Experimental Wireless

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Experimental Topics.

Trans-Atlantic Telegraphy.

DECEMBER, 1923, will always stand out as one of the stepping stones in the history not only of amateur experimental work, but of wireless progress in general. During the latter weeks some of the most remarkable transmissions ever recorded have been conducted, fuller details of which will be found elsewhere in these pages. It is only within the last few years that the problem of long-distance transmission has been approached from an entirely different view-point. Formerly, the tendency has been to erect gigantic stations using power of the order of some 50 kilowatts or more, and to operate these stations on extremely long wave-lengths. Recent events, however, seem to indicate that this system is now open to considerable rivalry, and its continuance will probably be a matter of some debate. Progress in short-wave transmission during the last few years has led up to a number of experiments on trans-Atlantic telegraphy using a directed beam with an input power of the order of one kilowatt. The success of these experiments has created considerable interest, but this accomplishment seems almost insignificant in light of the recent amateur performances. Mr. E. J. Simmonds, a regular contributor to EXPERIMENTAL WIRELESS, and one of the leading private experimenters in the country, has created what is surely a world's record in establishing two-way communication with a Mr. Dodman, of Summit, U.S.A., using a power of approximately 30 watts. The communication was conducted without the slightest difficulty, and it is not regarded in any sense as a freak performance. Previous to this accomplishment, we have news of Mr. Partridge and Mr. Hogg getting in touch with several American and Canadian stations on powers of approximately 100 watts. The workings were not confined to one or two short periods on one particular day, but were repeated on several occasions. There are two important deductions to be drawn from these events. It is clearly evident that the possibilities of short-wave low-power transmission are not yet fully realised, and are not likely to be so until further investigation has taken place, and, perhaps, it is not rash to suggest in the very near future, the shorter waves will be of greater use than the longer waves. What is more important, however, from the amateur point of view, is that these remarkable transmissions are primâ facie evidence of the value of private experimental work, and should serve to strengthen materially the amateur's position and his relationship with the authorities. While we are strictly opposed to the issue of transmitting licences to all who may care to apply for them, it is sincerely to be hoped that the genuine experimenter will be given greater facilities for further investigations. It is very gratifying to learn that many transmitting licensees are more than justifying their claims for a permit by doing such excellent work, and the fact that each year's performance excels that of the previous year is a clear proof, not only of their capabilities, but of the value of their investigations.

Un-licensed Transmission.

It appears from some information recently received that there are now in existence several amateur stations which are actively engaged in transmission experiments without being in possession of the necessary permit. While we have no wish for unrestricted experimental work, we would remind those concerned that the very existence of the experimenter is dependent on the Postmaster General's regulations, and it is unnatural to expect him to grant greater facilities if those already in existence are so openly abused. Perhaps the un-licensed transmitter does not fully realise that by continuing his experiments he is prejudicing not only his own position, but that of every experimenter. He need not think that his whereabouts are a profound secret, known only to his unlicensed associates, for already in more than one case he has fallen a prey to the D.F. loop, and it now only remains for him to close down. The Postmaster-General is always prepared to consider any application for a transmitting permit if the reasons for use can be fully justified. If the unlicensed transmitter has in view some definite and useful research there is little doubt that he will be granted a permit. If, on the other hand, he does little else than fill the ether with poor reproductions of bad gramophone records, the sooner his station sinks into obscurity the better it will be for all concerned.

The New Strength Code.

For some considerable time it has been customary to record signal-strength by the "R" code, in which there were no fewer than nine degrees of strength. This method of recording is obviously not absolute, being merely a comparison of standards which are subject to personal error. It is a matter of conjecture whether there is anything to be gained by using so many degrees, and the new "A" code, as it is termed, is confined to four degrees only, over which there can be no misunderstanding, and, in our opinion, it is adequate for anything but absolute measurement. Another useful feature of the code, full particulars of which were given in the last issue of EXPERIMENTAL WIRELESS, is that it shows the number of valves used for reception, and, therefore, gives a much clearer indication of the nature of the transmission. It is understood that many experimenters are now using this method in preference to the "R" code, which, it is hoped, will soon be universally superceded by the "A" code.

Terms and Definitions.

The British Engineering Standards Association has just issued a list of terms and definitions used in radio communication. The pamphlet, No. 166, is divided into various sections, and the whole field of wireless work is covered by some 600 definitions. Although most experimenters are fully conversant with wireless nomenclature, there are sure to be certain definitions over which there is considerable disagreement, and we advise our readers to refer to this most useful publication.

