As is well-known, the Federal Co. has been the Radio Corporation's greatest competitor; and it has recently conveyed to the Mackay cable interests all its rights in the communication field.

In the circumstances, one can only speculate on all the results of the changed situation; but one may be certain that it will lead to much litigation over those royalties which may now be claimed to have been paid to the wrong party. And it is just as well, perhaps, for the British radio trade that there *are* differences between patent law and practice in Britain and America.

Wave Propagation and the Weather.

By F. Charman.

IN the issue of *E.W. & W.E.* for December, 1925, Mr. S. K. Lewer showed how some very interesting research in wave-propagation may be carried out with the aid of a simple receiver only, and reproduced some very interesting curves which are the outcome of his work. For some considerable time the writer carried out some similar experiments, not, however, with the object of determining the causes of seasonal variations in the signal strength of distant stations, but in an endeavour to trace some relation between the daily variations superimposed on the seasonal changes and the meteorological conditions at the receiver. In this article a description will be given of the methods employed, followed by an account of the results obtained, and finally, some attempt will be made to explain the phenomena observed.

The obvious line of attack is to obtain a station at some large distance from the receiver, and to plot daily the field strength at the receiver alongside the barometric changes, noting as we proceed any peculiarities of the weather. Now, provided we have a good receiver, say an efficient detector followed by one stage of note-magnification, or a superheterodyne, it is fairly easy to "obtain" a station "A" at a large distance, and it is possible with a little care to plot the field strength coefficient to within an accuracy of about 10 per cent., but on the following day, when we go to take observations on station "A," it will perhaps not be working, and in its place we shall have another station in some more or less remote part of the globe, and radiating different energy. Now this state of affairs is not easily overcome, the only apparent means of escape being to arrange a schedule with the operator at the other end, which will be seen to be difficult when it is considered that the tests are likely to extend over years and daily figures are required.

The writer, therefore, before embarking on the tests proper, made a survey of the ether lasting over two to three months, in order to find out which part of the globe was most likely to provide a station whose daily appearance on the ether was a high probability, and finally evolved a scheme whereby the observations could be made on any one of a collection of stations and the results reduced to one of them. This overcame the difficulty mentioned above. It was found that the amateurs of New Zealand were the most reliable, particularly one, Z2AC, but even in this case it was seldom possible to hear the same station daily over any long period. It would appear on first consideration that the U.S.A. would offer the best possibilities, but an examination of the log showed that the American stations were very irregular in their appearance. It was decided to plot the more commonly heard New Zealand stations, and also to plot a curve of the average audibility of the U.S.A., obtained from the whole log daily.

During the year in which the experiments to be described were made great increase was made in the use of the shorter wavelengths, and now it would be only necessary, for the purpose of the experiments described here, to pick on a steady commercial station, many of which are now working continually on short waves.

The tests have so far been limited to the band of wavelengths, between 30 and 45 metres, as it was decided to deal with other wavelengths after something had been found of this one band. Reception has been carried out at the time of maximum audibility on the band, about two hours after sunrise, care being taken to avoid the sudden dip in strength which was found to occur every day in connection with sunrise. Thus the time of reception varies with the season, being about 06.00 G.M.T. in the summer, and falling to 08.30 in the winter.

The signal strengths noted were plotted in the well-known "R" code, against time, the barometric pressure being plotted alongside for comparison, and the whole operation repeated daily. The "R" code is very convenient for this purpose, since, being a logarithmic function of the field strength, it is capable of embracing wide limits within a small space.

The receiver employed consisted of an oscillating detector valve followed by one stage of low-frequency amplification, the collector being a small aerial, loosely coupled to the receiver. As a check on the receiver and on the operator's ear, a standard signal was measured daily, this being induced locally into the aerial system. The measurement was performed by means of the usual shunt resistance method. A fixed resistance was inserted in the anode circuit of the amplifier, and the telephones were tapped across this resistance. This method has several disadvantages, the chief being the difficulty in keeping a constant impedance in the anode circuit, but as great accuracy is not called for in these experiments, it was chosen as being most convenient.

Fig. 1 shows the result of the first three months' work. In this section 4 is the actual graph obtained for Station Z2AC, whilst sections 1, 2 and 3 cover other stations in New Zealand and Australia. Section 7 is a rough graph, plotted from the general appearance of the logbook, for east coast stations in districts 1, 2 and 3 of U.S.A. Section 6 shows the barometric variations, and section 8 represents the limiting effect of static upon reception. The static has been plotted with respect to other characteristics than its strength alone, and so, for example, static of strength R^4 would be plotted as R^2 or R^3 if it were only intermittent, but as R^5 if it were continual. In general, when an R^4 signal is the weakest that can be easily read through the static, the static is plotted as R^4. In section 5 a graph has been plotted to represent New Zealand. It was noticed that certain New Zealand stations, in particular Z2XA, always bore a constant signal strength ratio to Z2AC, and by comparing these other stations, the audibility curve for Z2AC has been filled in for dates when this station itself was not heard, and by carrying out this principle throughout the whole period of the tests, a very complete curve for New Zealand has been obtained. This method is, of course, only applicable to a number of stations located within a small area, and it would not do to build

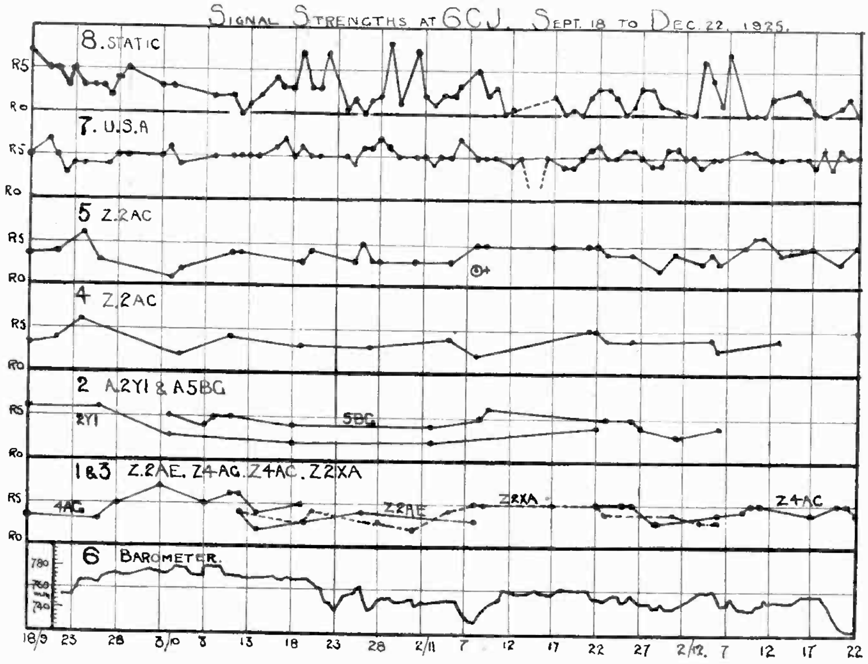


Fig. 1. *Curves obtained for the first three months.*

up a curve for Z2AC with the help of another station in, say, Brazil. It has been ascertained that the key station, Z2AC, has not altered its radiated power to any appreciable extent during the time of the measurements.

Fig. 2 shows a set of graphs completing a period of ten months, from September, 1925, to June, 1926. Australia has been plotted separately where possible, as it was noticed that signals from there differed from those coming from New Zealand. It was observed that signals from Brazil behaved in the same manner as those from New Zealand, but observations on Brazilian stations were not sufficiently numerous to allow of a good graph being plotted. The point is mentioned, however, as interesting in connection with certain indications having been obtained that the effect of the weather is selective with regard to direction.

The graphs thus obtained were very instructive, not because they yielded any very definite results but because they

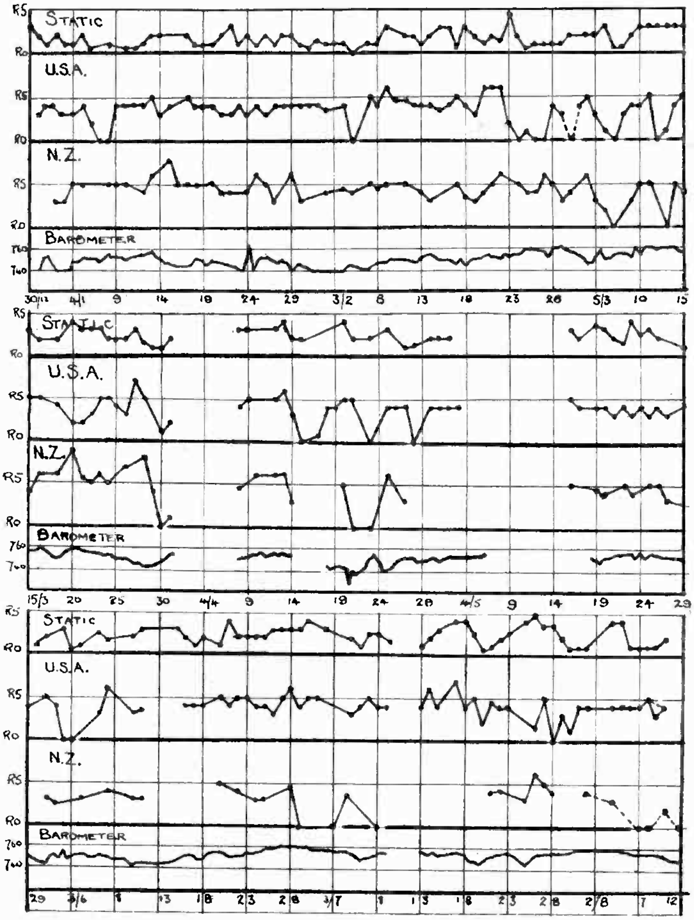


Fig. 2. *Extension of Fig. 1 to complete one year.*

indicated definite lines upon which to work, which have been followed up by the writer in the later periods of the tests. However, let us look at the graphs.

The first thing which is apparent is that whenever there is a sudden change in the pressure, the signal strength of all districts is affected, the effect sometimes preceding, and sometimes succeeding the pressure change. This in itself justifies the continuation of the work, as it indicates the existence of some relationship between the two. As an example, we will take the reception on and around 24th January. At this time it will be seen that the barometer had an exciting time, dropped fairly rapidly and rose very quickly again within a few hours. Signals from New Zealand, and also those from Brazil, rose to a very high value, and then dropped steadily. Those from the U.S.A., however, were not affected to any extent, except for a few hours, as shown by the log book. Now signals from New Zealand and Brazil come to England over practically the same great circle, whilst those from U.S.A. arrive by a path almost at right angles to that of the former, if we may assume that they travel by the shortest route, as is fairly reasonable. This point of the signals from the U.S.A. differing in behaviour from those from the south is well exemplified throughout the graphs, although there are cases where both are affected in the same manner. This would appear to indicate that some particular weather condition in the south, which might only show at the receiver as a slight change in the barometric pressure, might affect the signals crossing that area, whilst those arriving from the west without crossing that area would be unharmed. It then becomes obvious that it behoves us to look at other barometers that our own if we expect to learn the mechanism of the effects. The need became apparent to the writer soon after the beginning of the tests, for the reason shown above, and because many little effects were noticed which could not easily be drawn into the graphs. Accordingly, daily pressure charts were studied in conjunction with the log book.

That these effects are often local is shown by the fact that, in general, signals from both directions are affected at the same time, even if not in the same manner. A second point to be noted from the graphs is that a good settled barometer, a rare occurrence in this country, results in good strength of signals. If the weather did not play havoc with our short-wave signals, they might at least be good over long distances.

From a comparison of the graphs with the weather notes in the log book, it appears that the type of weather which favours "DX" in the winter is the dull, cold weather, and not the mild changeable sort, which produces more static than colder weather. In particular, there are always good signals on hand when snowy weather prevails. In the summer, it is the fine dry weather which is to be preferred, abnormally wet weather having a bad effect on signal strength. In general, then, weather which is in season is to be preferred, whilst weather out of season is not beneficial.

A little insight into the subject having thus been gained, a study of daily doses of isobars was commenced in early 1926, and this method revealed very much more than the former, as it might well be expected to do. Before a discussion of the results is attempted, however, it would be well to consider some modern ideas on the subject of wave propagation.

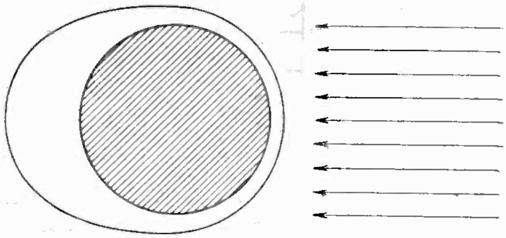


Fig. 3. *Showing changes in ionisation of the atmosphere between day and night.*

We have an earth, and surrounding it an atmosphere which is exposed to various celestial radiations, such as the ultra-violet waves from the sun, the result being that there is a tendency for the gases of the atmosphere to become ionised. By ionisation, is meant a dissociation of the molecules of the gases into parts bearing equal and opposite electric charges. There is always a tendency for these to recombine, but provided the ionising force remains constant, there will remain an equilibrium. The ionisation in the atmosphere varies considerably from place to place. At the surface of the earth there is very little, as the pressure of the superincumbent air is rather great, and also the ionising force is weak, the ionising radiations suffering considerable absorption during their passage through the atmosphere. As we recede from the surface of the earth the intensity of ionisation gradually increases, as the pressure becomes less and the ionising force greater, but at great heights there is so little gas that however great the ionising force the intensity of ionisation cannot become very large. Hence there is a point some distance above the surface where the intensity of ionisation is greater than at any height above or any depth below.

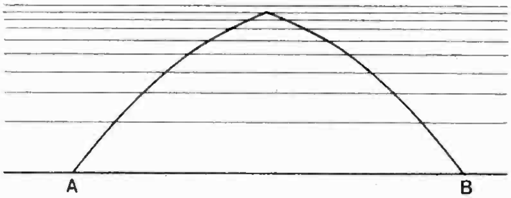


Fig. 4. *A wave group travelling through an electrically non-uniform medium.*

The effect of this ionisation as far as wireless waves are concerned is that ionised gas is a conductor of electricity, and that as a consequence wireless waves travel at a greater velocity in the conducting portions of the atmosphere than at the surface of the earth.

Now, if we imagine a wave group travelling off the earth at an angle to the surface, we shall have to give the waves a different velocity for each height as the group travels upwards. The result of this is that the track of the wave group will be bent toward the earth. Waves radiated at a fairly big angle will suffer this bending, or refraction, but will finally escape through the area of maximum ionisation or conductivity, but other waves sent off at a shallower angle will not be so fortunate, but will be bent toward the earth so much that they will eventually return to it, as shown in Fig. 4 where is shown the path of a wave group in a medium of increasing electrical density such as our atmosphere. The wave group travels upward and is gradually bent downward until its direction is in what is known as the critical angle, at which the denser medium refuses to transmit the waves, but totally reflects them. After reflection the wave group unbends itself, so to speak, and arrives back at the surface of the earth safe and sound, having suffered very little absorption in transit, the actual angle at which the waves must be projected to just achieve reflection is much less for short wavelengths than that shown in Fig. 4, and the shorter the wavelength, the less is this angle. A short wave will, for this reason, span a much greater distance in one reflection than a long one.* The effect of the wave groups returning to earth will present to observers situated at *A* and *B* exactly the same effect as would pure reflection, and the writer proposes here to consider the effect as such, for the purpose of simplicity. It can be shown that such treatment is legal, provided we keep within certain limitations. For the purpose of this article it will be sufficient to use the simpler treatment.

The sun's light is not present at the side of the earth which is in shadow, and consequently there will be a destruction of the equilibrium between the ionised particles and the ionising force, so that as the atmosphere is carried into the shadow with the advent of night time, de-ionisation sets in. Some ionising factor still remains, however, so that there still remains a conducting portion of the atmosphere, and the effect of the arrival of night may be regarded as a rising of the layers of conductivity to some much greater height, as represented in Fig. 3, where the line around the earth represents a contour of the maximum ionisation. Various figures are given for the two heights, which vary of course with the latitudes and the seasons as the amount of sunlight received varies; from 50 to 100 miles in the daytime and at night time of the order of 150 miles.

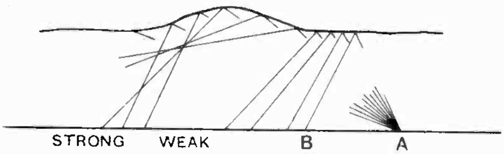


Fig. 5. *Reflection from a concave Heaviside layer.*

Now, considering the refracting medium as a single reflecting layer, suppose that there are undulations in this layer, as shown in Figs. 5 and 6, where is shown the paths of wave groups radiated at various angles from *A* and reflected down again to earth. It will be seen in Fig. 5, where the undulation is concave to the

* See *Q.S.T.*, October, 1925.

earth, that as we recede from A, we shall at first be in the well-known blind area of short waves, where no waves arrive from above because such would require to be reflected from the layer above at an angle greater than the critical angle, and where the only signal received is the badly attenuated direct wave along the surface. As we travel, the signals become weaker until they are inaudible. At some further distance, however, signals once more become audible, owing to the arrival of the downcoming waves. This point is represented by B in Fig. 5, but will not, in general, be very well defined, and the distance AB will depend on the wavelength and the height of the reflecting layer. In any case, waves of length greater than about 100 metres do not exhibit the blind area, since the ground wave arrives at B without experiencing sufficient absorption to render it inaudible, unless the power radiated from A is extremely small.

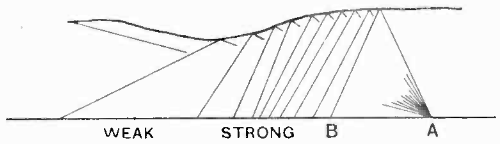


Fig. 6. *Reflection from a convex Heaviside layer.*

The effect of the concave disturbance will be that of bringing the signals from A to a focus, concentrating a good deal of the energy towards one point, so that as we recede somewhat farther from B than A, we shall find another area where signals are weak or inaudible. Still farther out we shall find a point where the energy is concentrated, and the signals are strong. It will be noticed that in the particular circumstances where the focus of the disturbance is at the surface of the earth we shall have a case of freak reception of very strong signals from A, which may be hundreds of miles distant.

In the case of Fig. 6, where the disturbance is convex, we shall find as we recede from A the usual blind area due to the signals experiencing a critical angle of reflection. From B onwards the signals will become increasingly stronger, the waves being thrown back from the sloping shelf, the first portion of the disturbance. Further on we come to a point where the signals become very weak again, having been brought to a virtual focus above the reflecting layer. The downward hump is acting as a screen or barrier to the waves. These two cases are the two simplest, and the effect of the waves which are reflected upward from the ground has not been shown. They will tend to complicate matters somewhat, but the total effect will be of the same nature as has already been shown for one reflection only.

Generalising the idea of irregularities in the reflecting layer, it may be said that a layer which slopes down towards the earth in the direction of wave propagation will tend to throw the wave back, and prevent it arriving at points beyond the region of the disturbance. Thus a disturbance in the nature of a downward hump will cast a real shadow behind it and the reverse before it.

From a study of the pressure distributions about the British Isles in conjunction with the logging of signals on 45 metres, the writer has come to the conclusion that effects of such a nature as have just been described exist in connection with cyclones and anti-cyclones and other distributions of barometric pressure. By daily comparing signals from different directions and comparing the passages of cyclones and anti-cyclones, it became apparent that signals were behaving in such a manner as would be expected were the reflecting layer higher than normal where the barometric pressure is high, and lower than normal where the pressure is lower than normal. Thus, for example, suppose that we have an area of low pressure over the North Sea, and an anti-cyclone off the West of Ireland. In this case we should expect, according to the above description, signals from the U.S.A. to be strong in England whilst on the Continent east of the depression they would be weak. Conversely, signals from the east will be weak. A very good example of this particular case has been noted at the time of writing. On the evening of 26th September, 1926, a fairly wide depression was centred off the east of England, and as the writer's receiver was practically beneath the centre, signals were not particularly good from any direction. By the following morning, however, an anti-cyclone had moved in to the west of Ireland, and the cyclone had moved slightly eastwards, the resultant field having a steep pressure gradient from west to east: on this evening, 27th September, signals from the U.S.A. were received at enormous strength, the writer's station then being in the position marked "strong" in Fig. 6. At the same time, signals from the east had almost completely faded away, the only readable station being a German commercial station which was audible at about a hundredth of its normal strength. By the following morning conditions had not changed much, and a low power station in California was copied with ease, but by the evening the gradient west to east had become practically zero, and U.S.A. has returned to normal strength.

The type of field which is most common in this country consists of a high pressure area off the south-west, with a stream of cyclones travelling in the direction of the Gulf Stream to the north-east between Scotland and Iceland, giving a field which is usually favourable for the reception of signals from the south and south-west. Sometimes a cyclone runs off this track and crosses the British Isles and on such occasions as this the theory is supported very well indeed by observations. In the more general case, however, observations are often rendered difficult of interpretation because of the complicated nature of the field of pressure. It has been noticed that signals from Brazil and New Zealand are very strong when there is a steep pressure gradient in a north-westerly direction, such as when snowy weather is about.

Again, if we consider the sunset and sunrise and their effect on the reflecting layer we obtain some very interesting facts. It has been pointed out that at sunset a de-ionisation sets in and if we transfer the idea of a gradual de-ionisation as the earth turns round, to the convenient form, we have a gradual rising of the reflecting layer, and the net effect will be one of a slope in the layer travelling round the earth. The gradient will be upwards from daylight in the west to darkness in the east. Similarly at sunrise we shall have a slope in the reverse direction. Now applying the ideas of reflection of the waves from these sloping surfaces, we see that as sunset approaches, signals from the east will show a drop below daytime strength, followed by a rise to a high value as the layer passes overhead and throws extra energy back. After the slope has passed over, and darkness has set in, signals will settle down to their normal night time strength.

Considering the curve paths of signals in connection with these effects, we see that the real effect of the "sloping layer" is one of bending the end of the curved path, and as waves of different frequencies follow paths of different curvatures, it is to be expected that the throwing back of the waves will vary with the wavelength. This is evidenced by the fact that on the longer wavelengths the sunset and sunrise effects take place in the darkness, whilst on short wavelengths the effects are noticed before sunset and after sunrise. On 45 metres the rise in signal strength takes place at about an hour before sunset, whilst on 20 metres it happens much earlier.

If it so happens that sunrise here coincides with sunset at some other given point, transmission and reception between these two points will be very easy at such times. Thus in September, New Zealand is heard well here apart from local fluctuations, because at this time of the year the two phenomena of sunset and sunrise occur together here and in New Zealand.

The cause of the relation between pressure and intensity of ionisation has yet to be explained, and for this an intimate knowledge of the structure of the cyclone and the anti-cyclone is necessary. The disturbances of the atmosphere associated with these is known to extend to great heights, heights of the same order as is given for the Heaviside layer, the layer of maximum ionisation. The increased intensity of ionisation for a given height which the writer believes to exist over a cyclone may be due to an actual movement downwards of some of the air in high regions with a thinning out of the air in the regions previously occupied by them. Such a change would allow the air to maintain the same degree of ionisation as it would at its normal height. In connection with this, it is interesting to note that at the lower limit of the stratosphere, the region of steady temperature is lower where the pressure is low than where it is high. Thus the tropopause, the lower limit of the stratosphere, presents a similar distribution to the layer shown in Figs. 5 and 6, though its height is of course much less, not exceeding ten miles. A theory of this nature has been put forward by Captain Sinclair.

As a conclusion, one or two amplifications of the ideas outlined in this article may prove interesting. Using the form of the reflecting layer, we can see that the direction of propagation of the signals can be changed slightly by humps in the layer. In Fig. 7 are shown two plans or maps, (A) of a cyclone, and (B) of an anti-cyclone, the circles representing contours of a particular degree of ionisation, and also isobars. Signals from a point A are shown by thick lines, the first dot on each line representing the point of reflection at the layer, and the second dot the point of arrival at the earth.

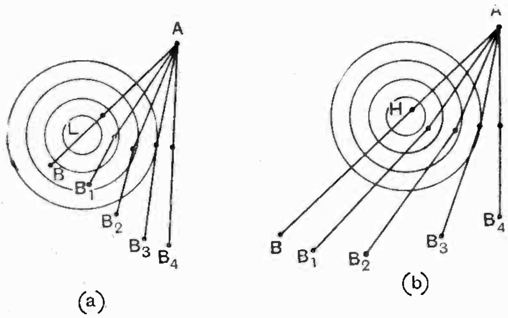


Fig. 7. *Change of direction of a signal passing through a cyclone or anticyclone.*

In each case it will be seen that the wave which passes squarely across the disturbance continues after reflection in the same vertical plane, but those which strike the disturbance obliquely are turned outwards in (A) and inwards in (B), arriving at B_1, B_2, B_3, etc., from the wrong apparent direction with the wrong direction of polarisation, and are no longer travelling in the vertical plane, as defined by A, B, and the point of reflection.

Another point of interest arises in connection with interference of two waves. It is possible for a signal to arrive at the receiver by two routes, particularly so in the light of the preceding paragraph, and as it is not very likely that these two paths will be of equal lengths, it is most probable that the E.M.F.s received will be of differing phases, giving a resultant E.M.F. which may be greater or less than that supplied by signals arriving by only one path. Now if the pressure system, with its attendant changes in the electrical properties of the atmosphere, is in a state of change or motion, the relative lengths of the two signal paths will also be in a state of change, with the result that the phases of the two received E.M.F.s will not be constant. The outcome of this on the resultant E.M.F. is a variation of the received signal strength of the type known as "fading." The same principle, applied to sunset and sunrise, can be made to account for the bad fading of short-wave signals noticed at these times.

The effects discussed, when applied to long distance transmission, can be applied at both ends, or any points in the path of the signals. If fading can be generated at the transmitter by some particular set of conditions it is less likely that there can be an integration of the signals which would otherwise be expected where great distances allow of many possible paths.

In the foregoing is outlined a fairly new theory which is being examined by the writer. It will have been noted that up to the present observations have been confined to one band of wavelengths only, and it is proposed to examine others in the same way. The reason for limitation to one band is not any previous assumption that this particular band would prove more fruitful than others, but simply that the experimental work was nothing more than an attempt to serve some useful purpose whilst being what is known in amateur circles as a "DX merchant." Indications have been received, however, that the phenomena explained are common to the broadcast wavelengths: in fact, it is expected that they will only vary with frequency in degree, in the same manner as day and night effects.

A Radio Signal-Intensity Recorder.

*By B. Saltmarsh (6SF).**

Introduction.

THIS instrument, as its name implies, was designed for the purpose of making a direct record of the intensity or strength of an incoming radio signal, and consequently of showing variations in such intensity.

Everyone who has tried to "reach out" with his radio receiver and has listened for signals from a distant station has, no doubt, noticed that the intensity of the signal is by no means constant. At one moment the signal may be quite strong and then, for no apparent reason, it suddenly dies away, often becoming quite inaudible. This dying away effect is commonly known as "fading," and from time to time various theories have been put forward to account for it.

Present-day Theory on Fading.

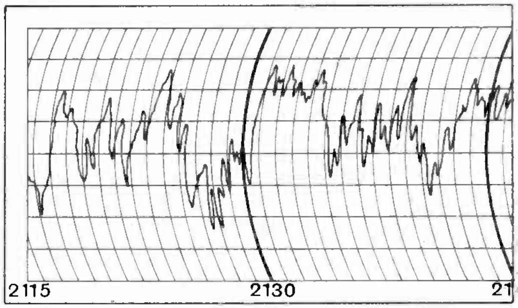
The theory most generally accepted to-day is that every transmitter sends out two waves, one of which travels close to the earth, and is known as the "ground wave," while the other rises through the ether until it meets the Kennelly-Heaviside Layer by which it is turned or deflected back to earth. This is known as the "deflected wave."

Close to the transmitter the ground wave will be the stronger, but at distances of over 90 miles away, the deflected wave comes into operation. This figure—90 miles—is not by any means constant, owing to the fact that the frequency of the wave transmitted governs the angle of deflection to a considerable extent, but it constitutes a very rough average. At this distance the ground wave will have dropped off very much in intensity due to absorption, and the deflected wave may only give rise to a very weak signal by itself, but if it so happens that both the deflected and ground waves arrive at the receiver "in step" then the one will back up the other, and a comparatively strong signal will be the result. Some slight change then takes place in the ether. It may be that the level of the Kennelly-Heaviside Layer has altered at the point where the deflected wave strikes it, causing the angle of deflection to vary slightly, and the two waves to arrive out of step at the receiver. They may get out of step to such an extent that one wave will actually neutralise the other. The result will be that the signal strength will fall off till the two waves once more get into step and help, instead of neutralise, one another.

* Received by the Editor, December, 1926.

Early Tests and Investigations.

This, however, is merely a theoretical explanation and may be no more accurate than the many which have preceded it, and it was seen some years ago that it was a waste of time to theorise on a subject about which practically nothing was known.



A record typical of reception of a broadcast programme from a medium-power station over a distance of 80-100 miles. Note the short-period variations. The vertical lines indicate time. The horizontal lines are merely to facilitate the comparison of records. Only the first half of the record is shown, but is full size.

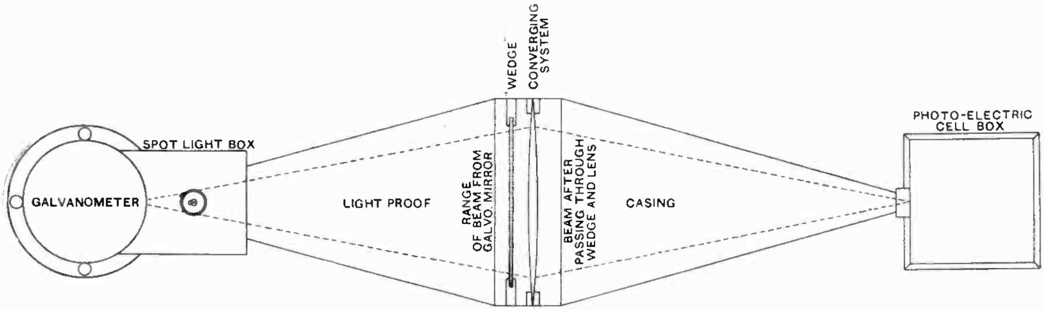
A series of tests was accordingly arranged and carried out both in this country and in America. In these early tests the human ear was the instrument used for detecting variations in the signal strength, the signals chosen being telephonic in preference to telegraphic, owing to their being continuous, and not cut up into the dots and dashes of the Morse code. The human ear, however, is not sensitive to very slight and rapid changes in sound intensity, nor is it able easily to discriminate between such effects as a drop in sound volume on the part of that which is modulating the radio wave, be it orchestra, piano, or voice, and the actual drop in intensity of the carrier wave.

Earlier Recorders.

It was therefore obvious that if the tests were to be of any real value, the human element must be cut out, and the records must be made independently of it. An instrument was designed in America for this purpose,* in which the carrier wave, after suitable amplification and rectification by a stable crystal, actuated a reflecting galvanometer, the beam from which moved over a photographic sheet mounted on a revolving drum. The carrier wave thus drew its own intensity curve, but this instrument, although highly accurate and sensitive, necessitated the work being done in a dark room, and by an expert, while considerable delay was involved before the record was ready for examination owing to the photographic sheet having to be developed.

Another form of recorder in use in America was one in which the rectified carrier wave actuated a pointer galvanometer, the movements of the pointer being traced by hand by the operator on a revolving drum. This method has the advantage of not requiring expert operation, and is free from the delay necessitated by photographic processes, but it is less accurate than the photographic recorder, and is naturally more tiring to work.

In the instrument designed by the writer, the aim has been to eliminate both the human element and the photographic process, and yet to retain accuracy and simplicity of operation. The recorder is very simple to work, and does not require a dark room. It also has the advantage that the record is made in the open, so that it can be examined while it is being made. Therefore, if the operator is wearing phones, he can mark the record when he hears an atmospheric discharge or jamming from another station interfering with his signal, and when examining his record, he will be able to see if these occurrences appear to have had an adverse effect on his signal, or otherwise.



Plan showing general lay-out of apparatus. The distance between the lens and the aperture in the photo-electric cell box is such that all the light passing through the wedge is converged by the lens to fall on the aperture in the box. This distance having once been ascertained will not need alteration.

The Signal-Intensity Recorder.

The incoming carrier wave after passing through a sufficient number of stages of high-frequency amplification to bring it up to a suitable strength, is rectified by a stable crystal. The rectified current then actuates a reflecting galvanometer, and the beam from this galvanometer moves over what is optically known as a " wedge." This consists of a strip of coloured glass, the colouring matter being so arranged that the strip is almost opaque at one end, while at the other it is quite lightly tinted, the colour being very carefully graduated. From this it will easily be seen that if the spot-light, which supplies the light to the mirror of the galvanometer, is kept steady, and if the beam

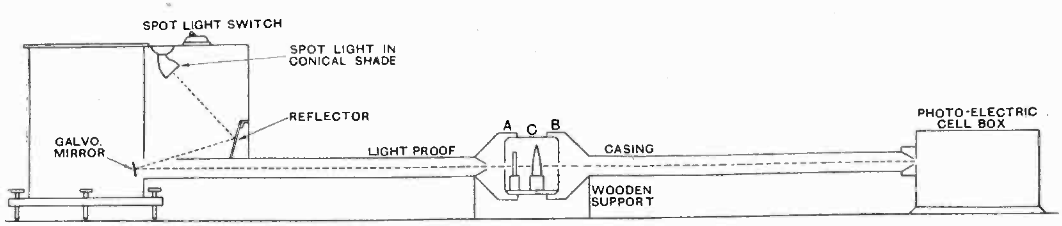
* See *Proceedings of the Institute of Radio Engineers*, Vol. 10, No. 2, April, 1924, "Short Period Variations in Radio Reception," G. W. Pickard.

from the mirror travels backwards and forwards over this wedge, then the amount of light which passes *through* the wedge will be governed by the density of the wedge at the point where the beam strikes it, and will be proportional to the deflection of the galvanometer. Thus, when the signal is coming in at full strength, and the galvanometer is at its greatest deflection, the beam is focussed upon the lightly tinted end of the wedge, and the maximum amount of light passes through; but as the signal strength falls off the deflection of the galvanometer diminishes, and the beam moves over the wedge towards the more deeply tinted end, and the nearer to that end it gets, the less will be the amount of light which penetrates through the wedge. From this it will be seen that the quantity of light passing through the wedge varies directly as the intensity of the carrier wave.

Behind this wedge—*i.e.*, on the side opposite to the galvanometer—a condensing lens is placed, forming a converging system, its object being to focus the light passing through any position on the wedge on to one point. At this point a photo-electric cell is mounted. Such a cell, as is probably known, is highly sensitive to minute variations in the amount of light focussed upon it, its resistance varying very considerably for a very small change of light.

Now, since the photo-electric cell is governed by the quantity of light passing through the wedge, this quantity being directly controlled by the deflection of the galvanometer, which, in its turn, is controlled by the incoming signal, it is obvious that the resistance of the cell and the consequent flow of current is going to vary strictly in proportion to the variations in the intensity of the signal.

The current controlled by the photo electric cell then passes through several stages of low-frequency amplification and then actuates an electro-magnetically operated pen. This moves over a rotating drum carrying specially ruled paper and makes a graphical record of the strength of the incoming signal. The drum, which is 15 inches round, rotates once an hour, and as the paper on it is divided into 60 equal sections, each section representing one minute of time, the pen travels over a horizontal distance of a quarter of an inch per minute. This speed of working gives quite a nice open record, and enables the smaller variations to be clearly shown. When two or three such records are made at the same time of the same signal, but at different receiving stations, it is as well to have the records as open as possible to enable more accurate comparisons to be made.



Side view of apparatus. Note special arrangement of spot-light. The light-proof casing may be detached from the box containing the wedge and lens at A and B, as shown. The wedge and lens are so mounted that they may be slid into and out of C, and their distance from each other is thus made adjustable.

Since the photo-electric cell is so sensitive to changes of light it has been found advisable to enclose the apparatus from the galvanometer to the cell in a light-proof box, as shown in the accompanying illustrations. If this were not done, the passage of the sun behind a cloud or, as is more likely in this country, the arrival of the sun from behind a cloud, would be quite sufficient to spoil a record, and it has been found easier to make the instruments light-proof than to keep them under the influence of a steady light.

Mathematics for Wireless Amateurs.

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

(*Continued from page 691 of November issue.*)

PART IV (CONTINUED).

9. Combinations of Impedance.

(A) *Series.*

If any number of impedances

$$z_1 = R_1 + jX_1$$
$$z_2 = R_2 + jX_2 \text{ etc., etc.}$$

are connected in series as shown in Fig. 49, *i.e.*, so that the same current flows through each of them, then the application of

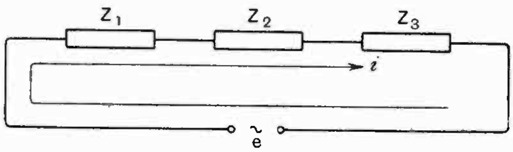


Fig. 49.

Kirchhoff's second law in its vector form will lead directly to the equation

$$(z_1 + z_2 + z_3 + \text{etc.})\,\mathbf{i} = \mathbf{e}$$

i.e., $\mathbf{i} = \mathbf{e}/(z_1 + z_2 + z_3 + \text{etc.}) = \mathbf{e}/z$

where $z = z_1 + z_2 + z_3$ etc.

$$= (R_1 + R_2 + R_3 + \text{etc.}) + j(X_1 + X_2 + X_3 + \text{etc.}).$$

In other words the separate impedances are equivalent to a single impedance the components of which are given by the addition of the components of the individual impedances. The impedance operators are added together in accordance with the rules for the addition of such operators. If the individual impedances be represented as vectors, as explained in paragraph 7 (November) then the vector representing the single equivalent impedance is the vector sum of the separate vectors, as in Fig. 50.

(B) *Parallel.*

Consider first the case of two impedances in parallel, as shown in Fig. 51. Applying Kirchhoff's second law to the circuits *ABCDFA* and *ABCEFA* in succession gives the equations

$$\mathbf{e} - \mathbf{i}_1 z_1 = 0 \text{ or } \mathbf{i}_1 = \mathbf{e}/z_1$$
$$\mathbf{e} - \mathbf{i}_2 z_2 = 0 \text{ or } \mathbf{i}_2 = \mathbf{e}/z_2$$

Further, applying Kirchhoff's first law to the point *C*

$$\mathbf{i} = \mathbf{i}_1 + \mathbf{i}_2$$

Therefore

$$\mathbf{i} = \frac{\mathbf{e}}{z_1} + \frac{\mathbf{e}}{z_2} = \mathbf{e}\left(\frac{1}{z_1} + \frac{1}{z_2}\right) = \frac{\mathbf{e}}{z}$$

where

$$\frac{1}{z} = \frac{1}{z_1} + \frac{1}{z_2}$$

Thus the two impedances z_1 and z_2 in parallel are equivalent to a single impedance related as above to the individual impedances. The result can obviously be extended to the case of any number of impedances in parallel giving

$$\frac{1}{z} = \frac{1}{z_1} + \frac{1}{z_2} + \frac{1}{z_3} + \frac{1}{z_4} \text{ etc., etc.}$$

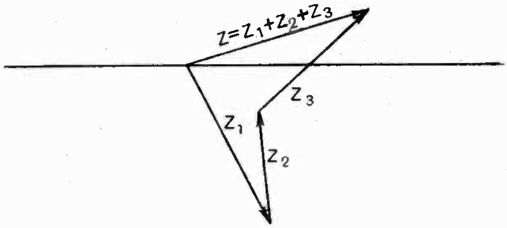


Fig. 50.

10. Graphical Representation of Impedances in Parallel.

Parallel combinations of impedances play a very large part in the technique of wireless communication, having interesting and valuable properties which arise from the complex reciprocal relationships described above. These properties are most easily apprehended in graphical form, and it is, therefore, proposed to describe some simple constructions. One of these, corresponding to the general case, has probably not been published in this country before.

(A) *Impedances of Equal Phase Angle.*

If two impedances are of equal phase angle, *i.e.*,

$$z_1 = Z_1\epsilon^{j\theta}$$
$$z_2 = Z_2\epsilon^{j\theta}$$

the impedance equivalent to these in parallel can be drawn as in Fig. 52*a*. AC is any

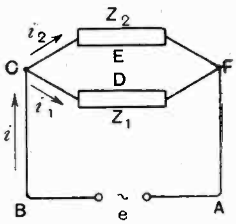


Fig. 51.

convenient distance. The rest of the construction is obvious. The proof is as follows:—

$$\frac{z}{z_1} = \frac{Z\epsilon^{j\theta}}{Z_1\epsilon^{j\theta}} = \frac{Z}{Z_1} = \frac{BC}{AC}$$

and similarly

$$\frac{z}{z_2} = \frac{AB}{AC}$$

Therefore

$$\frac{z}{z_1} + \frac{z}{z_2} = \frac{AB}{AC} + \frac{BC}{AC} = \frac{AC}{AC} = 1$$

i.e.,

$$\frac{1}{z} = \frac{1}{z_1} + \frac{1}{z_2}$$

Notice that the equivalent impedance is of the same phase angle as the component impedances and necessarily less in magnitude than either.

Important special cases are

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

for two resistances in parallel, and

$$\frac{1}{j\omega L} = \frac{1}{j\omega L_1} + \frac{1}{j\omega L_2} \; i.e. \; \frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$$

for pure inductances in parallel (provided there is no mutual inductance). (*Note* that since the impedance of a condenser of capacity C is $1/j\omega C$, as already shown,

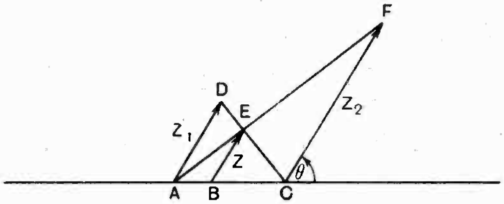


Fig. 52a.

capacities in parallel combine by simple addition, *i.e.*,

$$C = C_1 + C_2$$

For condensers in series, on the other hand, we have by the addition of the separate impedances an equivalent single capacity given by

$$\frac{1}{j\omega C} = \frac{1}{j\omega C_1} + \frac{1}{j\omega C_2} \; i.e. \; \frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

a relationship to which the above construction applies. This apparent reversal of the laws of series and parallel combination in the case of capacities is simply due to the fact that the impedance of a condenser is already in the form of a reciprocal).

(B) *Impedances of Opposite Phase Angle.*

i.e.,
$$z_1 = Z_1\epsilon^{j\theta}$$
$$z_2 = Z_2\epsilon^{j(\theta+\pi)} = -Z_2\epsilon^{j\theta}$$

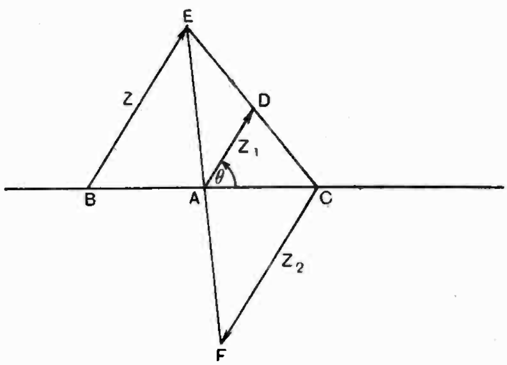


Fig. 52b.