The Model Engineer Exhibition.

THE Seventh Annual Small Power Engineering and Scientific Exhibition, organised by the publishers of this journal, will be held at the Royal Horticultural Hall, Westminster, from January 4 to 11. Wireless equipment has always been a feature of the exhibits at this show, and the coming Exhibition will be no exception to the rule. But apart from the radio exhibits themselves, there will be numerous other items of special interest to wireless experimenters. Small lathes, precision tools, and workshop sundries of all kinds will be there in abundance, while general electrical apparatus will be strongly represented. Naturally Model Engineering will form a big section, and the many fine model locomotives, engines and boats, which will be on view will give the wireless visitor an insight into another kind of hobby which, in its way, is quite as interesting as his own. There will be some model railway tracks, 72 ft. long, on which passenger-hauling model locomotives will be constantly at work, and even if the radio enthusiast is wrapped up in the contemplation of some of the newer wireless gadgets in the trade section, his family or his friends will find much to entertain them in the Working Model Railway Enclosure. The Exhibition opens at noon each day, and closes at 10 p.m. The price of admission is 1s. 6d., which includes tax.

Microphone Amplifier and Control Circuits.

By ALAN L. M. DOUGLAS, M.I.Radio Eng.

Most experimenters are content to confine their attention to the adjustment of circuits rather than microphones Below will be found some practical suggestions for the adjustment of microphones for the transmission of music.

IT is rather remarkable that, whilst so much experimental work is done by amateurs on telephony control circuits, they are generally content to accept as a basic exciter the ordinary Post Office type of solid-back carbon microphone.

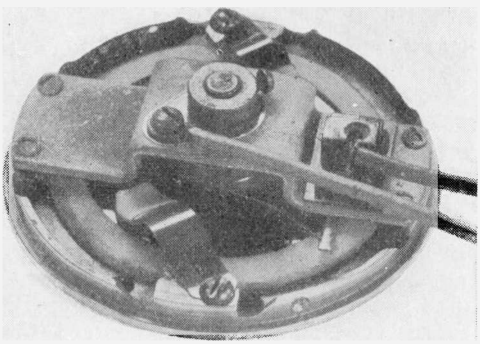


Fig. 1.—Illustrating the Construction of the solid back microphone.

Admittedly the great amount of research work which has been done on such microphones makes them very practical for voice frequencies about the middle register, but from a musical reproduction viewpoint they are vile. There are a number of reasons for this. First of all, the diaphragm of the ordinary Post Office microphone has a natural frequency of about 500. This means that sound-waves having the same frequency, plus or minus about 100, will cause the diaphragm to be energised most and so produce the greatest current changes in the granules. Then the diaphragm, although made of aluminium so as to be as light and as "dead" as possible, is much too thin, and is liable either to (*a*) respond to harmonics, or (*b*) rattle. Much of this could be cured by rigidly clamping the edges of the diaphragm instead of permitting the usual elastic suspension of rubber and springs to be used.

Again, the mica diaphragm carrying the insulated contact of the actual microphone button is much too thin, and is liable to respond on its own (especially at the edges) to high note frequencies which fail to attack the diaphragm proper. Then the granules should be finer and there should be more of them ; the button can, with advantage, be packed almost full, but the carbon must be of an even character, and the granules,

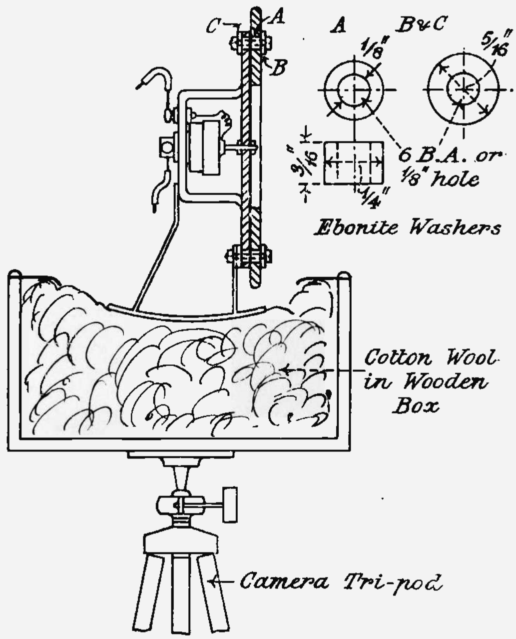


Fig. 2.—Showing a solid back microphone adapted for music transmission.

as far as possible, of the same weight and shape. The correct degree of packing is found by trial.