The construction for this case is shown in Fig. 52*b*, and is carried out in exactly the same way as for (A). The proof also is the same except that we shall now have

$$\frac{z}{z_2} = -\frac{Z_1}{Z_2} = -\frac{AB}{AC}$$

which will lead to

$$\frac{z}{z_1} + \frac{z}{z_2} = \frac{CB - AB}{AC} = \frac{AC}{AC} = 1$$

from which the desired result follows.

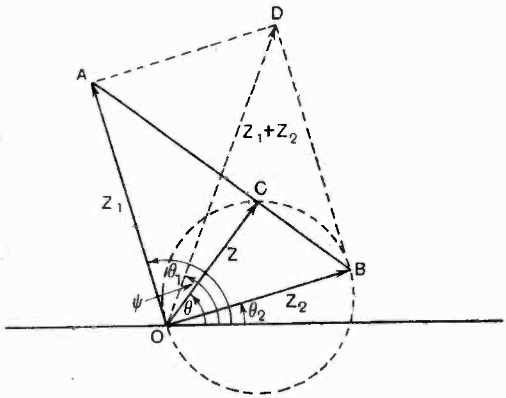


Fig. 53.

A very important special case of this is given by a pure capacity and a pure inductance in parallel. It will be found that if the impedances of these are equal in magnitude, *i.e.*, if $\omega L = 1/\omega C$ the lines CE and FE become parallel, *i.e.*, E goes to infinity and the equivalent impedance is infinite. The case is never realised in practice, of course, since it is impossible to get either a capacity or an inductance without some small resistance term, which limits the resultant impedance, but the construction throws some light on the behaviour of such a combination.

Both of the above cases (equal and opposite phase angle) have already been described by the writer in a slightly less general form in this journal (December, 1924), and readers are advised to refer to this.

(c) *Phase Angles differing by Ninety Degrees.*

For instance, a pure resistance and a pure reactance, or more generally,

$$z_1 = Z_1 \epsilon^{j\theta_1}$$
$$z_2 = Z_2 \epsilon^{j\theta_2} = Z_2 \epsilon^{(j\theta_1 - \pi/2)}$$

Let OA and OB in Fig. 53 represent z_1 and z_2 respectively. Join AB. Draw OC perpendicular to BA. Then OC represents z, the impedance equivalent to z_1 and z_2 in parallel. For proof, complete the rectangle as shown by the dotted lines. Then OD represents $z_1 + z_2$, in magnitude and phase.

Now,

$$\frac{z_1}{z} = \frac{Z_1\epsilon^{j\theta_1}}{Z\epsilon^{j\theta}} = \frac{Z_1}{Z}\epsilon^{j(\theta_1-\theta)} = \frac{OA}{OC}\epsilon^{j(\theta_1-\theta)}$$

Also

$$\frac{z_1+z_2}{z_2} = \frac{OD\epsilon^{j\psi}}{OB\epsilon^{j\theta_2}} = \frac{OD}{OB}\epsilon^{j(\psi-\theta_2)}$$

But the triangles OCA and OBD are similar. Therefore,

$$\frac{OD}{OB} = \frac{OA}{OC}$$

and

$$(\psi - \theta_2) = B\hat{O}D = C\hat{O}A = (\theta_1 - \theta)$$

so that

$$\frac{z_1 + z_2}{z_2} = \frac{OA}{OC}\epsilon^{j(\theta_1-\theta)} = \frac{z_1}{z}$$

i.e.,

$$\frac{1}{z} = \frac{z_1+z_2}{z_2 z_2} = \frac{1}{z_1} + \frac{1}{z_2}$$

Notice further that if OB remains constant while OA varies in magnitude the locus of C is a circle on AB as diameter (since $O\hat{C}B$ is a right angle for all values of OA).

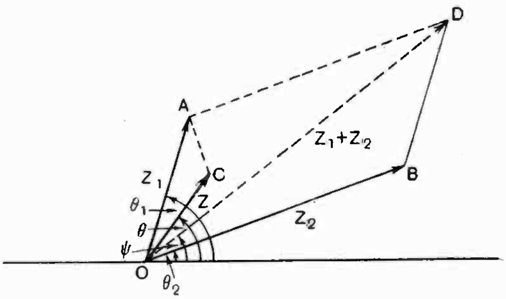


Fig. 54.

This construction also was described, in a slightly less general form and with a less satisfactory proof, in the article referred to above, in which a practical application of the construction to a "wireless" problem was also given.

(D) *A general Construction for any Two Impedances in Parallel.*

The following construction, which the writer ought to have discovered for himself as an obvious generalisation of the foregoing special case, is taken from the *Wechselstromtechnik* of Dr. Arnold.

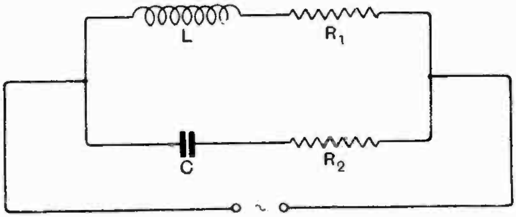


Fig. 55.

If OA and OB in Fig. 54 represent the impedances z_1 and z_2, complete the parallelogram $OADB$, and draw the triangle OCA similar to OBD. Then OC represents z, the impedance equivalent to z_1 and z_2 in parallel. The proof is word for word as in (C) above.

It would be easy to multiply examples of the application of the above rules for the combination of impedances and of the above graphical constructions but space cannot be given to this in a series which is intended to deal more with general technique than with individual problems. Various articles which have appeared in this journal will supply illustrative and useful examples —for instance that by W. A. Barclay in the issue for February, 1927. One peculiar case may, however, be brought to the notice of readers. If in the circuit shown in Fig. 55 $R_1 = R_2 = R$ and $L = CR^2$, then it can be shown that with respect to the external E.M.F. $e = \hat{e} \sin \omega t$ the circuit will behave like a non-inductive resistance at all frequencies. It will be a useful exercise to demonstrate this and to determine the magnitude of the resistance.

11. Coupled Circuits.

(A) *Mutual Inductance.*

Two inductive circuits so disposed that the magnetic field produced by a current in either is linked with the other, *i.e.*, cannot be removed without cutting the other, are said to possess a mutual inductance. Any change in the current flowing in either circuit will give rise to a change in the "flux linkages" of the other, *i.e.*, will give rise to an E.M.F. in the other circuit. The E.M.F. induced in either circuit by a change in the current in the other is proportional to the rate of this change. The mutual inductance M between two inductances L_1 and L_2 carrying currents i_1 and i_2 is so defined that the E.M.F. induced in L_1 by any change in i_2 is given in magnitude by $M(di_2/dt)$. It is an electrical proposition for which space cannot be spared that for the same circuits the E.M.F. induced in L_2 by any change in i_1 is given in magnitude by $M(di_1/dt)$. As far as sign is concerned a new convention is required, for that already laid down refers only to the currents and potential differences of a single circuit. Actually it will appear later that as far as either circuit is concerned individually the sign attributed to the mutual inductance is quite immaterial, but for interpreting the relation between the primary and secondary currents a sign convention is desirable. There is no universally agreed convention, but for the present purpose it will be taken that currents in the two circuits are of the same sign if each tends to increase the "flux linkages" due to the other. With this understanding it will be

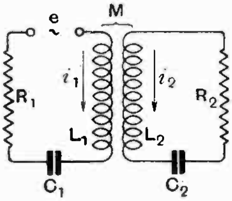


Fig. 56.

found that a negative sign must be attributed to the E.M.F. due to mutual induction. The vectorial forms for the mutually induced E.M.F.s will obviously be $-M\omega j\mathbf{i}_2$ and $-M\omega j\mathbf{i}_1$.

Consider now the circuits shown in Fig. 56. That containing the external E.M.F. will be referred to as the primary circuit, and the other as the secondary. Kirchhoff's second law applied to these circuits will give

$$\mathbf{e} - (R_1 + jX_1)\mathbf{i}_1 - M\omega j\,\mathbf{i}_2 = 0$$

or

$$(R_1 + jX_1)\mathbf{i}_1 + M\omega j\,\mathbf{i}_2 = \mathbf{e}$$

(for the primary)

and $(R_2+jX_2)\,\mathbf{i}_2+M\omega j\,\mathbf{i}_1=0$ (for the secondary)

where

$$X_1=\omega L_1-1/\omega C_1$$

and

$$X_2=\omega L_2-1/\omega C_2$$

From the second of these equations

$$\mathbf{i}_2=-\frac{M\omega j}{R_2+jX_2}\,\mathbf{i}_1$$

$$=-\frac{M\omega j\,(R_2-jX_2)}{Z_2^2}\,\mathbf{i}_1$$

where $Z_2^2=R_2^2+X_2^2$

and substituting in the first equation this value of $\mathbf{i}_2$ in terms of $\mathbf{i}_1$

$$\left\{(R_1+jX_1)+M^2\omega^2\frac{(R_2-jX_2)}{Z_2^2}\right\}\mathbf{i}_1=\mathbf{e}$$

i.e.,

$$[\{R_1+(M^2\omega^2/Z_2^2)R_2\}+j\{X_1-(M^2\omega^2/Z_2^2)X_2\}]\mathbf{i}_1=\mathbf{e}$$

or

$$\mathbf{i}_1=\frac{\mathbf{e}}{\{R_1+(M^2\omega^2/Z_2^2)R_2\}+j\{X_1-(M^2\omega^2/Z_2^2)X_2\}}$$

All the interesting and useful properties of the above coupled circuits are implicit in the above two equations for $\mathbf{i}_2$ in terms of $\mathbf{i}_1$ and for $\mathbf{i}_1$ in terms of $\mathbf{e}$ and a whole series of articles could easily be written on the basis of these equations. The most important general deduction is that in consequence of the mutual inductive coupling the two circuits are virtually a single system so that no electron can agitate itself in the one without producing responsive tremors in the other. In particular the resistance of the primary circuit is increased by a certain fraction of the resistance of the secondary and its reactance diminished by the same fraction of the reactance in the secondary circuit. Considering this latter effect more closely—if the capacities are made infinite (which amounts to the same thing as short-circuiting them) and if the resistance of the secondary circuit is such that R_2^2 is negligible compared with $\omega^2L_2^2$, then the effective reactance of the primary circuit can be expressed in the form

$$\omega L_1(1-M^2/L_1L_2)$$

The quantity $M/\sqrt{L_1L_2}$ is called the coefficient of coupling and it approaches the value unity as the coupling is made closer and closer. Thus the effect of a short-circuited low resistance close-coupled secondary circuit is practically to wipe out the inductance of the primary. On the other hand, notice that if X_2 is made zero, as it can be by suitable variation of ω or of C_2 the effective reactance of the primary is unchanged, a fact which can be used experimentally to establish the condition $X_2=0$.

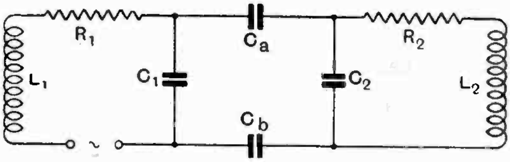


Fig. 57.

Considering further the case in which the circuits do not include the capacities, notice that if R_2^2 is small compared with $\omega^2L_2^2$ (a condition very easy to realise at radio frequencies) then the amplitudes of the primary and secondary currents are related by

$$\frac{i_2}{i_1}=\frac{M}{L_2}$$

a ratio which is independent of frequency. This fact has been turned to valuable account by Dr. Dye, of the National Physical Laboratory, in the design of radio-frequency current transformers for measurement purposes.

(B) *Capacitative Coupling.*

A network such as that shown in Fig. 57 in which the capacities C_a and C_b are in general of relatively small magnitude, has properties very similar to those of the inductively coupled circuits considered above and are therefore described as capacitatively coupled circuits. Space cannot be given to the detailed analysis of this arrangement but the methods described and illustrated in the inductive case should suffice for the reader who wishes to study it. In this connection it may be pointed out that at radio frequencies exceedingly small capacities will suffice to produce coupled circuit phenomena. In fact the unintentional stray capacities of any such system are in general quite sufficiently large to produce appreciable coupling effects, so that the loosely coupled circuits of modern wireless practice are in general both inductively and capacitatively coupled and are likely to exhibit the characteristics of both types of coupling unless suitable screening arrangements are used.

The above two types do not, of course, exhaust the possibilities of coupled systems, which may and frequently do contain more than two closed circuits coupled in a variety of ways. However, Kirchhoff's laws and the vector methods described in these articles provide a perfectly general method of analysis of all such arrangements.

12. Damped Oscillations.

The alternating currents so far considered have been currents of constant amplitude for the maintenance of which some external source of E.M.F. is required. There is another type of alternating current which is of importance in electrical theory—that of which the "alternations" or "oscillations" are analogous to those of a tuning fork or pendulum or similar mechanical system, which, when displaced in any way from its normal condition of rest vibrates freely with diminishing amplitude and finally comes to rest again. The general type of such alternating currents is $i = \hat{\imath}\epsilon^{-kt} \cos(\omega t + \theta)$ where k is a positive number. Fig. 58 is the picture of such a current.

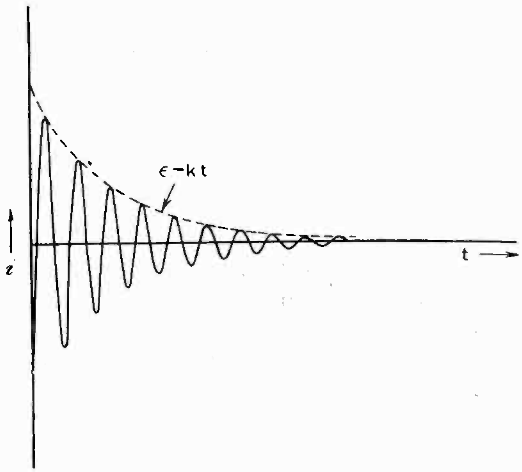


Fig. 58.

It was shown in paragraph 12 (October, 1927) that such an oscillation can be represented by a vector $\mathbf{i}$ of exponentially decreasing magnitude $\hat{\imath}\epsilon^{-kt}$, rotating with constant angular velocity ω. It was also shown that for such a vector

$$d\mathbf{i}/dt = (-k + \omega j)\mathbf{i}$$

Following exactly the same steps as in paragraph 4 (November, 1927) it is easy to show that the back E.M.F.s e_R, e_L, and e_C produced by such a current in a resistance R, an inductance L and a capacity C respectively are represented by the vectors

$$\mathbf{e}_R = -R\mathbf{i}$$

$$\mathbf{e}_L = -(\omega j - k)L\mathbf{i}$$

and $$\mathbf{e}_C = -\frac{\mathbf{i}}{(\omega j - k)C} = \frac{(\omega j + k)}{(\omega^2 + k^2)C} \cdot \mathbf{i}$$

Now, consider the simple series circuit shown in Fig. 44 (November, 1927) and imagine that at the instant when the current in the circuit has the value i_0 the source of E.M.F. is replaced by a short circuit. It is obvious on physical grounds that the current cannot fall to zero instantaneously, but as long as it continues to flow it must be such as to require no external source of E.M.F. to maintain it, *i.e.*, by Kirchhoff's second law, in its vectorial form,

$$\mathbf{e}_R + \mathbf{e}_L + \mathbf{e}_C = 0$$

Now, it is easy to show that for certain values of k and ω this condition is satisfied by a damped oscillatory current of the type considered above, for

$$\begin{aligned}\mathbf{e}_R + \mathbf{e}_L + \mathbf{e}_C &= -R\mathbf{i} - (\omega j - k)L\mathbf{i} - \frac{\mathbf{i}}{(\omega j - k)C} \\ &= -\left\{R + (\omega j - k)L - \frac{(\omega j + k)}{(\omega^2 + k^2)C}\right\}\mathbf{i} \\ &= -\left[R - k\left\{L + \frac{1}{(\omega^2 + k^2)C}\right\}\right. \\ &\qquad \left. + \omega j\left\{L - \frac{1}{(\omega^2 + k^2)C}\right\}\right]\mathbf{i}\end{aligned}$$

Now, if the values of k and ω are such that $\omega^2 + k^2 = 1/LC$ this becomes

$$\mathbf{e}_R + \mathbf{e}_L + \mathbf{e}_C = -\{R - k(2L)\}\mathbf{i}$$

so that if in addition $k = R/2L$

$$\mathbf{e}_R + \mathbf{e}_L + \mathbf{e}_C = 0$$

We have shown therefore that a current

$$i = \hat{\imath}\epsilon^{-kt} \cos(\omega t + \theta)$$

where

$$k = R/2L$$

and

$$\omega^2 + k^2 = 1/LC \quad i.e., \quad \omega^2 = \frac{1}{LC} - \frac{R^2}{4L^2}$$

will satisfy the requirements of the problem. It can, moreover, be shown that this is the *only* current which will satisfy the requirements, but the proof is beyond the scope of these articles. Also we have not yet determined the quantities $\hat{\imath}$ and θ. These, however, can be determined if required by other conditions that the current has to satisfy. For instance, if time is reckoned from the instant when the external E.M.F. is removed, we have the condition that $i = i_0$ when $t = 0$, whence

$$i_0 = \hat{\imath} \cos \theta.$$

Further since the back E.M.F. across the inductance cannot change instantaneously its value at $t=0$ will be that corresponding to the immediately preceding steady state condition, which can be determined as shown in paragraph 8. Thus $-L(di/dt)$

$$= \omega L\hat{\imath}\epsilon^{-kt} \sin(\omega t + \theta) + kL\hat{\imath}\epsilon^{-kt} \cos(\omega t + \theta)$$

so that

$$-L(di/dt)_{t=0} = \omega L\hat{\imath} \sin\theta + kL\hat{\imath} \cos\theta$$

and since the value of this is known we have two equations for determining $\hat{\imath}$ and θ.

Generally speaking, however, it is the type, the damping factor k and the periodicity $2\pi/\omega$ that one is more interested in, and these are determined as shown. Notice that the current at any instant t is

$$\hat{\imath}\epsilon^{-kt} \cos(\omega t + \theta)$$

and at a complete period later, *i.e.*, at the instant $t = T$, it will be

$$\hat{\imath}\epsilon^{-k(t+T)} \cos\{\omega(t+T)+\theta\} = \hat{\imath}\epsilon^{-kt}\epsilon^{-kT} \cos(\omega t+\theta)$$

The ratio of the first of these to the second is therefore ϵ^{kT}, which is independent of t, *i.e.*, a constant with respect to t. The logarithm of this ratio to the base ϵ is kT, which is called the "logarithmic decrement" of the circuit.

Circuits more complicated than the simple case considered will permit of a number of simultaneous "free oscillations." These will, however, be of the same general type as the example given, differing only in frequency and damping factor, and the above method of vector analysis will still apply. For further information the reader is referred to *Electric Oscillations and Electric Waves* by G. W. Pierce (McGraw-Hill) or to the writer's own book *Alternating Currents and Transients* (McGraw-Hill).

13. Power in Alternating Current Circuits.

Consider a conductor carrying a current i the potential difference between the ends of the conductor being e. It is a matter of elementary electrical theory that electrical energy is being absorbed by the conductor at a rate proportional to the product, *i.e.*, this energy being transformed into some other kind of energy (heat, motion, or chemical energy). The practical units are so chosen that if i is expressed in amperes and e in volts the rate of absorption or transformation of energy is, ie "joules" per second, or, otherwise expressed, the power is ie watts. If i and e are varying quantities, as in alternating current circuits, the relation still holds at any given instant considered. Thus if $e = \hat{e} \cos \omega t$ and $i = \hat{\imath} \cos (\omega t - \phi)$ then the instantaneous power absorbed by the conductor is

$$ie = \hat{\imath}\hat{e} \cos \omega t \cos (\omega t - \phi)$$

Now, as shown in Part II,

$$\cos A \cos B = \tfrac{1}{2} \{\cos (A+B) + \cos(A-B)\}$$

Applying this to the present instance

$$ie = \frac{\hat{\imath}\hat{e}}{2} \cos \phi + \frac{\hat{\imath}\hat{e}}{2} \cos (2\omega t - \phi)$$

and is seen to consist of a constant term $\frac{1}{2}\hat{\imath}\, \hat{e} \cos \phi$ and a double frequency periodic term. The mean value of ie over a complete period (*i.e.*, from $t = 0$ to $t = T = 2\pi/\omega$) is (see paragraph 15, October, 1927).

$$\frac{1}{T}\int_0^T ie\, dt$$

$$= \frac{1}{T}\int_0^T \frac{\hat{\imath}\hat{e} \cos \phi}{2} dt + \frac{1}{T}\int_0^T \frac{\hat{\imath}\hat{e} \cos (2\omega t - \phi)}{2} dt$$

$$= \frac{1}{T} \frac{\hat{\imath}\hat{e} \cos \phi}{2} \int_0^T dt + \frac{1}{T} \frac{\hat{\imath}\hat{e}}{2} \int_0^T \cos (2\omega t - \phi) dt$$

$$= \frac{1}{T} \frac{\hat{\imath}\hat{e} \cos \phi}{2} \Big[t \Big]_0^T + \frac{1}{T} \frac{\hat{\imath}\hat{e}}{2} \left[\frac{\sin (2\omega t - \phi)}{2\omega} \right]_0^T$$

$$= \frac{1}{T} \frac{\hat{\imath}\hat{e} \cos \phi}{2} (T - 0) + \frac{1}{T} \frac{\hat{\imath}\hat{e}}{2} \frac{1}{2} \frac{(\sin -\phi - \sin -\phi)}{2\omega}$$

$$= \frac{\hat{\imath}\hat{e}}{2} \cos \phi$$

In connection with alternating current circuits the term "power" is always taken to mean the mean value of the instantaneous power over a period. Notice that the vector representation of the alternating currents and potential differences concerned leads to a very simple expression for the power, for ϕ is the angle between the vectors **i** and **e** and the mean power is therefore half the scalar product of these vectors, *i.e.*,

$$P = \tfrac{1}{2}(\mathbf{i}\cdot\mathbf{e}) = \tfrac{1}{2}(\hat{\imath}\,\hat{e}\cos\phi)$$

In this way it is easy to show that the resistance term is the power absorbing component of a general impedance, for if

$$\mathbf{i} = \mathbf{e}/(R + jX) \text{ or } \mathbf{i}(R + jX) = \mathbf{e}$$

then

$$P = \tfrac{1}{2}(\mathbf{i}\cdot\mathbf{e}) = \tfrac{1}{2}(R + jX)\mathbf{i}\cdot\mathbf{i} = \tfrac{1}{2}R(\mathbf{i}\cdot\mathbf{i}) + \tfrac{1}{2}X(j\,\mathbf{i}\cdot\mathbf{i})$$

Now, as shown in paragraph 11 (June, 1927), $\mathbf{i}\cdot\mathbf{i} = \hat{\imath}^2$ and $j\,\mathbf{i}\cdot\mathbf{i} = 0$ (since these two vectors are mutually perpendicular). Therefore

$$P = \tfrac{1}{2}\hat{\imath}^2 R$$

The X or reactance term is thus seen to be "wattless." The above process is equivalent to resolving the potential difference **e** into two terms one in phase and the other 90 degrees out of phase with the current **i**. In a similar manner the current can be resolved into two terms $R\mathbf{e}/Z$ and $jX\mathbf{e}/Z$ where $Z^2 = R^2 + X^2$, which are respectively in phase and 90 degrees out of phase (or in "quadrature") with **e**. The corresponding expression for P is

$$P = \tfrac{1}{2}\hat{e}^2 R/Z$$

showing that it is only the "in phase" component of i which is associated with power.