Now, much useful work may be done upon the transmission of music and similar items requiring great flexibility in the microphone by the use of an ordinary Post at 6 volts. Natural frequency of the diaphragm is 500. Now, for the successful transmission of music the diaphragm must be made to have a natural frequency either above or

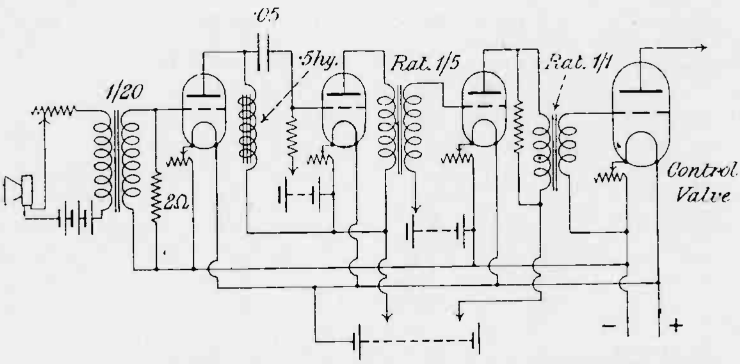


Fig 3.—A typical amplifier for musical frequencies

weighs ·17 oz. The mica diaphragm is ·0022 inch thick and weighs (with carbon contact) ·18 oz. The mica alone weighs ·03 oz. The carbon granules weigh ·08 oz., and when in place, with the button closed

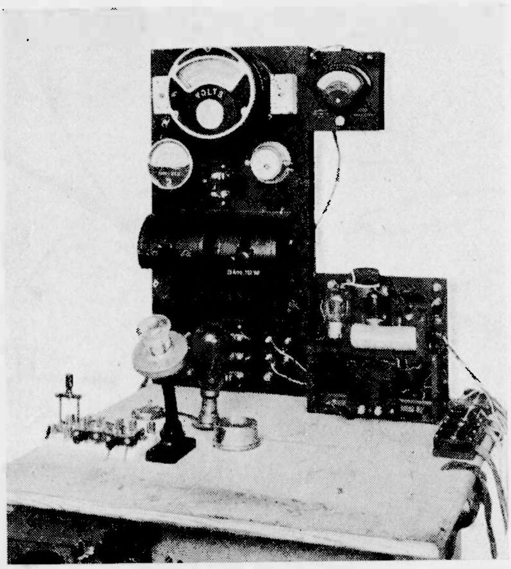


Fig. 4.—A general view of the music amplifier.

for action, so to speak, has a resistance of 17 ohms. This latter figure is approximate, being never twice exactly the same. The pressure exerted by the springs on the aluminium diaphragm is ·64 lb. each side. The average current consumption is ·03 amps. at 6 volts. Natural frequency of the diaphragm is 500. Now, for the successful transmission of music the diaphragm must be made to have a natural frequency either above or below the highest or lowest musical notes; this is practically equivalent to saying above or below audibility. Both of these arrangements are employed in practice; both are equally successful. But for our purposes we will find a sub-audible natural frequency, the most useful, because it is difficult for the average experimenter to stretch the diaphragm until its frequency is raised to such a high figure.

To convert successfully the Post Office microphone we proceed as follows:—It must be remembered that I am dealing here with the transmission of gramophone records, as this is the form of music available to most of us. A gramophone record successfully reproduced is an achievement of which one may well be proud, as it is the most difficult conceivable thing to do well. By well here I mean as well as, let us say, 2LO.

To begin with, the metal diaphragm is removed, together with the tension springs, mica diaphragm, and centre contact button. The granules are emptied out and fresh ones obtained. Very suitable carbon may be obtained from the Western Electric Company. Next, the paper packing ring under the faceplate is scrapped, and a series of six equally-spaced holes drilled round the circumference of the plate where the edge of the diaphragm lies. These holes may be about ¼ in. diameter. The central domed portion of the faceplate should, if possible, be turned right out, as it forms a resonating chamber, which causes "damping" in rapid musical passages.