If in the above analysis we put $e = i$ it can be shown that the square root of the mean value of i^2, *i.e.*, of $\hat{\imath}^2 \cos^2(\omega t - \phi)$ over a period is $i/\sqrt{2}$. Similarly the root-mean-square (or R.M.S.) value of e is $\hat{e}/\sqrt{2}$. Putting I and E for these R.M.S. values the above expressions become

$$P = I\,E\cos\phi = I^2 R = E^2 R/Z^2$$

14. Conclusion.

At the end of the last article of a very long series the writer can only hope that he has well and truly laid the foundations of the mathematical technique of elementary electric circuit theory. The space available for specific instances has of necessity been very limited, for the series has been concerned with general principles of technique rather than particular problems. More detailed application of the ideas will be found in the book by the writer referred to above. However, the real purpose of this final word is not to advertise a book of which the merits, viewed in retrospect, appear less obvious than the defects, but rather to avoid concluding with a paragraph numbered 13.

Answers to Examples in November Issue.

1. (*a*) $10 + 329.3j$.
   (*b*) $i = 30.37 \times 10^{-6} \cos(2\pi \times 830 \times 10^3 t - \phi)$, where $\tan\phi = 32.93$.
   (*c*) $368.5\mu\mu$F.
   (*d*) 52.12.

Notes on the Accuracy of Variable Air Condensers for Wavemeters.

By W. H. F. Griffiths, A.M.I.E.E., Mem.I.R.E.

IT is not *essential* that one should know with great accuracy the capacity, wavelength, or frequency corresponding with settings of variable air condensers used as means of tuning radio-receivers to resonance with incoming signal E.M.Fs. It is sometimes *desirable* that variable condensers of complicated receivers should have a reasonable degree of accuracy so that one or more of its circuits may be calibrated in order to simplify tuning adjustments.

The variable condensers of apparatus such as wavemeters must, however, have an accuracy of calibration as high as possible. Accuracy is, in fact, the first essential quality of a wavemeter condenser, varying grades of wavemeters requiring variable condensers of varying degrees of precision.

There are many factors to be taken into consideration in the estimation of the overall accuracy of a variable air condenser. In order to have, at all times, a complete knowledge of the accuracy of such a condenser at any scale reading it is necessary not only that it should have been calibrated against a standard of known accuracy, but also that it should have a degree of mechanical perfection sufficiently high to ensure that it "holds" this calibration.

The actual measurement or calibration of the variable condenser, whether it be in terms of capacity, or in terms of the wavelength or frequency of a circuit with which it is associated, depends primarily upon the accuracy of the standard or sub-standard instrument against which it is to be compared. The standard should, of course, be of a higher degree of precision than that of the condenser being calibrated. Assuming this and an ample sensitiveness of method, the accuracy with which the calibration can be transferred from the standard to the test condenser depends upon :—

1. The actual order of capacity of the condenser. The capacity of the condenser should not be too low and it should preferably have its zero "set-up" by another *air* condenser of fixed value.

2. The completeness of the screening of the condenser under test ; this becomes more serious in condensers having very low capacities.

3. The quality of the bearing of the rotary conductor system.

4. The freedom from any "back-lash" between the rotary plates themselves and the actual device by which their angular position is indicated.

5. To some extent upon the temperature at which the calibration is being performed.

6. The closeness with which the scale can be either read or set to a given value.

7. The number of points throughout the range of the condenser at which calibration is effected.

The accuracy with which the condenser, once calibrated, will "hold" this calibration over a period of time will depend upon :—

1. The quality of the bearing of the rotary conductor system. It must be sufficiently good to prevent any movement of this conductor system except that of true rotation about the axis of the shaft, *i.e.*, there must be absolute freedom from "end play" and "side play." Moreover, the bearing must not "wear."

2. True rotation of the moving plates. Each moving plate should rotate truly parallel with, and exactly midway between, the pair of fixed plates with which it interleaves. It would seem at first that this truth of rotation is only important in so far as it affects the uniformity of the law of the condenser, but it has an even more direct bearing upon calibration constancy because of the inverse law effect* which operates when an exact equalisation of

* See the author's article in *E.W. & W.E.*, Jan., 1926.

all the dielectric gaps has not been effected or is destroyed by want of truth of rotation.

3. A mechanical rigidity of each conductor system as a whole.

4. The mutual mechanical rigidity of the conductor systems, *i.e.*, the perfect rigidity of the solid insulating material with which the two systems are mechanically separated. This rigidity must be considered taking into account the effects of age, temperature, and shock.

5. The gradual natural distortion of the conductor plates themselves, especially the moving plates, by plate sagging or due to residual stresses remaining in the plates at the time of calibration.

6. The geometrical permanence of the scale both with age and temperature variation; by no means negligible in some materials.

The accuracy with which the condenser, once calibrated, can be set to a given value of C, λ or f, or with which a given scale reading can be stated and interpreted will depend upon :—

1. The perfection of screening.

2. The closeness with which the scale divisions can be read or set.

3. The angular displacement of the required setting from the nearest point for which a calibration exists. If the original calibration was not effected at a sufficient number of points a serious interpolation error may be present if the conformity to the general law of capacity change is not good.

4. To some extent, perhaps, upon temperature.

5. To some extent, possibly, upon the smoothness with which rotation can be effected. The moving system must be capable of gradual rotation by infinitely small angular increments in order to give freedom from "jumpy" adjustments which frequently prevent the exact setting of the system at a given position.

The above enumeration of qualities is intended only as a guide to the selection of a suitable variable condenser for wavemeters and other measuring apparatus, and it is not the author's intention to amplify them. It is intended, however, to explore more fully the inaccuracy introduced by reading a condenser scale.

The Accuracy of Scale Reading.

The accuracy with which the scale can be read or set may become an important factor in the overall accuracy of a condenser of precision. The closeness of reading depends, of course, to some extent upon the fineness of the lines of the dividing as well as upon the index line and the circumferential dimension of the scale, but in general it is not possible to estimate with certainty a scale reading to a closer accuracy than that corresponding to 0.01 inch of scale circumference (even when a vernier is employed) without magnification or other special means. This scale arc expressed as an angle $\delta\theta$ in degrees becomes

$$\delta\theta = \frac{0.01 \times 180}{\pi R_s} = \frac{0.573}{R_s}$$

where R_s is the radius of the scale in inches. The probable inaccuracy of scale reading at any point of the scale can therefore be expressed as

$$\delta\theta \cdot \frac{dC}{d\theta} \Big/ C$$

Expressed as a percentage this becomes

$$\frac{57.3}{R_s} \cdot \frac{1}{C} \cdot \frac{dC}{d\theta} \quad \ldots \quad \ldots \quad (1)$$

This *inaccuracy of reading* will, of course, vary throughout the scale in all condensers except those designed to have an exponential law. The actual *capacity inaccuracy* also varies somewhat throughout the scale, being usually somewhat smaller at higher capacities. The probable inaccuracy of scale reading should be of a lower order than that expected in the condenser itself.

Simple expressions for scale reading accuracy can readily be formed for condensers designed for any capacity law—expressions from which the correct scale radius for any given accuracy can be quickly found.

Linear Law Condenser (S.L.C.).

$$C_1 = a_1\theta + b_1$$

where

$$a_1 = \frac{\text{Max. cap.} - \text{Res. cap.}}{180}$$

and $b_1 = \text{Res. cap.}$

$$dC_1/d\theta = a_1$$

$\therefore$ from (1) the probable scale reading inaccuracy is

$$\frac{57{\cdot}3a_1}{R_s(a_1\theta + b_1)} \quad \ldots \quad \ldots \quad (2)$$

The law constants a and b are always known during design whatever the condenser law, and so this and the following expressions for scale reading inaccuracy are very quickly evaluated.

Corrected Square Law Condenser (S.L.W.).

$$C_2 = (a_2\theta + b_2)^2$$

where

$$a_2 = \frac{\sqrt{\text{Max. cap.}} - \sqrt{\text{Res. cap.}}}{180}$$

and

$$b_2 = \sqrt{\text{Res. cap.}}$$

$$dC_2/d\theta = 2a^2\theta + 2ab$$

$\therefore$ from (1) the probable reading inaccuracy is given by

$$\frac{57{\cdot}3\{2a_2(a_2\theta + b_2)\}}{R_s(a_2\theta + b_2)^2} = \frac{114.6a_2}{R_s(a_2\theta + b_2)} \quad (3)$$

Inverse Square Law Condenser (S.L.F.).

$$C_3 = (a_3\theta + b_3)^{-2}$$

where

$$a_3 = \frac{1}{180}\left\{\frac{1}{\sqrt{\text{Res. cap.}}} - b_3\right\}$$

and

$$b_3 = \frac{1}{\sqrt{\text{Max. cap.}}}$$

$$\frac{dC_3}{d\theta} = \frac{-2a_3}{(a_3\theta + b_3)^3}$$

the minus sign obtained when differentiating can be ignored and the probable reading inaccuracy is therefore—

$$\frac{57{\cdot}3\,(2a_3)}{R_s(a_3\theta + b_3)^{-2}\,(a_3\theta + b_3)^3} = \frac{114.6a_3}{R_s(a_3\theta + b_3)} \quad (4)$$

Exponential Law Condenser (E.L.).

$$C_4 = a_4\epsilon^{b_4\theta}$$

where

$$a_4 = \text{Res. cap.}$$

and

$$b_4 = \frac{\log.\,(\text{Max. cap.}) - \log.\,(\text{Res. cap.})}{78.17}$$

$$\frac{dC_4}{d\theta} = a_4 b_4 \epsilon^{b_4\theta}$$

$\therefore$ the probable reading inaccuracy is

$$\frac{57{\cdot}3\,a_4 b_4 \epsilon^{b_4\theta}}{R_s a_4 \epsilon^{b_4\theta}} = \frac{57{\cdot}3\,b_4}{R_s} \quad \ldots \quad (5)$$

a constant quantity throughout the whole range since the condenser is designed to give a uniform percentage change of wave-length throughout its scale.

In Fig. 1 are plotted * the probable percentage scale reading inaccuracies for the four types of condensers having similar scale dimensions and capacity values, the ratio of maximum to minimum capacity being five to one.

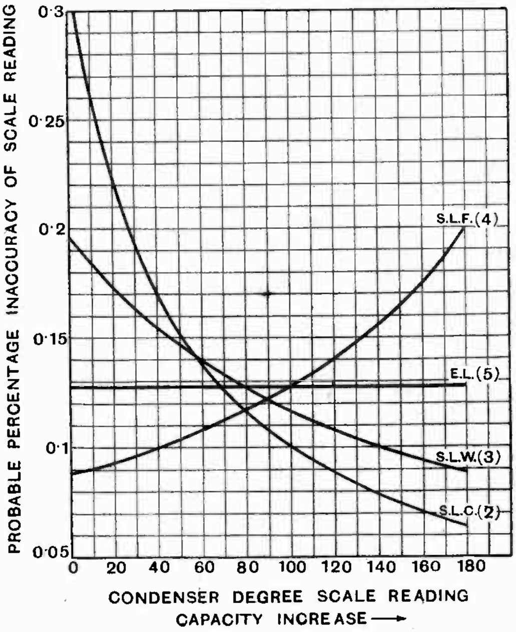


Fig. 1.

Capacity at 180 degrees = 1000$\mu\mu$F.
Capacity at 0 degrees = 200$\mu\mu$F.
Scale radius = 4 *inches.*

* The curve of the S.L.F. condenser has been reversed in order to make its capacity increase with an increase of scale reading to correspond to the curves of the other condensers.

It will be observed that the scale reading inaccuracy is inversely proportional to the actual capacity in the case of the ordinary S.L.C. condenser. In the case of the S.L.W. condenser, however, the scale reading is proportional to wavelength, which is, in turn, proportional to the square root of capacity; the scale reading inaccuracy, therefore, being, of course, inversely proportional to wavelength, is inversely proportional to the root of the capacity.

In the S.L.F. condenser the scale reading is proportional to frequency, which is, in turn, inversely proportional to the square root of capacity; the scale reading inaccuracy therefore, being inversely proportional to frequency, is proportional to the root of capacity.

It follows, therefore, that the *variation* of scale reading accuracy throughout the scale will be less in S.L.W. and S.L.F. condensers than in those having a linear capacity law, this advantage becoming, of course, more appreciable as the capacity range of the condenser is increased, as is shown in the curves of Fig. 2 for condensers of 13.9 to 1 capacity ratio.

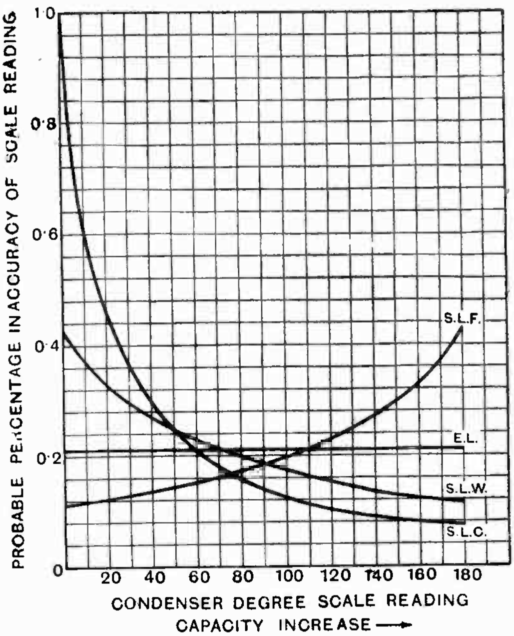


Fig. 2.

Capacity at 180 *degrees* = 1000$\mu\mu$F.
Capacity at 0 *degrees* = 72$\mu\mu$F.
Scale radius = 4 *inches*.

Atmospherics and Transatlantic Telephony.

A New Directional Polar Curve.

I.E.E. Wireless Section, Chairman's Address.

THE opening meeting for the session of the Wireless Section of the Institution of Electrical Engineers was held on Wednesday, 2nd November, the chair being taken by the Institution President, Mr. A. Page.

A very cordial vote of thanks to the retiring Section Chairman (Prof. C. L. Fortescue) for his services during the previous session was moved by Major B. Binyon, seconded by Dr. R. V. Hansford, and carried with acclamation. The President then called upon the new Chairman of the Wireless Section, Lt.-Col. A. G. Lee, M.C., B.Sc., to deliver his inaugural address.

The address dealt with the problem of atmospherics, more particularly in connection with Transatlantic telephony, the lecturer reviewing the matter generally, and discussing directional methods of minimising the effect of atmospherics. In connection with these methods a novel method of direction finding giving a very sharp polar curve for a combination of single frame and vertical aerial was described.

When the Wireless Section was started in 1920, said the Chairman, much of the matter dealt with referred to war-time research and development, which, for various reasons, had not been previously published. Since then there had been a lag between research and the publication of results, but the supply of papers for the new session was good. He also referred to the small number of papers dealing with broadcasting, although the informal discussions on this subject held during the last session had been very successful.

The important wireless matters of the past year had been beam working, and Transatlantic telephony, but instead of dealing with general aspects of these, he proposed to confine himself to one question. This was the problem of atmospherics, and the practical illustrations he proposed to take from their experience on the Transatlantic telephony working.

Useful information on the wave form of atmospherics had been given by Appleton, Watson Watt

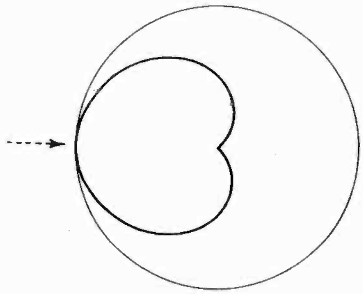


Fig. 1.

and Herd. This showed that the atmospherics were generally of an aperiodic or quasi-periodic form of about .003 second mean duration, and .1 volt per metre mean field strength. This was much greater than average signal strength. The work had also shown the existence of ripples on the main waveform.

Examination of the distribution in azimuth had been made by the cathode ray direction finding system described by Watson Watt and Herd, where two loop aerials were used at right angles and their

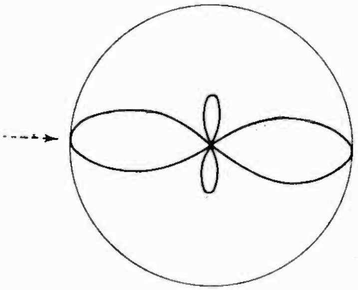


Fig. 2.

voltage applied to the plates of a cathode ray oscillograph. Observations with this apparatus had been made during the past summer at Cupar, Fifeshire, the Post Office receiving station for the Transatlantic service. A slide was shown giving the results obtained in the form of a target diagram, using the direction of the American signal as zero. The most prominent disturbance was at about 200 degrees to this zero. Simultaneous observations between Cupar and Slough, with the two points connected by telephone line, had shown that these sources were mostly in Germany, Latvia, Russia and farther away, also that this portion of Europe had been much disturbed during this summer.

Before selecting Cupar as the site for the reception of the Transatlantic telephony observations of signal/atmospheric ratio had been made at various places in England and Scotland. Going North, the signal was generally stronger and the atmospherics less. At Cupar the ratio of signal to atmospherics was four times that at Wroughton, Wiltshire, while at Thurso it was eight times.

Another type of atmospherics trouble was due to rainstorms. When signals were weak, electrified rain produced a hissing sound, sometimes sufficient to put the circuit out of action. It was hoped that large frames suitably spaced would effect an improvement in this respect.

The lecturer next turned to the spectrum of atmospherics. Lord Rayleigh had shown that an aperiodic pulse was capable of being analysed into

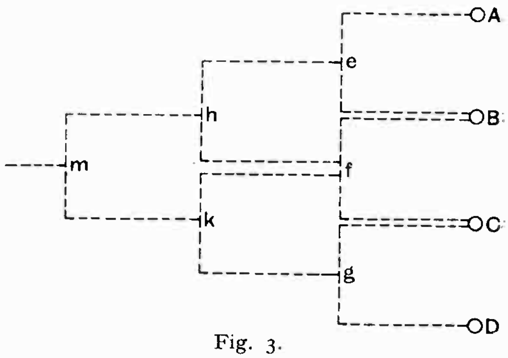


Fig. 3.

a continuous spectrum of a Fourier series of sinusoidal components. Atmospherics thus contained all frequencies. If a receiving circuit admitted a certain band, it admitted atmospheric frequencies in that band, and it was impossible to exclude them by an increase of selectivity.

As regards the possibility of effects from the ripples mentioned, there was no evidence that effects were more pronounced at one frequency. The change in spectrum was smooth, although the spectrum did change with different times of day.

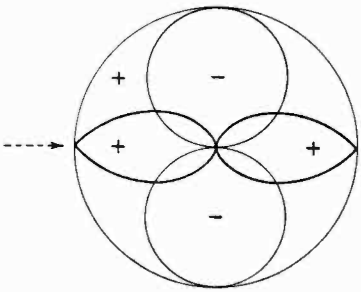


Fig. 4.

This was no doubt due to differences of attenuation by day and night.

Extensive measurements had been made for several years before the Transatlantic circuit was opened, on a band of 2,500 cycles wide. It was concluded that a wavelength between 5,000 and 6,000 metres was optimum for Transatlantic working.

The receiver must admit a band sufficient for intelligibility and further reduction of the band width for the exclusion of atmospherics would only reduce intelligibility. The Transatlantic circuit used a single side band of frequencies corresponding to the voice frequencies of 400 to 2,800 cycles. This was found sufficient for intelligibility, although not for complete naturalness. Considerable energy would be required for the transmission of the voice frequencies below 400, while the narrow band used limited the exposure to atmospherics.

The lecturer then proceeded to a brief description of the Post Office receiver used at Cupar. It employed single detection, as compared to the American receiver where double detection was used. Filtering at high frequencies was difficult, and the final narrowing of the band was done by low frequency filtering.

Slides were shown of the low pass and high pass filters, and of attenuation curves for the filters and for the complete receiver.

After a narrow band the only other method was directive reception, which he then proceeded to discuss.

Experiments on wave antennæ had shown this type of antenna to be suitable, and it had been adopted for use at Cupar. The wave antenna picks up the horizontal field which is weak at the near end, increasing towards the farther end, where it is transformed and transmitted to the receiver by transmission lines. Its properties depend on tilt to give a horizontal component; and the tilts at Chedzoy (Somerset), Wroughton and Cupar had been found to be .1, .7 and 1 degree respectively, as against the 2 or 3 degrees found in America. This was presumably due to differences in the soils. A slide showed directional curves of a wave antenna, three curves being given, *A* for the effect with no vertical, *B* for the calculated effect as it existed, and *C* for the same with methods of compensation for vertical. Slight differences existed between the three limbs of the wave antenna, due to differences in the ground. This had the disadvantage of giving bad combination when desired for more directive reception.

The lecturer then turned to a discussion of various systems of spaced antenna to obtain highly directive antenna arrays. The beam system was an example of the effect of suitably spaced antenna.

Two cases were illustrated by slides. The first was of two vertical aerials spaced one quarter of a wavelength apart in the line of transmission, with 90 degrees phase difference. This gives a cardioid polar diagram as in Fig. 1. The other case was that of two vertical aerials spaced 0.6 of a wavelength apart broadside on to the line of transmission with 0 degree phase difference. This gives a polar curve of a long, narrow figure-of-eight in the line of transmission, with a short, narrow figure-of-eight at right angles, as in Fig. 2.

A pyramid combination of antennæ could be arranged as in Fig 3, to give any combination, taking advantage of the separate properties of *A*, *B*, *C*, and *D*, then of their combinations into *e*, *f*, and *g*, and so forth. Directional curves (on Cartesian co-ordinates) were shown for various antenna arrays, and their properties briefly discussed by the lecturer.

Col. Lee then proceeded to describe a new system of frame and vertical aerial combination to give the polar curve shown in Fig. 4, to which he gave the name of "the leaf-shaped diagram."

The combination of frame and vertical aerials was already known in the usual arrangement to give a heart-shaped diagram, which resulted from the change of sign between the two loops of the figure-of-eight diagram due to reversal of phase. If the same phase was preserved in each loop of the figure-of-eight diagram, the effects could be regarded as showing each loop as of negative sign, while the non-directional circle diagram was shown as positive (as is shown in Fig. 4). The combination gave the narrow leaf-shaped polar diagram shown in heavy lines.

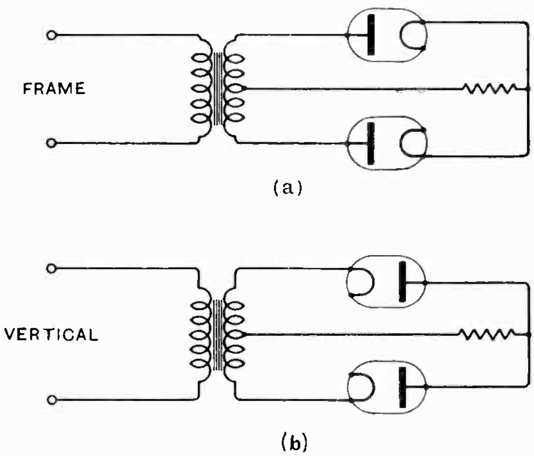


Fig. 5.

The similarity of phase in the two loops of the figure-of-eight diagram could be obtained, for example, by an arrangement of full wave rectification, as shown in skeleton in Fig. 5.

A final directional curve (or Cartesian co-ordinates) was shown for a triple broadside array of leaf-shaped diagrams, giving a very striking directive effect.

The lecturer concluded by expressing the view that directional reception provided the only means of defence against atmospherics. For long waves and long distances, atmospherics and signals arrive from a horizontal direction. Only the atmospherics from near thunderstorms arrived from vertical directions, and in this country these were not numerous and much less disturbing.

At the conclusion of his address a vote of thanks to the new Chairman was carried with acclamation on the motion of the President.

Book Reviews.

TRANSFORMATOREN - VERSTÄRKER (Transformer-Amplifiers). By Müller and von Ardenne. 137 pp. and 66 Figs. R. C. Schmidt & Co., Berlin. 4M.

This forms Vol. 22 of the "Radio-Reihe" issued by these publishers, and is a companion volume to von Ardenne's book on Resistance Amplifiers which formed Vol. 17 of the series. The book is divided into four parts. In the first part the three-electrode valve is explained and its characteristics derived and discussed; the second part deals with the iron-cored transformer, the effects of capacity, iron loss, and superposed direct current, etc., the resonant frequencies and the ratio, methods of measuring and analysing the performance of transformers. Stress is laid on a point which is often overlooked, viz., the importance of taking the direct anode current into account in designing the iron core of the transformer. The authors give $H = 3$ as the maximum allowable value of the steady magnetising force. The third section deals with the problem of the valve and the transformer combined and the desirable characteristics of each in order that the combination may give a maximum amplification with a minimum of distortion. The concluding section describes a few actual amplifiers of which diagrams and photographs are given. The book can be thoroughly recommended to those interested in the subject.

G.W.O.H.

FASCHENBUCH DER DRAHTLOSEN TELEGRAPHIE UND TELEPHONIE. Edited by Dr. F. Banneitz. xvi. + 1,253 pp. with 1,190 Figs. and 131 Tables. Julius Springer, Berlin. Price 64.5M.

Although called a pocket-book, this is not a book that one would care to carry in his pocket; it is rather a reference book to keep on one's desk and use on every possible occasion. It is a wonderfully complete compendium of radio telegraphy and telephony written by a large number of German experts; it deals in an authoritative manner with all the latest developments of the subject, naturally in a condensed form, but giving the essentials and plentiful references to original papers for those who require further information. It contains also a section on mathematical tables and formulæ, with brief descriptions of graphical and symbolic methods; an English-German and a French-German technical dictionary—in fact, it contains everything that a radio engineer could possibly want to know, and there is no need to enumerate the contents. We have only found one flaw, and that is the omission to give *E.W. & W.E.* among the list of radio magazines published in various countries. We can unreservedly recommend this book to those who have any knowledge of German. It costs over three guineas, but is worth it.

G.W.O.H.

DIE ELEKTRONENRÖHRE (Thermionic valves). By Forstmann and Schramm. 239 pp. with 197 Figs. Published by R. C. Schmidt & Co., Berlin. Price 9.50M.

This is Vol. 24 of the series "Radio-Reihe" issued by this publisher. It is subdivided into three parts: the theory of the valve, valve circuits, and practical applications. A section deals with valve manufacture but, generally speaking, the book deals with theory and deals with it in a very clear and logical way, the treatment of audio-frequency amplification being very thorough and yet easily followed. The references are almost entirely to German work, the authors being either unaware of the work done in other countries or regarding it as of little interest to their readers. We were surprised to see that Prof. Zenneck's name was misspelt in the only two places we noticed it. The use of the valve as a generator of oscillations is not considered, nor is its application to heterodyne reception, the scope being indicated on the title page by the sub-title "Its theory and application in receiver and amplifying circuits." It is a book which can be unreservedly recommended to anyone with the necessary knowledge of German.

G.W.O.H.

Correspondence.

Amplification of Small Currents.

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

SIR,—I read with interest Mr. Wilson's letter with reference to my article "The Amplification of Small Currents by Means of the Thermo-Relay, etc." I regret that I was unaware of Mr. Wilson's work in this particular direction, but it is naturally quite outside my scope to deal with a question of priority. Nevertheless, I shall see that the letter comes to the observation of Prof. Moll and Dr. Burger.

It is possible, though on this point I am not certain, that the principle of the method is old. There is, however, a very real difference between such methods as given by Mr. Wilson and those of Moll and Burger. The latter use the thermo-relay, and this is really the whole secret of the success of the method. This relay, constructed of thin thermo-foil of small heat capacity and mounted in vacuum, is a precise and reliable instrument, and even if this were all that Moll and Burger had done, it would be a tremendous advance on previous methods.

I might also point out that the article dealt with the method "by means of the thermo-relay," so that I may be excused, by definition, of dealing with less satisfactory methods of small current amplification.

Cambridge. JAMES TAYLOR.

Abstracts and References.

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PROPAGATION OF WAVES.

THE CORRELATION OF RADIO RECEPTION WITH SOLAR ACTIVITY AND TERRESTRIAL MAGNETISM—II.—G. W. Pickard. (*Proc. Inst. Radio Engineers*, 15, 9, pp. 749-766, September, 1927.)

The following summary is given: The solar, magnetic and reception data from the author's recent paper on this subject are now compared by periodic means, and clearer pictures of their inter-relations are given. The solar rotation period and its second, third, and fourth harmonics (27.3, 13.6, 9.1 and 6.8 days) are found for all three elements, the general relation being that sunspots on the solar meridian coincide with disturbances of terrestrial magnetism, lowered night reception and higher day reception. Night static at 1,330 kilocycles is found inversely related to night signal reception at the same frequency and therefore directly correlated with sunspots. Day static at 15-25 kilocycles is also, although less definitely, inversely related to the day signal at the same frequency, and therefore in general inversely correlated with sunspots. Periodic means of eight years of day reception show a marked double frequency annual component, with maxima near the vernal and autumnal equinoxes closely paralleling the well-known annual variation in terrestrial magnetism. Tables of daily sunspot numbers for 20 degrees and 40 degrees central zones are given for 1926, and night reception values for WBBM are continued from the former paper to 31st March, 1927.

LONG-WAVE RADIO MEASUREMENTS AT THE BUREAU OF STANDARDS IN 1926, WITH SOME COMPARISONS OF SOLAR ACTIVITY AND RADIO PHENOMENA.—L. W. Austin. (*Proc. Inst. Radio Engineers*, 15, 10, pp. 825-836, October, 1927.)

A summary of the measurements made by the Bureau of Standards on long-wave signal intensities and atmospheric disturbances during 1926, together with some measurements from former years, for the purpose of studying the relations of radio transmission and atmospheric disturbances to other natural phenomena.

The observations show with considerable certainty that there is a general increase of signal strength with increasing sunspot numbers; there also appears to be a possible periodic relationship between the sunspot numbers and daylight signals, in which, in the case of most stations observed, the signals are nearly in opposite phase to the periodic changes of the sunspots. This is in agreement with the results of Pickard in the broadcasting range. With regard to long-wave daylight atmospherics, a comparison of the monthly averages of sunspots, covering several years, shows little certain correlation between the two.

It is stated that a limited number of mimeographed copies of the Bureau of Standards record of daily signal measurements of long-wave stations since 1st January, 1924, are available for distribution to those engaged in the study of radio transmission phenomena.

ZUR BERECHNUNG DES ROTATIONSSYMMETRISCHEN STRAHLUNGSFELDES (Calculation of the radiation field of rotational symmetry).—M. Willstätter. (*Annalen der Physik*, 84, 1, pp. 163-166.)

Last year in these Annalen (80, 7, pp. 728-740; these abstracts, January, 1927, p. 49), Kiebitz published a paper calculating the propagation of the waves of wireless telegraphy. On the simplifying hypothesis that the resultant electric force E at any point in space is equal in magnitude to the magnetic field strength H, as with plane waves, he obtained from Maxwell's equations, by integrating after the method of characteristics, a solution of remarkable simplicity, firstly quite generally and then for the particular case of propagation around the globe. However, a strict solution of the problem, as is well known, leads to a complicated series development with Bessel and spherical functions. At the suggestion and with the support of Prof. Sommerfeld the author has closely examined Kiebitz' results: without going into the general case, even the simplest case of the Hertzian oscillator shows that Kiebitz' methods lead to incorrect results, as is set out here.

The conclusion is reached that while Kiebitz' methods of calculation are mathematically correct, the statement of the problem in no way corresponds to the physical conditions of wireless telegraphy, particularly the requirement that the solution must be finite everywhere, besides at the source (transmitter). (*Cf. L'Onde Electrique*, December, 1926, and March, 1927; these abstracts, July, 1927, p. 441).

CONSIDERAZIONI SULLA PROPAGAZIONE DELLE ONDE ELETTROMAGNETICHE (Discussion of the propagation of electromagnetic waves).—G. Pession. (*L'Elettrotecnica*, 14, 27, pp. 666-682.)

The author surveys the work that has been done on wave propagation and forms the opinion that the only waves really interesting at present for long distance communication are those below 100 metres, medium waves being kept for comparatively short distances.

WAVELENGTH CHANGES.—TIDAL INFLUENCE. (*Electrical Review*, 21st October, 1927, p. 701.)

Variations of the transmitter frequency of station WCGU, at Sea Gate, Coney Island, U.S.A., are due to the rise and fall of the tides, according to the chief engineer of the station. Tests with a laboratory oscillator showed that during ebb tide the wavelength decreased and then, as flood tide approached, increased to more than the wavelength prescribed for the station. The aerials are 75 ft. from the breakers, and the sand, when wet, becoming an excellent conductor of high-frequency current, adds capacity to the antenna while reducing its effective height. The operators are obliged constantly to check the wavelength of the station.

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY.

RADIO ATMOSPHERIC DISTURBANCES AND SOLAR ACTIVITY.—L. W. Austin. (*Proc. Inst. Radio Engineers*, 15, 10, pp. 837-842, October, 1927.)

Various graphs of observations are shown, from which the conclusion is drawn, that while there appears to be some evidence of solar influence on long-wave daylight atmospheric disturbances, at present it is insufficient to establish any connection with certainty. It may be that the influence of solar activity on the weather and that of the weather on atmospherics is the indirect path by which the connection must be traced.

TWO CONTRASTING EXAMPLES WHEREIN RADIO RECEPTION WAS AFFECTED BY A METEOROLOGICAL CONDITION.—E. H. Kincaid. (*Proc. Inst. Radio Engineers*, 15, 10, pp. 843-868, October, 1927.)

This paper is intended primarily to show that static has sufficiently definite relationship to the distribution of the atmosphere as plotted on the daily weather map to enable one by proper observations to make use of static in weather forecasting, and to make use of our present knowledge of atmospheric distribution and movement in static forecasting. The "two contrasting examples" are, that on one occasion, static was terrific and the observer was within the 29.60 isobar, south-east quadrant of a hurricane, and on the other occasion, the observer was within a homogeneous High and static was practically nil. Some observations of others who have studied this subject are reproduced.

LOI DE DISTRIBUTION DES ORAGES MAGNÉTIQUES ET DE LEURS ÉLÉMENTS. CONSÉQUENCES À EN TIRER SUR LA CONSTITUTION DU SOLEIL (Law of distribution of magnetic storms and their elements. Inferences to be drawn regarding the composition of the sun.)—H. Deslandres. (*Comptes Rendus*, 185, 14, 3rd October, 1927, pp. 626-630.)

A third article on this subject (see *Comptes Rendus*, 183 and 185, pp. 1313 and 10 respectively; these abstracts, September, 1927, p. 572). The daily variation of the magnetic needle is attributed to the ultra-violet and X radiations and also in part to the corpuscular radiation emanating from the whole solar disc, but actual magnetic storms come either directly or indirectly from the permanent volcanoes in the deep rotating layer. Spots are secondary emission centres and it is explained why magnetic storms are not always in agreement with them.

PROPERTIES OF CIRCUITS.

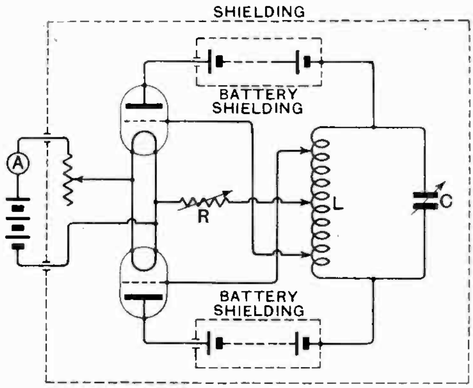
THE TESTING OF AUDIO-FREQUENCY TRANSFORMER-COUPLED AMPLIFIERS. — H. Diamond and J. Webb. (*Proc. Inst. Radio Engineers*, 15, 9, pp. 767-791, September, 1927.)

The performance of an audio-frequency transformer-coupled amplifier is considerably affected by the reaction load across the coupling-transformer secondary due to the impedance in the plate circuit of the valve following the transformer. This paper discusses the effect of such reaction, and four methods of test are described whereby the actual performance of a given amplifier may be measured under any condition of loading (due to reaction).

The first two methods of test are essentially bridge circuits in which the amplifier output E.M.F. is balanced against an auxiliary voltage, the magnitude and phase relationship of which (relative to the amplifier input voltage) is determinable. In the third method, the second amplifier valve serves both for loading and for balancing, the auxiliary balancing valve being omitted. The fourth test method is oscillographic.

A CONSTANT FREQUENCY OSCILLATOR AND ITS OSCILLATION FREQUENCY.—H. Nukiyama and K. Nagai. (*Proc. Imperial Academy Japan*, 3, 7, pp. 430-433.)

In order to keep the frequency change in the oscillation current of a valve oscillator as small as possible, Messrs. Matsudaira and Nukiyama have suggested the arrangement shown below.



The two sets of plate battery are introduced in the plate circuit of each valve separately so that the impedance of the grid circuit is small and the average grid voltage can be kept at the right value. The resistance R introduced between the filament and the oscillation circuit will give an increasing bias when the amplitude of oscillation increases. If the value of R is properly chosen, the frequency of oscillation is almost independent of the filament current within a wide range. Since in this condition the valve may not give out reactive power, investigation was made as to whether the frequency of oscillation is not equal to the resonance frequency of the oscillation circuit.

From the experiments it was concluded that when a valve oscillator has a character of constant frequency, the frequency of oscillation itself is a particular frequency, *i.e.*, the resonance frequency. This fact furnishes ground for stating that a constant frequency oscillator can reasonably be used as a permanent standard of frequency.

THE ALTERATION OF RESISTANCE, INDUCTANCE AND CAPACITY BY MEANS OF RESISTANCE-COUPLED AMPLIFIERS.—C. Aiken. (*J. Opt. Soc. Amer. and Rev. Sci. Instr.*, 15, 2, pp. 85-95.)

Various schemes for altering the effective resistance, inductance and capacity of a circuit employing a resistance-coupled amplifier are discussed. The possibility is shown of multiplying the reactance of a circuit by a large factor which may be made either positive or negative. Thus the reactance of a circuit can be neutralised for all frequencies. Resistance reducing schemes may be divided into two classes: (1) those which are independent of frequency, suitable for the reduction of large resistances to a relatively small value; and (2) those which are fairly insensitive to small frequency changes and are suitable for the annulment of small resistances.

DIE BERECHNUNG DES ANODENSTROMES UND DER VERSTÄRKUNGSZAHL BEI WIDERSTANDSVERSTÄRKERN (Calculation of the anode current and amplification factor in resistance amplifiers).—W. Bermbach. (*E.N.T.*, 48, 22, pp. 757-759.)

With negative grid tension, the anode current can be calculated with the help of the space charge formula. This is reduced to a simple cubic equation by suitable transformation and the introduction of a new unknown. From calculation work curves are plotted from which data on the amplification factor can be obtained. The influence exerted by the different constants on the amplification is shown by means of examples.

DIE BERECHNUNG DER SCHEINKAPAZITÄT BEI WIDERSTANDSVERSTÄRKERN (Calculation of the apparent capacity in resistance amplifiers.)—M. von Ardenne and W. Stoff. (*Zeitschr. für Hochfrequenz.*, 30, 3, pp. 86-89.)

A formula for the calculation of the apparent capacity of an amplifier stage with any anode load is derived, in which the phase displacement between E_a and E_g must be taken into account. The reaction of the anode load on the grid circuit in the case of the individual stages of a threefold low frequency amplifier with resistance coupling is shown by means of a numerical example. It is to be noted here, that in consequence of this reaction, besides an additional capacity, an additional ohmic resistance must be assumed in the grid circuit. The calculation further shows that in the case of the three-fold amplifier mentioned, only the first stage possesses any perceptible frequency relation.

RESONANCE IN SERIES AND PARALLEL CIRCUITS.—H. J. Boyland. (*E.W. & W.E.*, November, 1927, pp. 675-683.)

NOTE ON DETECTION BY GRID CONDENSER AND LEAK.—W. van B. Roberts. (*Proc. Inst. Radio Engineers*, 15, 9, pp. 793-796, September, 1927.)

It has been said that detection by the ordinary grid-condenser and leak gives poor quality (*i.e.*, low audio-frequencies favoured at the expense of the higher ones) unless an undesirably small condenser or low leak resistance is used. This paper attempts to show as simply as possible, that actually, good quality can be obtained even when using as large a grid condenser as desirable, because the resistance which determines the relative loss of high frequencies is not the resistance of the grid-leak alone, but the resistance of the grid-leak and grid-filament resistance of the valve in parallel. Under usual operating conditions the latter is so low that loss of quality is very slight. The resistance of the grid-leak is important chiefly in determining the grid-filament resistance of the valve, and need not be low itself.

TRANSMISSION.

ABHANGIGKEIT DER AN- UND ABSCHWINGVORGÄNGE DES RÖHRENSENDERS VON DEN BETRIEBSBEDINGUNGEN (Dependence of the phenomena of growth and decay of oscillation in the valve transmitter upon the working conditions).—W. S. Pforte. (*Zeitschr. für Hochfrequenz.*, 30, 3, pp. 83-86.)

A paper dealing with the dynamic processes of modulation, with the phenomena of growth and decay of oscillations. By means of a large series of oscillographic records and their evaluation, the dependence of these phenomena upon the different transmitter elements of the heating, grid and anode circuits is considered. The significance of these phenomena for high-speed telegraphy and telephony is pointed out.

DIE TELEFUNKEN-RUNDFUNKSENDER IN DEUTSCHLAND (Telefunken broadcast transmitters in Germany).—W. Meyer. (*Telefunken-Zeitung*, 45/46, pp. 11-38.)

A map is shown giving the geographical position of German broadcast transmitters, which appear to number 27, 21 of which were constructed by the Telefunken Company. Maps are also given indicating the ranges of these stations for crystal and one- and three-valve receivers. The Telefunken transmitters are of seven different types, each of which is described. The article is profusely illustrated.

RECEPTION.

THE SCREENED VALVE IN L.F. CIRCUITS.—N. W. McLachlan. (*Wireless World*, 19th and 26th October, 1927, pp. 536 and 577 respectively.)

SOME NOTES ON THE EFFECT OF COUPLING BETWEEN LOOP AND BEATING OSCILLATOR CIRCUITS IN A SUPERHETERODYNE RECEIVER.—E. Ullrich and A. Reeves. (*E.W. & W.E.*, November, 1927, pp. 652-656.)

H.F. AMPLIFICATION ON SHORT WAVES.—F. Charman. (*Wireless World*, 12th October, 1927, pp. 519-523.)

Description of a practical three-valve receiver with one H.F. stage.

Über Empfangsbeobachtungen bei Gleichwellenrundfunk (Observations on the reception of broadcast transmissions of the same wavelength).—F. Eppen. (*Elekt. Nachr. Technik*, 4, 9, pp. 385-387.)

The endeavour to bring broadcast reception within the reach of as many listeners as possible—and that with the simplest means—leads to the erection of ever more transmitters. Since, for financial reasons, many of these transmitters are unable to offer their own programmes, but act as intermediate transmitters, conveying the programme of a principal transmitter, the attempt was made to discover whether one could not have several transmitters, for instance, all the intermediate transmitters of a principal transmitter, working on the same wave. This would have the advantage of many fewer waves being necessary and so the individual transmitters would have greater freedom from disturbance.

The investigation showed that, at many places, undistorted reception is not to be attained, owing to interference between the carrier frequencies, but that if for those regions a transmitter working on another wave can be provided, the advantages of broadcast transmissions of the same wavelength are undoubtedly realisable.

Un Perfectionnement Intéressant d'un Montage Bien Connu (An interesting improvement of a well-known circuit-arrangement.)—H. de Joubert. (*Radio-Revue*, October, 1927, pp. 467-8.)

Description of a four-valve receiver in which the reaction coil does not start from the plate of the detecting valve, as is usual, but from that of the high-frequency valve, the advantages of which are enumerated.

Die Entwicklung von Rundfunkempfängern (The development of broadcast receivers.) Dr. Ewald. (*Telefunken-Zeitung*, 45/46, pp. 49-54.)

Receiver with over 2,000 Listening Points.—(*Wireless World*, 26th October, 1927, pp. 575-576.)

Description of an automatically controlled installation, without batteries, capable of working 2,000 pairs of headphones and 80 loud-speakers simultaneously.

Über moderne Musik- und Sprachübertragungsanlagen (Modern means of conveying music and speech).—Dr. Kühn. (*Elekt. Nachr. Technik*, 4, 9, pp. 391-396.)

Communication from the amplifier department, Siemens and Halske, discussing systems of microphone, amplifying apparatus and loud-speaker, for supplying, say, a hospital or hotel.

Theory of Receiving Aerials.—F. M. Colebrook. (*E.W. & W.E.*, November, 1927, pp. 657-666.)

Receiver for the Sudan Government. (*Electrician*, 28th October, 1927, p. 548.)

Brief description of a portable set for waves of 15-150 metres for receiving short-wave time signals from the principal stations of the world, and also for the checking of chronometers. There are only two valves—one detector with reaction, and one low frequency. The aerial is semi-aperiodic, with a tuned grid, and comprises a surveyor's tripod on which a vertical rod is mounted, arranged in four sections, the complete aerial with its earth mat fitting into a leather carrying case.

Further Investigation of Synthetic Galena Detectors and a New Theory of Crystal Rectifiers.—W. Ogawa, C. Nemoto and S. Kaneko. (*Researches of the Electrotechnical Laboratory*, Japan, 1927.)

The various metallic sulphides are investigated and no definite relation is found between sensitivity and composition. After a review of the various theories, known as electrolytic, electrothermal, and electronic unilateral conduction, the authors propose that the electron-emitting faculty of the surface layer of each electrode and the electron receiving faculty of each electrode be the main basis for discussion. They conclude that to obtain good rectification the difference of the electronic characteristics of the electrodes must be as large as possible, that the resistance of the electrode must be great enough to minimise metallic conductivity, but must not be so great as to retard the passage of electrons, especially at the anode, and that the contact pressure and area must be small enough to minimise metallic conductivity. With a soft crystal a light contact is necessary.

VALVES AND THERMIONICS.

Über Arbeitskennlinien und die Bestimmung des güngstigsten Durchgriffes von Verstärkerröhren (On working characteristics and the determination of the optimum "Durchgriff" ($1/\mu$) of amplifying valves.—A. Forstmann and E. Schramm. (*Zeitschrift für Hochfrequenz.*, 30, 3, pp. 89-95.)

Equations for the working characteristics of a valve are derived when the plate circuit is loaded with a real and a complex resistance. From these equations a method is given by which, taking account of the conditions for rectilinearity and the limiting value for the internal valve resistance, the most favourable "Durchgriff" ($1/\mu$) can be found.

The Performance of Valves in Parallel.—R. P. Denman. (*E.W. & W.E.*, November, 1927, pp. 669-674.)

Space Charge as a Cause of Negative Resistance in a Triode and its Bearing on Short Wave Generation.—L. Tonks. (*Physical Review*, 30, 4, pp. 501-511.)

The mathematical theory of negative resistance in both plate and grid circuit of a triode is worked out. Negative resistance is found when a virtual cathode is formed between grid and plate. In general this requires a plate voltage low compared with the grid voltage, a minimum electron current density depending upon the voltages used, and proper electrode spacing. For plane parallel construction the plate-grid distance must exceed the grid-cathode distance and for cylindrical construction the ratio of plate to grid diamete must exceed 2.15. Typical theoretical plate and grid characteristics are plotted. Failure of the experimental verification of these static characteristics through the occurrence of oscillations is not unexpected in view of the short relaxation time of the triode. When this theory, in combination with that proposed by Gill and Morrell, is applied to the short-wave oscillations discovered by Barkhausen and Kurz, their main features are explained.

X-Rays and Radio Valves.—J. Taylor. (*E.W. & W.E.*, November, 1927, pp. 666-668.)

Les Lampes Spéciales et leur Utilisation (Special valves and how they are used).—R. Leclère. (*Radio-Revue*, October, 1927, pp. 464-465.)

A brief discussion of valves with one grid and two plates, with one plate and two grids, and with two grids and two plates.

The Characteristics of Tungsten Filaments as Functions of Temperature. Part III. —H. Jones and I. Langmuir. (*General Electric Review*, August, 1927, pp. 408-412.)

Concluding part of an article, the first two parts of which appeared in the June and July numbers of the *Review*, giving the most recent data on the characteristics of tungsten filaments at various temperatures.

Apparat zur selbsttätigen Aufzeichnung der Röhrencharakteristik (Instrument for plotting valve characteristics automatically). (*E.T.Z.*, 48, 36, p. 1,192.)

A Device to draw Valve Characteristic Curves Automatically.—G. Campbell and G. Willard. (*J. Opt. Soc. Amer. and Rev. Sci. Instr.*, 15, 1, pp. 53-55.)

Plate-current is plotted against grid-potential. To make the ordinate represent plate-current, a known resistance of suitable magnitude is put in the plate circuit across which an L and N recording pyrometer is connected, thus recording the potential drop across the resistance which is directly proportional to the current. To make the abscissa represent grid-potential, the roll of co-ordinate paper is rotated uniformly with the variation of the grid-potential, which is effected by operating both the paper roll and the grid-potential potentiometer by the same motor though speed reducing gears.

The Theory and Characteristics of Radiotrons.—L. Koller and H. Schroeder. (*General Electric Review*, August and September, 1927, pp. 400 and 453, respectively.)

An elementary article on valves, intended to give a complete account of fundamental theory and supply a logical and up-to-date assembly of the related facts.

DIRECTIONAL WIRELESS.

The Round Island Radio Beacon. (*Electrical Review*, 7th October, 1927, p. 600.)

Illustrated description of the new wireless station for the assistance of navigation at sea, installed by the Marconi Company for Trinity House.

Berechnung von Richtstrahl-Antennen (Calculation of directional-beam antennæ).—H. Plendl. (*Zeitschr. für Hochfrequenz.*, 30, 3, pp. 80-82.)

Radiation equations and diagrams are given for

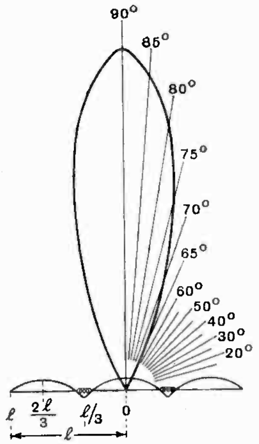


Fig. 2.

the horizontal antennæ described above, which are caused to radiate in the same phase by means of phase reversal coils. In order to show how the radiation differs when the phase is like and unlike,

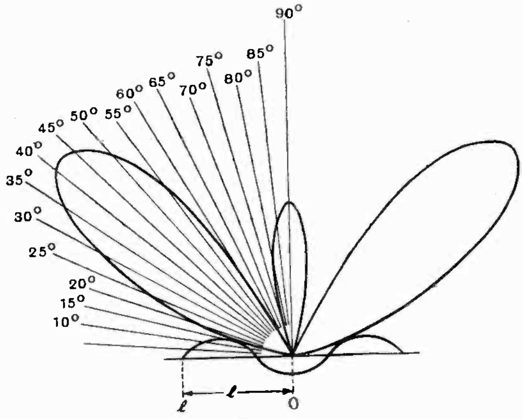


Fig. 3.

the polar curves in the two cases are drawn for comparison for an antenna three half-waves in length.

In Fig. 2 the phase is like, and in Fig. 3 unlike.

Das Rückstrahlfeld einer Hochantenne und seine Abhängigkeit von der Frequenz (The re-radiated field of an elevated antenna and its dependence on the frequency).—F. A. Fischer. (*E.T.Z.*, 48, 12, 1927, pp. 396-397.)

The re-radiated field of an elevated antenna can be split up into two components, one in phase with the incoming wave and the other at 90 degrees to it. The first produces a quadrantal directional error, and the second a blurring of the signal minimum and requires an auxiliary antenna for its compensation. The behaviour of these components is discussed in relation to the mistuning of the elevated antenna from the frequency of the incoming waves. When the antenna is distuned, the second effect is present, but when tuned, only the former is present, producing a deviation with sharp minima.

RICHTSTRAHLUNG MIT HORIZONTALEN ANTENNEN (Directional radiation with horizontal antennæ).—A. Meissner. (*Zeitschr. für Hochfrequenz.*, 30, 3, pp. 77-79, September, 1927.)

Continuation of the author's experiments with horizontal antennæ and reflectors, described in

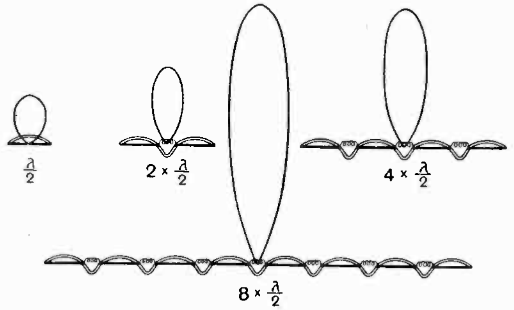


Fig. 1.

this *Zeitschrift* for September last year (these Abstracts, November, 1926, p. 699). It is found that the energy radiated by a transmitter can be concentrated in a horizontal circle by combining several horizontal antennæ oscillating in the same phase, as shown in Fig. 1, and in a vertical circle, by arranging a parabolic reflector around these antennæ, as represented in Fig. 2.

For a beam concentrated in this way, determination was made of the most favourable angle of

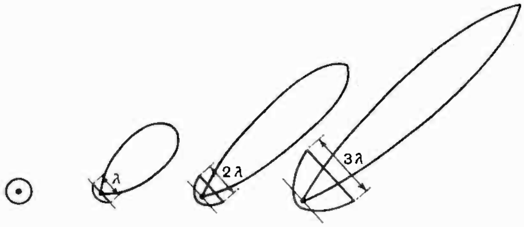


Fig. 2.

radiation at the transmitter. In order to minimise the dimensions and cost, the smallest possible wave was employed, namely that of 11 metres, thus below the limit of the wave-range within which reception over 10,000 km. (South America) was to be expected, according to theory (Taylor and Hulbert, *Phys. Rev.*, 27, 189, 1926), which indicated that the radiation would be bent away from the earth at such high frequencies. The experiments showed not only that a wave of 11 metres undoubtedly works over great distances, but also that this wave was mostly the best for day communication to South America: it was even heard sometimes when part of the path was in darkness. Maximum intensity was received at Buenos Ayres when the angle of radiation at the transmitter was

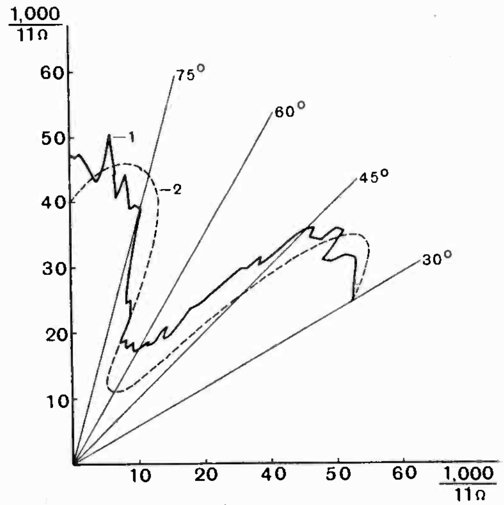


Fig. 7.

38 degrees and a second somewhat smaller maximum with an angle of 80 degrees. The figure below shows the average values of the intensity received for different angles of the reflector.

It took two men less than four minutes to move the reflector so that the angle of radiation turned through from 30 degrees to 90 degrees. In about 10 per cent. of the observations no maximum could be found when the reflector was rotated.

MEASUREMENTS AND STANDARDS.

"UNIVERSAL" FREQUENCY STANDARDISATION FROM A SINGLE FREQUENCY STANDARD.—J. K. Clapp. (*J. Opt. Soc. Amer. and Rev. Sci. Instr.*, 15, 1, pp. 25-47.)

Description of a method for obtaining from a single frequency standard source (quartz plate oscillator) a very large series of frequencies related to the known frequency by a ratio of simple integers. The frequencies thus attainable range from a few hundred to several millions of cycles per second, covering the entire gamut of audio and radio frequencies now in use. In addition to providing a means for the calibration of oscillators and wavemeters and of obtaining a desired frequency for laboratory measurements, the method can also be used to effect a direct comparison of frequency standards.

CONFRONTI FRA MISUSE DI FREQUENZA, PER MEZZO DI PIEZORISUONATORI (Comparison between measurements of frequency by means of piezo-resonators).—G. Vallauri. (*L'Elettrotecnica*, 14, 27, pp. 682-684.)

DISCUSSION AT PITTSFIELD MEETING. (*Journal A.I.E.E.*, September, 1927, pp. 955-967.)

Report of the discussions at the regional meeting in Pittsfield, Mass., last May, which include discussion of several of the papers dealing with measurements at high frequencies prepared by the Committee on Instruments and Measurements during the year 1926-1927. The discussion at Pittsfield on "Notes on the Use of a Radio-Frequency Voltmeter" is given in the October number, p. 1115.

HIGH-FREQUENCY MEASUREMENTS.—A Knowlton. (*Journ. Amer. I.E.E.*, October, 1927, pp. 1033-1040.)

Report of the Committee on Instruments and Measurements with a long bibliography.

The report is discussed on page 1127 of this same issue.

THE ALTERNATING CURRENT BRIDGE AS A HARMONIC ANALYSER.—I. Wolff. (*J. Opt. Soc. Amer. and Rev. Sci. Instr.*, 15, 3, pp. 163-170.)

SUBSIDIARY APPARATUS.

A HOT WIRE VACUUM GAUGE.—A. M. Skellett. (*J. Opt. Soc. Amer. and Rev. Sci. Instr.*, 15, 1, pp. 56-58.)

Description of a new gauge with which pressures as low as 6 by 10^{-6} mm. have been accurately measured.

THE TORUSOLENOID.—R. Gunn. (*Proc. Inst. Radio Engineers*, 15, 9, September, 1927, pp. 797-808.)

Description of an improved high frequency inductance of radical design, representing the successful attempt to combine into one inductance all the desirable features of both the toroid and the single layer solenoid. The new inductance has been found to incorporate the following features: substantially zero external magnetic field; a high value for the "gain" (a measure of coil performance); very low distributed capacity; and no major disadvantages.

GLEICHSTROM - HOCHSPANNUNGSMASCHINEN ALS ANODENGENERATOREN (Direct current high tension machines for supplying the anodes of valve transmitters.)—E. Rappel. (*E.T.Z.*, 48, 36, pp. 1285-1290.)

Discussion of the construction and action of the machines, also of the causes of the harmonics in the direct tension together with means of eliminating them.

DAS SCHALTEN GROSSER LEISTUNGEN MIT QUECKSILBERDAMPFRÖHREN IN DER DRAHTLOSEN TELEGRAPHIE (The control of large outputs in wireless telegraphy with mercury vapour tubes).—H. Schuchmann. (*Elekt. Nachr. Technik*, 4, 9, pp. 396-399.)

Description of an arrangement for controlling direct current and alternating current of any frequency by means of the mercury vapour switch. Oscillograms are shown.

ÉTUDE ÉLECTRIQUE DE QUELQUES REDRESSEURS (Electrical investigation of some rectifiers). —J. Quinet. (*Radio Revue*, October, 1927, pp. 455-463.)

A study of the working and properties of some rectifiers with a view to supplying receivers directly from the mains or charging accumulators.

AUTOMATIC WIRELESS ALARM DEVICE. (*Journ. Sci. Instr.*, 4, 12, p. 395.)

Brief account of a new automatic alarm device for giving warning on a vessel where constant watch cannot be kept, which is described in a leaflet No. 2051 recently issued by Messrs. Siemens Brothers & Co., Ltd.

EIN NEUE BAUART DES KATHODENOSZILLOGRAPHEN (A new method of constructing cathode oscillographs).—W. Rogowski, E. Flegler and R. Tamm. (*Archiv. für Elektrot.*, 18, 6, pp. 513-524.)

ÜBER DIE WIRKUNGSWEISE DER KONZENTRIERUNGSSPULE BEI DER BRAUNSCHEN RÖHRE (On the manner of working of the concentrating coil in the Braun tube).—H. Busch. (*Archiv. für Elektrot.*, 18, 6, pp. 583-594.)

MIKROPHONE FÜR HOCHWERTIGE ÜBERTRAGUNG (Microphones for high quality transmission). —C. A. Hartmann. (*Elekt. Nachr. Technik.*, 4, 9, pp. 375-378.)

After first explaining how the frequency amplitude relation for microphones is obtained, the extent to which it has been able to reduce distortion in the case of some representative types is shown. Consideration is made of high quality carbon microphones, and Gerlach's band microphone in the class of electrodynamic microphones, also of the condenser microphone for high quality transmission developed in America and Germany. Frequency and amplitude curves are shown and compared with those of an ordinary carbon microphone.

ELECTROMAGNETIC MICROPHONE.—I. Koga. (*Journ. Inst. Elect. Eng. Japan*, No. 470, pp. 906-909.)

The high-frequency oscillatory current of a valve is varied both in frequency and intensity, under certain conditions, when changes occur in (1) the magnetic or static coupling between plate and grid circuit, and (2) the magnetic coupling between the oscillatory circuit and a short-circuited coil or a metallic diaphragm placed nearby. If such a coil or metallic diaphragm is made to vibrate by a sound wave, the system may be employed as a microphone transmitter, the output of which is stated to be considerably greater than the Marconi electromagnetic microphone and others, also in the case of a metallic diaphragm, the construction of the microphone is much simpler than the present condenser type of microphone transmitter.

NEUES ÜBER RUNDFUNKAUFNAHMEN (New information on broadcast "pick-up" devices). —W. Schäffer. (*Elekt. Nach. Technik.*, 4, 9, pp. 387-390.)

In practice it is found that reception quality is prejudiced much less by inferior reproduction of the highest and lowest frequencies than by the introduction of harmonics that are not present in the original—due to faulty working of the contrivances. Methods of discovering this latter form of distortion are discussed here, also the elimination is investigated of sources of error arising from the acoustical conditions in the microphone cavities.

Motional Impedance Test of Loud-speakers.—K. Kurokawa and T. Hirota. (*Journ. Inst. Elect. Eng. Japan*, No. 469, August, 1927, pp. 865-873.)

The results are given of analysing fourteen loud-speakers from prominent makers by the motional impedance method. (This paper is in English.)

STATIONS : DESIGN AND OPERATION.

Die Hauptfunkstelle Norddeich (The Norddeich high-power station).—W. Meyer. (*Telefunken-Zeitung*, 45/46, pp. 102-107.)

Description of the German Post Office coastal wireless station at Norddeich, whose equipment until recently comprised two 5kW valve transmitters and various others of smaller output, but which now includes two large Telefunken valve transmitters of 20 and 10kW respectively. Reconstruction of the antenna system will be carried out in the near future. New station buildings have been erected, views of which are shown.

America's new 100kW Transmitter.—A. Dinsdale. (*Wireless World*, 5th October, 1927, pp. 491-494.)

Illustrated description of this new Schenectady broadcast transmitter, which uses two 100kW valves in the high-power amplifier unit and three more in the modulator unit, and a preliminary report of the results of thirty days' special test.

New American 50kW Broadcast Transmitter. (*Wireless World*, 19th October, 1927, pp. 550-554.)

Description of the plant at WEAF, Bellmore, Long Island.

Belgium—New Station at Ruysselede. (*Electrical Review*, 14th October, 1927, p. 632.)

On 3rd October the Ruysselede wireless station, which has been designed specially for communication with America and the Congo, was inaugurated The new station lies between Ghent and Bruges and covers an area of 358 acres ; the aerials are slung between eight pylons, each 930 ft. in height, and both long and short waves will be used at will.

Die Entwicklung des europäischen Funkverkehrs (Development of wireless communication in Europe. — H. Lengsfeld. (*Telefunken-Zeitung*, 8, 45/46, pp. 99-102.)

Data are tabulated of the transmissions between Berlin and the principal capitals of Europe.

United States Radio. (*Electrical Review*, 28th October, 1927, p. 733.)

The leading chain of stations in America is that of the National Broadcasting Co. ; a rival chain was recently framed by the Columbia Gramophone Co., and it is now announced that a third chain of 60 stations is being formed. On 24th September last, the number of stations in the U.S.A. was 278, made up as follows : 170 of 0.5kW, 9 of 0.75kW, 44 of 1.0kW, 8 of 1.5kW, 7 of 2kW, 6 of 2.5kW, 2 of 3.5kW, 26 of 5kW, 2 of 15kW, 1 of 30kW and 3 of 50kW ; now there is one station using 100kW.

GENERAL PHYSICAL ARTICLES.

Undamped Extra-short Waves obtained with the Magnetron.—K. Okabe. (*Journ. Inst. Elect. Eng. Japan*, No. 469, pp. 860-864.)

These very short waves were obtained with various valves where a high voltage was applied to the anode and the intensity of the magnetic field applied parallel to the cathode was increased above a certain value. The experiments showed that the following conditions require to be satisfied :—

1. The anode must be cylindrical in shape with its length greater than its diameter.

2. The intensity of the magnetic field must be kept in the vicinity of or above the critical value.

3. The diameter of the cathode must be sufficiently large.

4. The anode current must be properly adjusted, since for a given voltage and magnetic field there is an optimum value for the anode current.

Untersuchung über die Hautwirkung in Eisenleitern (Investigation on the skin effect in iron conductors).—K. Mittelstrass. (*Archiv. für Elektrot.*, 18, 6, pp. 595-615.)

Sur le Calcul de la Chaleur Dégagée par les Courants de Haute Fréquence (Calculation of the heat liberated by high frequency currents).—C. Fabry. (*Comptes Rendus*, 185, 15, 10th October, 1927, pp. 684-687.)

A short calculation showing that the Joule effect suffices to account for all the heat liberated, if note is taken of the fact that the current measured by the ammeter is the superposition of a conduction current and a capacity current, and that the former only liberates heat, the latter being wattless. The possibility of a liberation of heat due to dielectric hysteresis is not excluded. The subject is of interest for the difficult investigation of the dielectric constants of imperfect insulators.

Electrophysics.—V. Karapetoff. (*Journ. Amer. I.E.E.*, October, 1927, pp. 1029-1031.)

Annual report of the Electrophysics Committee presented at the summer convention of the A.I.E.E., Detroit, Mich., June, 1927.

The Electrical Resistivity of Insulating Materials.—H. Curtis. (*Journ. A.I.E.E.*, October, 1927, pp. 1095-1103.)

The belief is expressed that all the known facts concerning conductions through insulators can be explained by the ionic theory. While details of this theory are sufficiently developed to account for all the experimental facts in the case of gases, a complete explanation of the phenomena for liquids and solids awaits further investigation.

MAXWELL'S THEORY OF LAYER DIELECTRIC. (*Journ. Amer. Inst. E.E.*, October, 1927, p. 1006.)

A letter from E. R. Leghait referring to the discussion of Dr. Murnaghan's paper on Maxwell's theory of the layer dielectric, published in the July number of the *Journal A.I.E.E.*, p. 727.

SECONDARY EMISSION FROM MO DUE TO BOMBARDMENT BY HIGH-SPEED POSITIVE IONS OF THE ALKALI METALS.—W. J. Jackson. (*Physical Review*, 30, 4, pp. 473-478.)

THE VELOCITY AND NUMBER OF THE PHOTO-ELECTRONS EJECTED BY X-RAYS AS A FUNCTION OF THE ANGLE OF EMISSION.—E. C. Watson. (*Physical Review*, 30, 4, pp. 479-487.)

ELECTRIC STRENGTH OF SOLID AND LIQUID DIELECTRICS (abridged).—W. Del Mar, W. Davidson and R. Marvin. (*Journ. Amer. Inst. E.E.*, October, 1927, pp. 1002-1006.)

Abstract of a report to the Division of Electrical Engineering of the National Research Council. The report is a summary of existing literature and it is hoped that its discussion by the Institute will bring out obscure phenomena and new interpretations of the data reviewed and that it will afford a starting point for original research in many directions.

The report is discussed on page 1127 of this same issue.

OVER DE ONDULATIETHEORIE VAN EEN DEELTIGE, ZIJN UITGESTREKTHEID EN ZIJN BESTENDIGHEID (On the wave theory of a particle, its extent and permanence).—A. Fokker. (*Physica*, 7, 7, 1927, pp. 233-244.)

MISCELLANEOUS.

DER EMPFANG BILDTELEGRAPHISCHER SENDUNGEN (The reception of picture telegraphy).—Dr. Illberg. (*Telefunken-Zeitung*, 45/46, pp. 43-49.)

Some account of the methods employed in the reception of pictures telegraphed between Nauen and Rome and Rio de Janeiro, and the progress made on the reception side during these transmissions.

A RADIO INTER-COMMUNICATING SYSTEM FOR RAILROAD TRAIN SERVICE.—H. C. Forbes. (*Proc. Inst. Radio Engineers*, 15, 10, October, 1927, pp. 869-878.)

The problem of communication between the front and rear ends of long freight trains is briefly discussed and a two-way telephonic radio intercommunicating system, developed for this service, described. The results of tests of the apparatus under working conditions are also given.

A COMBINED RADIO GRAMOPHONE INSTALLATION.—A. Dinsdale. (*Wireless World*, 19th October 1927, pp. 539-542.)

Description of an electrostatic pick-up energised with H.F. oscillations from a broadcast receiver.

ELECTRICAL REPRODUCTIONS FROM PHONOGRAPH RECORDS.—E. W. Kellogg. (*Journ. A.I.E.E.*, October, 1927, pp. 1041-1049.)

Electrical reproduction may be considered in three steps, (1) generations of a voltage by the vibrations of the needle, (2) amplification, (3) conversion of electrical power into sound. The first of these steps involves some interesting mechanical and electrical problems, and it is with these that the paper primarily deals. Several types of phonograph "pick up" are possible; electrostatic, piezo-electric, electromagnetic, and variable resistance or microphonic: in the device considered here the electromagnetic principle is employed.

D.E.H.

ERRATUM.

"RESONANCE IN SERIES AND PARALLEL CIRCUITS."—Equation 5 on page 677 is correct but in the line below $C = \frac{1}{\omega^2 C^2 + R^2}$ is given instead of $C = \frac{L}{\omega^2 L^2 + R^2}$

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto - Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

PROPRECOJ DE CIRKVITOJ.

RESONANCO ĈE SERIAJ KAJ PARALELAJ CIRKVITOJ. —H. J. Boyland.

La artikolo analizas certajn kombinojn de Induktanco, Kapacito, kaj Rezisteco, por derivi la parencecon, kiu devas ekzisti por kontentigi la kondiĉojn :—

Por Seriaj Cirkvitoj :—

(*a*) Maksimuma potenciala diferenco trans la induktanco ;

(*b*) Maksimuma p.d. trans la kapacito ;

(*c*) La kurento devas esti maksimumo.

Por Paralelaj Cirkvitoj :—

(*d*) La ekvivalenta reaktanco devas esti nulo ;

(*e*) La impedanco devas esti maksimumo.

Simpla matematika analizo estas donita por la diversaj ekzemploj de

Seriaj Cirkvitoj :—

1. Induktanco kaj kapacito en serio sen rezisteco ;
2. Induktanco, kapacito kaj rezisteco en serio ;
3. Induktanco kun enhavita rezisteco en serio kun kapacito.

Paralelaj Cirkvitoj—

4. Pura induktanco (sen rezisteco) kaj pura kapacito en paralelo ;
5. Induktanco kaj rezisteco en paralelo kun pura kapacito ;
6. Induktanco kaj rezisteco en paralelo kun kapacito kaj rezisteco.

Esprimoj estas derivitaj por la diversaj ekzemploj montritaj.

LA FUNKCIADO DE VALVOJ EN PARALELO.—R. P. G. Denman.

La artikolo provizas ekzamenon pri la ĝenerala ekzemplo de nombro de valvoj funkciantaj paralele, portantaj komunan ŝarĝon. La ekzemplo de n baterioj en paralelo estas nune ĝeneraligita laŭ la Leĝoj de Kirchhoff, kaj la esprimoj derivitaj estas aplikitaj al tiu de n valvoj en paralelo. Speciala ekzemplo estas donita pri du valvoj de konataj malsimilaj karakterizoj (t.e., de malsama modelo), kun plua ekzemplo de du valvoj de simila modelo sed kun μ kaj r malsamaj je ĉirkaŭ 10%. Oni utiligas la kurvojn Anodvoltajn—Anodkurentajn (vidu E. Green, *E.W. & W.E.*, Julio-Aŭgusto, 1926a), kaj oni montras ke, je certaj okazoj, la malplibona valvo regas la situacion, kaj ke la alia, kvankam eventuale kapabla trakti pligrandan potencon, ne povas ricevi ĉi tion sen troŝarĝo de la malsupera valvo. La utiligo de apartaj krad-potencialaj alĝustigoj permesus plibonan elmeton. Oni uzas similan rezonadon rilate al la utiligo de du aliaj valvoj samspecaj, sed kun iomete malsimilaj karakterizoj.

La aŭtoro finas, rimarkigante, ke eble fabrikistoj solvus la malfacilecon se ili provizus malgrandajn grupojn de potencaj valvoj kun karakterizoj garantiitaj laŭ apudaj limoj.

RICEVADO.

KELKAJ NOTOJ PRI L'EFEKTO DE KUPLO INTER KADRAJ KAJ BAT-OSCILATORAJ CIRKVITOJ EN SUPERHETERODINA RICEVILO.—E. H. Ullrich and A. H. Reeves.

Oni unue aludas al la fakto, ke en supersona ricevilo la kuplo inter la batanta oscilatoro kaj la ricevila kadro igas, ke la agordo de iu cirkvito influas la alian. Sub 100 metroj ĉi tio fariĝas ĝenema. Mallonga matematika analizo de ĉi tiuj efektoj estas donita, kaj metodo enkonduki la batantan oscilatoran tension estas diskutita kaj ilustrita. Je 200 metroj neniu variado estis detektita. Je 50 metroj la anodkrada kapacito havis percepeblan perturbigan efekton sed estis korektebla per ekvilibriga kondensatoro.

TEORIO PRI RICEVAJ ANTENOJ.—F. M. Colebrook.

La artikolo estas verkita kun la intenco provizi respondojn al la demandoj :—

1. Kia estas la efektiva impedanco de riceva anteno laŭ la vidpunkto de interrilatigita aparato ?
2. Ĉu la efektiva impedanco dependas de (*a*) la speco de la agorda cirkvito, (*b*) la distribuo de la kampo kaŭze de la signalo ?
3. Kiun rolon ludas la distribuita rezisteco de anteno ?
4. Kiom estas la efektiva alteco de anteno, kaj ĉu ĝi dependas de (*a*) la agord-cirkvitaj kondiĉoj, (*b*) la kampa distribuo ?
5. Ĉu estas optimuma distribuo por difinita longeco de anteno ?

La ĝenerala temo de la riceva anteno estas analizita matematike kaj aplikita al la solvo de ĉi tiuj punktoj.

La respondoj deduktitaj el ĉi tiuj demandoj povas esti mallonge resumitaj laŭjene :—

1. La anteno povas esti rigardita kiel ordinara impedanco de la tipo ($R+jX$) en serio kun efektiva Elektromova Forto kaŭze de la signalo ;
2. La efektiva impedanco dependas nur de la elektraj konstantoj kaj la formo de la anteno ;
3. La distribuita rezisteco de la anteno eniras en la rezistecan komponanton de l'efektiva impedanco kaj ankaŭ, kvankam ne multege, en la efektivan reaktancon ;
4. La efektiva alteco ne estas influita per la agordigo de la anteno, sed dependas de la frekvenco kaj kampa distribuo ;

5. Neniu ĝenerala respondo estas donebla pro tio, ke la efektiva alteco, kaj tial la efektiveco, de l'anteno dependas de la formo de la kampo en kio ĝi troviĝas.

VALVOJ KAJ TERMIONIKO.

X-RADIOJ KAJ RADIO-VALVOJ.—D-ro. J. Taylor.

Post mallonga diskutado pri la proprecoj de X-radioj, la aŭtoro priskribas la generadon de ĉi tiu radiado, per malalttensia tubo kun "Coolidge" (t.e., varmigita) katodo. Li tiam diras ke, principe, ĉiu senfadena diodo aŭ triodo estas generilo de X-radiado, kvankam la kvanto generita estas eble tre malgranda.

Oni priskribas eksperimentojn per tubo de proksimume valvelektroda konstruo, kun aldonitaj elektrodoj por la detekto, kaj mezuro de la X-radiado per fotoelektra rimedo. La eksperimentoj montras, ke devas esti produkto de mola X-radiado inter la triodaj kaj diodaj valvoj uzitaj en praktiko, speciale ĉe molaj valvoj.

DIVERSAĴOJ.

LA NACIA RADIO-EKSPOZICIO, OLYMPIA, 1927a.

Redakcia artikolo traktanta pri certaj el la montraĵoj ĉe la Brita Nacia Radio-Ekspozicio, tenita ĉe Olympia, Londono, de la 24a Sept. ĝis la Oktobro.

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.

MATEMATIKO POR SENFADENAJ AMATOROJ.—F. M. Colebrook.

Daŭrigita el antaŭaj numeroj. La nuna parto (Parto IV de la serio) traktas pri la aplikadoj de la antaŭa teksto al elektraj problemoj sub la fakaj rubrikoj de la Fundamentaj Leĝoj de Kurentaj Retaĵoj, Induktanco, Kapacito, Vektora Reprezentado de Retro-E.M.F.—oj, Vektora Analizo de Alternkurentaj Cirkvitoj, k.t.p.

Review of Publications.

QUARTZ. — PRESENT-DAY APPLICATIONS OF THE PIEZO-ELECTRIC EFFECT IN RADIO ENGINEERING. By A. Hinderlich, M.A. Published by Quartz Oscillators Ltd., 1, Lechmere Road, London, N.W.2. 67 pp. and 12 Figs. Price 2s. 6d.

Readers of *E.W. & W.E.* are familiar with the author's non-mathematical experimental style of approach to the quartz oscillator. No attempt is made to explain the theory or principles involved but a great number of practical wrinkles are given in the technique of making and using quartz plates. The book is addressed to the wireless amateur who wishes to build a crystal-controlled oscillator unit, and it should answer this purpose admirably. There are sections on wavelength standards and miscellaneous applications, and an excellent bibliography giving references to sixty papers on the subject. There is also a list of patents which have been taken out for various applications of the quartz oscillator.

We make an effort to keep up with the slang with which the amateur loves to decorate the subject, but a "hay-wire" version of the quartz-controlled oscillator unit, is new to us; it is probably not unconnected with the fact that the book concludes with a section headed "Americana."

LOW FREQUENCY AMPLIFICATION. A pamphlet of 48 pages issued by the R.I. and Varley Co. Price 1s.

The transformer lion has laid down beside the resistance-capacity lamb and this pamphlet represents their joint effort; the first half is mainly devoted to the lion and the second half to the lamb. Who would have expected to read in a pamphlet bearing the letters "R.I." that "the overwhelming advantages of resistance-capacity coupling for low frequency amplifiers are now so well-known and acknowledged that it must soon absolutely supersede any other form of coupling where faithful, pure, and realistic reproduction of speech and music are desired? Seriously, however, we welcome this pamphlet which discusses the theory of both methods and gives National Physical Laboratory curves of amplification over the frequency range obtained by both methods using, of course, components supplied by the company. The transformer employed was the new R.I. super transformer which contains about 2½ times as much iron as their older model; they have probably found that the heavy direct anode current passing through the primary greatly reduces the effective inductance to the audio-current and necessitates this increase of iron. The transformer has three windings, the turns being in the ratio of 100 : 175 : 175; these can be connected in various ways to give different ratios depending on the A.C. resistance of the preceding valve. A warning is given that the anode current should not exceed 4 milliamperes through the first or 3 milliamperes through the other two windings.

A new method of coupling is recommended for use after high-amplification high-resistance valves; this consists in taking a connection from the anode of the valves through a $0.01\mu F$ condenser to the grid of the following valve, in addition to the ordinary transformer arrangement. It appears to be a combination of transformer and choke coupling and is referred to in the pamphlet as balanced inductive coupling; the reason for this name is not clear as no explanation is given of the principles underlying the suggested arrangement.

G.W.O.H.

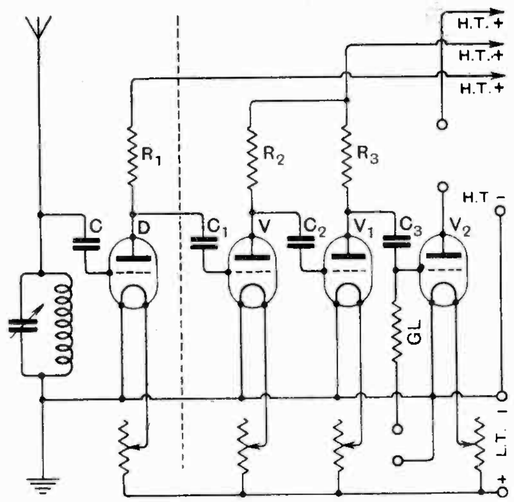
Some Recent Patents.

The following abstracts are prepared, with the permission of the Controller of H.M. Stationery Office, from Specifications obtainable at the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1/- each

RESISTANCE-CAPACITY COUPLINGS.

(*Application date, 7th July,* 1926. *No.* 276,479.)

Plate resistances R_1 R_3 of the order of megohms, 2 megohms being mentioned as a suitable value, are used in combination with insulated or "free" grids. As shown in the Figure, a detector stage D is coupled to three stages V, V_1, V_2, of low



frequency amplification through resistances R_1 R_3 and coupling condensers C, C_3 having a capacity not less than 0.0003μF. A high tension voltage of 60 is used on the first three valves, and 100 on the last stage.

The elimination of grid-leaks and biasing batteries removes a source of damping on the input circuit, and leads to improved selectivity. In the case of the last valve V_2, a high leak of from 5 to 10 megohms may be provided to relieve the heavy load. There is a tendency for the grid of the first valve to acquire an unduly large negative bias when the filaments are first lit. In order to prevent any temporary paralysis due to this cause, the rheostat switch may momentarily connect that grid to the filament circuit at the instant of switching on; or a separate switch may be provided for this purpose.

Patent issued to P. L. Wostear and R. H. Billingsley.

DUAL-DIELECTRIC CONDENSERS.

(*Application date, 5th October,* 1926. *No.* 276,508.)

A movable plate of solid dielectric, such as resin, is arranged to interleave certain of the plates of a tuning condenser, the remainder of the plates being separated by air dielectric as usual. One knob may control the position of the solid dielectric, whilst another controls the air-separated plates; or there may be a simultaneous control for both parts of the condenser. The instrument is particularly suitable for combined long and short-wave receivers, as the capacity can be varied practically instantaneously, from, say, 0.0005 to 0.005μF.

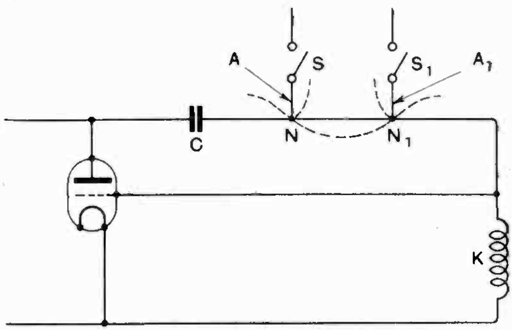
Patent issued to C. Hollins.

SHORT-WAVE RADIATION.

(*Convention date (Germany), 7th October,* 1925. *No.* 259579.)

In short-wave signalling the generator is usually connected to the radiating system either by inductive coupling or through a capacity. According to the present invention the aerial is connected directly to the oscillation generator by a metallic conductor located at a voltage node. As shown in the Figure, the main oscillatory circuit comprises a simple wire connection between the electrodes, together with a series capacity C.

The inductance of the wire, the condenser C, and the inherent grid-anode capacity of the valve are the factors which determine the frequency of the oscillations generated. Reaction is secured through a choke K and the inter-electrode capacity of the valve. Stationary waves are set up in the Lecher wire system so formed, and a number of radiating aerials A, A_1 are connected at the nodal points



N, N_1. Several aerials may be arranged in this way to form a directional system. Maximum radiation only takes place when the length of each aerial is equal to one or an odd number of quarter wavelengths. This fact is utilised to control signalling by inserting switches S, S_1 to alter the effective lengths of the antennæ.

Patent issued to Dr. A. Esau.

SHORT-WAVE TRANSMISSION.

(*Convention date (Germany), 7th October*, 1925. *No.* 259577.)

In short-wave radiation emitted at an angle of from 45 to 70 degrees to the horizontal from an aerial insulated from the ground, it is found that an improved range can be secured when the conductivity of the earth in the vicinity of the transmitter is artificially increased. Further, it is found that maximum efficiency occurs when the area of the artificially-prepared soil bears a definite relation to the wavelength employed. The present invention consists in preparing the ground near the aerial over an area having a radius of from three to four times the signal wavelength, either by laying down wire star or similar networks; or by covering it with metal gauze, chips, or filings; or by impregnating it with salt or other chemical solutions.

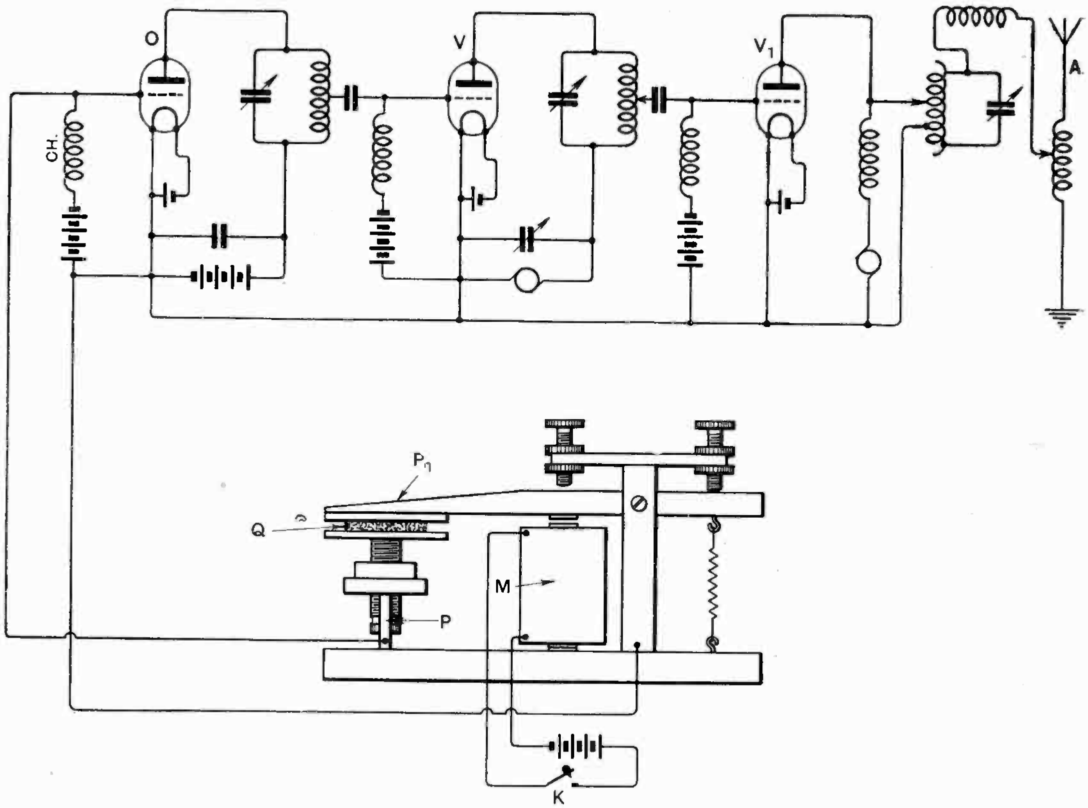
Patent issued to Dr. A. Esau.

SIGNALLING BY PIEZO-CRYSTAL CONTROL.

(*Convention date* (*U.S.A.*), *7th August*, 1926. *No.* 275581.)

Signalling is effected by varying the space relationship of two plates separated by a piezo-electric crystal. The crystal *Q* is in the grid circuit of a low-powered oscillator *O*, and is shunted by a radio-frequency choke *Ch* in series with a grid-biasing battery. It is also mounted between a rigid support *P* and a plate P_1, or armature, acted upon by an electro-magnet *M* included in a circuit containing the signalling key *K*.

When the plate P_1 is moved towards or away from the crystal the capacity value of the latter is altered. As the crystal forms a part of the condenser dielectric, the intensity of the transverse electric field changes accordingly, together with the frequency output from the oscillator *O*. The latter is coupled through successive amplifying stages *V*, V_1 to the aerial *A*.



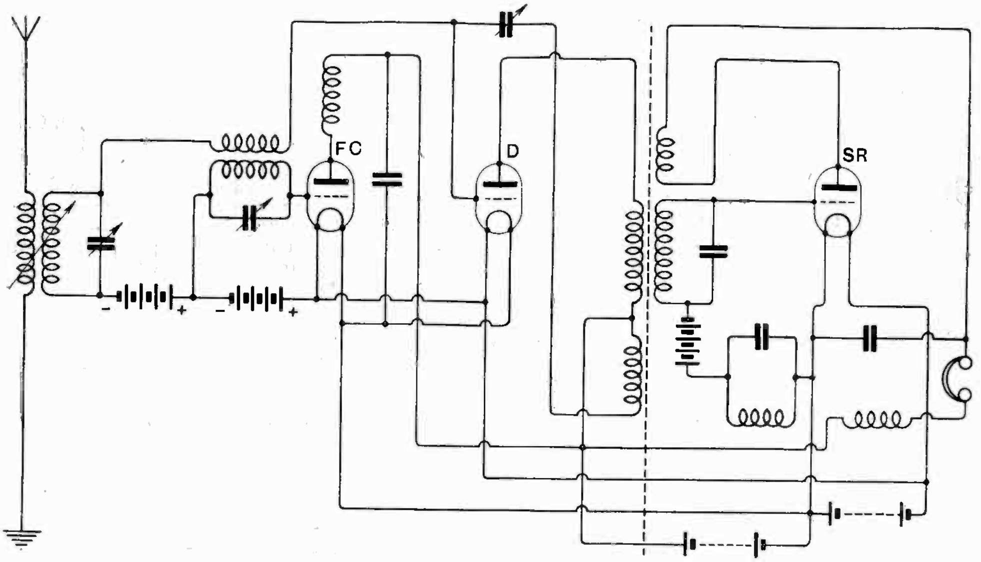
A very small movement of the plate P_1 is sufficient to cause a frequency shift of from 500 to 1,000 cycles, which is ample to impress signal variations on the radiated energy. Such a keying device consumes no appreciable power, and has the additional advantage that it is safe in use, since no voltage is involved higher than that necessary to secure a proper bias on the grid of the oscillator tube *O*.

Patent issued to the Westinghouse Electric Co.

SUPER-REGENERATOR CONTROL.

(*Convention date* (*U.S.A.*), *12th April*, 1926. *No.* 269207.)

In order to simplify the control of a super-regenerative receiver, the circuits *SR* are tuned permanently to a definite optimum value, and the incoming signals are then heterodyned by a frequency-changer *FC*, until the ensuing beat frequency coincides with that to which the super-regenerator has been set. The beat frequency is preferably of the order of 3,000 kilocycles, the incoming signals being stepped up to this value by adjusting the circuits of *FC*. A detector valve *D* transfers the stepped-up frequencies to the permanently-tuned super-regenerative amplifier *SR*.

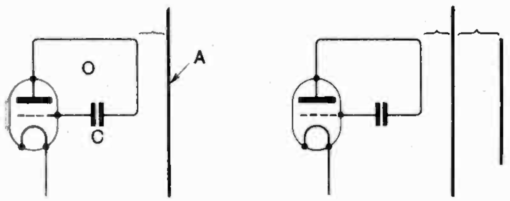


Patent issued to Metropolitan Vickers Co.

SHORT-WAVE GENERATORS.

(Convention date (Germany), 18th February, 1926. *(No.* 266372.)

In attempting to generate very short waves, a natural limit is imposed by the electrical constants, and particularly the inter-electrode capacity of the valve oscillator. It is, however, known that



it is possible, by coupling one oscillatory system to another, to produce a number of separate wavelengths dependent upon the degree of coupling employed. Advantage is taken of this fact to produce waves varying from a few metres down to a few centimetres in length.

In the Figure the constants of the main oscillatory circuit *O* comprise the plate-grid electrode capacity, an external capacity *C* and the connecting wires. This circuit is placed in close proximity to a radiating rod or aerial *A*. For a certain degree of coupling between the circuits, the radiated wave will correspond with the fundamental frequency of the circuit *O*. For a tighter coupling, two waves will appear, the frequency difference between them depending upon the closeness of coupling. This difference can be increased to the required degree by detuning the aerial *A* from the circuit *O*. Either frequency may be selected for transmission; or the two frequencies may be made approximately equal, and a common signal applied to both, with the object of minimising fading effects.

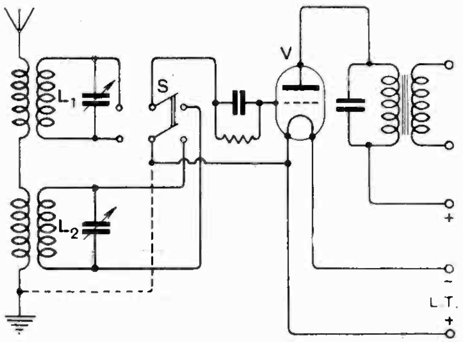
Patent issued to Dr. A. Esau.

DUAL-RECEPTION RECEIVERS.

(Application date, 14th September, 1926. *No.* 277799.)

Two or more differently-tuned units are associated with the aerial or input circuit of a receiver, and a switch is arranged so that when one unit is feeding desired signals to the detector the other unit is functioning as a wave-trap to eliminate interference. Various combinations of acceptor, rejector, and absorber circuits designed to ensure alternative reception from at least two transmitting stations, free from mutual interference, are described in the specification.

In the example shown in the Figure the unit L_1 is tuned, say, to station A, whilst unit L_2 is tuned to a different station B. With the switch *S* in the left-hand position, the unit L_1 is inserted across the grid and filament of the detector *V*. This brings in station A. Simultaneously, interference from station B is minimised by the open-circuited unit L_2 which acts as a wave-trap or "absorber" to signals of this frequency. When the switch is moved over to the right, the circuit connections of the units L_1 and L_2 are reversed. Signals from station B are then received, any interference from station A being cut out by the unit L_1 which acts as a wave trap. The aerial inductances, which



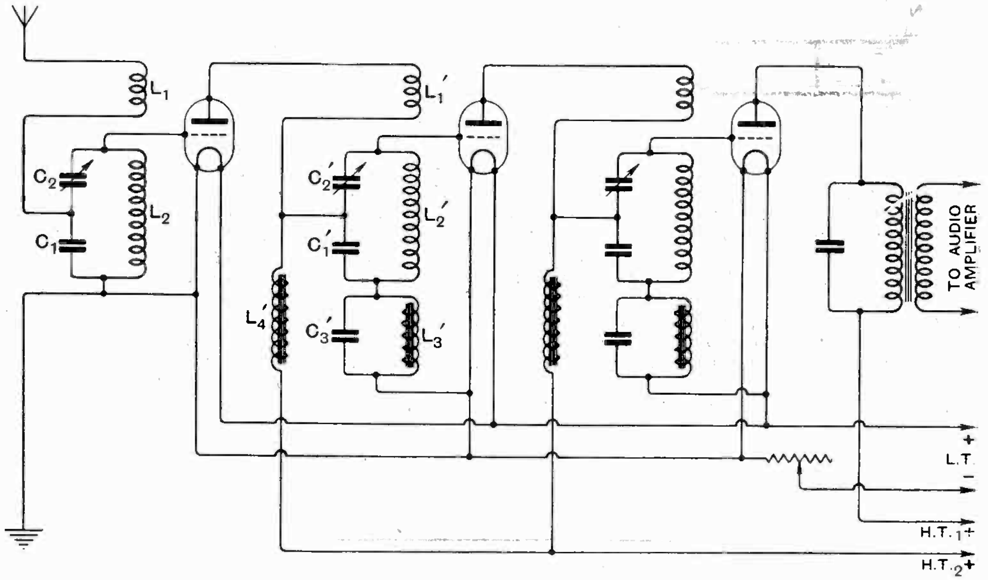
are small relatively to those of the units L_1 and L_2, are so chosen that the total aerial impedance is suitable to receive either station A or B.

Patent issued to British Thomson-Houston Co. and T. H. Kinman.

A STABILISED HIGH-FREQUENCY CIRCUIT.

(*Convention date* (*U.S.A.*), *24th December*, 1925. *No.* 263804.)

The aerial circuit comprises an inductance L_1 and capacity C_1, and is coupled to a secondary circuit C_1, C_2, L_2, forming the input of the first valve, partly through the common condenser C_1,



and partly by the coils L_1, L_2. By suitably adjusting the polarity or phase of the coils L_1, L_2, the effective transfer of energy through the combined couplings can be made a positive or negative factor, owing to the fact that the rate of energy transfer across the capacity coupling decreases as the working frequency increases, whilst the inductive transfer across the coils falls off, and *vice versa*.

In the plate circuit, the coils L_1' and L_2' and the coupling condensers C_1', C_2', and C_3' can be adjusted so that the overall reactance of the system may be either inductive or capacitative, or purely resistive in character. The precise theoretical conditions involved are set out at length in the specification.

The objects aimed at are to secure a complete elimination of the inter-electrode capacity effect throughout the entire tuning range of the receiver, whilst at the same time keeping the effective reactance of the coupling elements at a low value, so as to facilitate an efficient and constant energy-transfer ratio from one valve to the next. The arrangement is stated to be independent of the dimensions or spacing of the valve electrodes, so that any one particular type of valve may be replaced by another without upsetting the balance of the system. High-frequency chokes L_3' and L_2' are inserted across certain of the coupling condensers as shown, so as to permit the necessary operating voltages to be applied direct to the plate and grid of each valve from the high and low tension batteries.

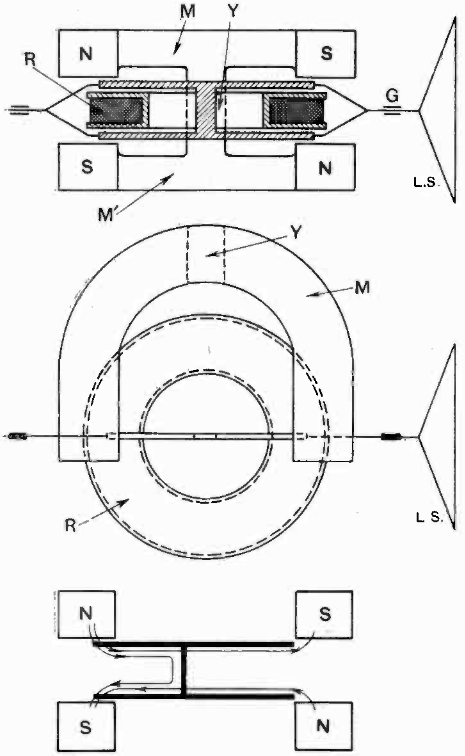
Patent issued to E. H. Loftin.

LOUD-SPEAKERS.

(*Application date, 7th May*, 1926. *No.* 277052.)

A ferromagnetic armature is mounted so as to move longitudinally within a narrow air gap between permanent pole-pieces, so that the to-and-fro movement is unrestricted mechanically by the width of the gap. The energising coil is fixed, but is so mounted around the armature as to allow a free vibration of several millimetres. The arrangement is highly sensitive, a comparatively small current producing a large lateral displacement of the armature. The arrangement of the parts is shown in plan and in elevation in the figure, whilst the distribution of magnetic flux at a particular instant of operation is also shown.

The permanent system comprises two magnets, M, M_1 connected by a central yoke Y, the polarity of adjacent faces being opposed as shown. Mounted within the air-gap is a movable H-shaped armature, shown shaded, one end being connected by rods passing through a guide G to the cone diaphragm of a loud-speaker LS. The armature is energised by means of a ring-shaped winding R, which is immovably mounted between the upper and lower legs of the armature, and at such a distance from the centre leg as to allow the armature to vibrate freely in a lateral direction between the permanent poles, N, S.



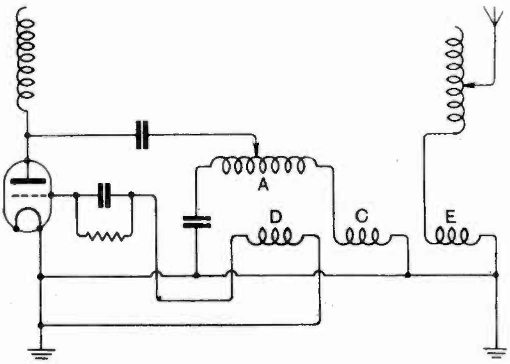
When there is no current flowing in the ring R, the magnetic flux through the system is such as to retain the armature in a definite position of equilibrium. The effect of the energising current is to vary the polarity of the armature, and so cause it to move alternatively to the right or left as the direction of current-flow reverses. At the moment shown in the bottom figure the resulting magnetic flux is pulling the armature towards the left.

Patent issued to H. Wade, the invention being a communication from the Philips Glowlamp Co. of Eindhoven.

TRANSMITTING CIRCUITS.

(*Convention date* (*Holland*), *22nd May*, 1926. *No.* 271450.)

In order to prevent the coupling effect known as "oscillation hysteresis," in which two separate wavelengths are produced and the system tends to swing over from one to the other, advantage is taken of the fact that the two wavelengths have a phase-difference of 180 degrees to make the reaction, say, on λ_1 greater than that on λ_2 and so eliminate the latter. According to the present invention the coupling coil C constitutes



only a small proportion of the total inductance A, C of the main oscillatory circuit, whilst the associated coil E is only a small part of the total aerial inductance, the third coil D constituting the grid inductance. The winding direction of the coil E is so chosen that for wave λ_1 the currents in coils C and E are in the same direction, whilst for wave λ_2 they are in opposition. As the coupling is increased the system therefore tends to become stabilised on the wavelength λ_1.

Patent issued to Nederlandsche Seintoestellen Fabrik.

BUYERS' GUIDE.

ACCUMULATORS.—Accumulators Elite, Bedford Street, Halifax. C. A. Vandervell & Co., Ltd., Acton, London, W.3

OILS.—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.

COIL HOLDERS.—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.

CONDENSERS.—Bowyer-Lowe Co., Ltd., Letchworth. Claude Lyons, Ltd., 76, Oldhall Street, Liverpool. Dubilier Condenser Co. (1925), Ltd., Ducon Works, Victoria Road, North Acton, W.3. L. Holzman, 109, Kingsway, W.C.2. Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. Marconiphone Co., Ltd., 210, Tottenham Court Road, W.1. W. G. Pye & Co., "Granta Works," Montague Road, Cambridge. Wilkins & Wright, Ltd., Kenyon Street, Birmingham.

CRYSTALS.—Quartz Oscillators, Ltd., 1, Lechmere Road, London, N.W.2.

GALVANOMETERS (CAMBRIDGE UNIPIVOT).—Cambridge Instrument Co., Ltd., 45, Grosvenor Place, S.W.1.

GRID LEAKS.—Dubilier Condenser Co. (1925), Ltd., Ducon Works, Victoria Road, North Acton, W.3. Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.

H.F. CHOKES.—Claude Lyons, Ltd., 76, Oldhall Street, Liverpool. R.I. & Varley, Ltd., 103, Kingsway, W.C.2.

MASTS.—J. & J. Laker Co., Beckenham, Kent.

MEASURING INSTRUMENTS.—F. C. Heayberd & Co., 9, Talbot Court, Eastcheap, E.C. Sifam Electrical Instrument Co., 10a, Page Street, Westminster, S.W.1. Weston Electrical Instrument Co., Ltd., 15, Great Saffron Hill, E.C.1.

PERIODICALS. — "Journal of Scientific Instruments," Institute of Physics, 90, Great Russell Street, W.C.1.

PIEZO-ELECTRIC CRYSTALS.—Adam Hilger, Ltd., 24, Rochester Place, London, N.W.1. R. A. Weber, 303, Hither Green Lane, S.E.13.

RESISTANCES (ANODE).—R.I. & Varley, Ltd., 103, Kingsway, W.C.2.

RESISTANCES (FILAMENT).—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C.

SUPERHETERODYNE COMPONENTS. — Bowyer - Lowe Co., Ltd., Letchworth.

SWITCHES.—Wilkins & Wright, Ltd., Kenyon Street, Birmingham.

TERMINALS (SPECIAL TYPE).—Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. Pettygrew & Merriman (1925), Ltd., 2 & 4, Bucknall Street, New Oxford Street, W.C.1.

TRANSFORMERS.—Bowyer-Lowe Co., Ltd., Letchworth. Claude Lyons, Ltd., 76 Oldhall Street, Liverpool. Ferranti, Ltd., Hollinwood, Lancs. Igranic Electric Co., Ltd., 149, Queen Victoria Street, E.C. R.I. & Varley, Ltd., 103, Kingsway, W.C.2. W. G. Pye & Co., "Granta Works," Montague Road, Cambridge.

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