The small holes just drilled must be carefully bushed with ebonite, and washers provided for front and back attachment. The bushes will only be 3-16th in. long (see Fig. 2). Six bushes and twelve washers are required. A diaphragm ·15 inch thick, and weighing approximately ·3 oz., must be prepared from hard sheet aluminium. This should be beaten out to reduce its resonant properties and to harden the metal, and then rolled absolutely flat. It is no use if it is kinked or dented, and these operations must be performed *cold*. The diaphragm may be enamelled on both sides to prevent corrosion and to minimise the small "room noises" from affecting the applied sound waves, and six ¼-in. holes must be carefully drilled around its edges to correspond exactly with the holes in the faceplate. As the holes in the bushes will only be ⅛ in., or 6 B.A., this size of screw should now be used to secure the diaphragm in position, great care being taken that (*a*) the paper insulating washer is in place, and (*b*) that the screws pass through the centre of the ¼-in. holes and do not touch the aluminium. The ebonite washers are, of course, placed under gramophone sound-box, the central hole (·13 inch) being already drilled. It does not matter if this is ·17 inch, as it will be if taken from a gramophone, as the diaphragm is securely clamped between the carbon disc and the brass washer with lock-nut and adjustment screw thereon. The capsule should be about seven-eighths filled with fine carbon granules, these being adjusted until

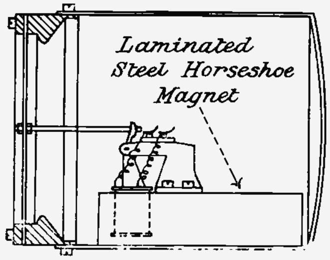


Fig. 5.—A suggested arrangement for a balanced amateur microphone.

the mean resistance of the microphone is approximately 300 ohms with the mica in position. This will mean that the output will be very small, but this is desirable, as it can be further amplified. As an example, with a two-stage amplifier about to be described the best position for gramophone

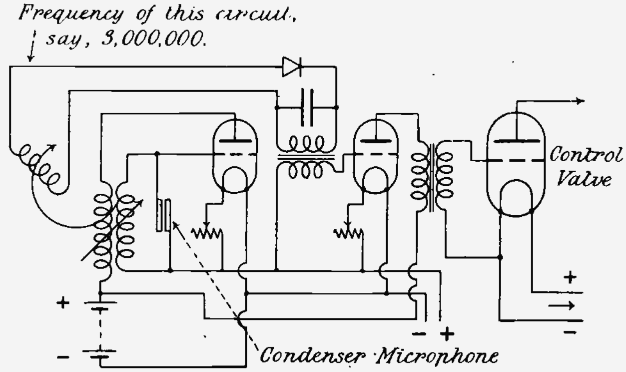


Fig. 6.—An electrostatic microphone circuit in which the modulated output of an oscillator is rectified by a crystal, and subsequently amplified.

the heads and the bolts of each screw and nut. This can all be gathered from Fig. 2. The centre hole in the diaphragm is ·13 inch.

The next step is the correct proportioning of the mica diaphragm. This should be cut from condenser mica of absolutely flawless grade ·05 inch thick, and should weigh ·09 oz. Better still, it may be cut from a transmissions (using a soft needle) will be from 6 to 10 ft. from the instrument, amplification being about 40 per cent. For speech with the same degree of amplification about 3 ft. from the faceplate will be found correct. The reconstructed microphone can be easily assembled, and the adjustment is soon found.

Now the microphone transformer should generally have a primary resistance equivalent to that of the microphone, but it will be found that, if this is carried out, pronounced voltage peaks will be encountered, even when the natural frequency of the diaphragm is only about 10 (as it is in the present case). The windings are, therefore, open to experiment, and the best results are obtained with the following data. A 6-ohm rheostat should be used in series with the microphone battery.

Core.		Primary Winding.		Secondary Winding.	
Length.	Diameter.	Gauge.	No. of Turns	Gauge.	No. of Turns.
4½ ins.	⅜ in.	22 S.W.G. D.S.C. copper.	380	40 S.W.G. S.S.C. Copper.	20,000
28 S.W.G. soft iron wire, tightly packed, open ends.					

A resistance of about 2 megohms should be connected across the secondary winding to control further any peak voltages which may arise. This will also relieve the load when the microphone switch is opened, and prevent a possible sudden rush of current when the circuit is broken on the primary side. In a 100-watt transmitter I have personally experienced a flash-over of the control valve when the microphone circuit was opened, due to the absence of this resistance.

Core.		Winding.		Inductance Values.
Length.	Diameter.	Gauge.	No. of Turns.	
4 ins.	½ in.	40 S.W.G. S.S.C. copper.	3,000	·57 hy.
28 S.W.G. soft iron wire, tightly packed. This choke should *not* have a closed core.				

This microphone transformer is best incorporated into a low-frequency speech amplifier, such as is shown in Fig. 3. The third stage in this amplifier may be omitted if desired, but the coupling to the control valve must be by means of a 1 : 1 ratio transformer. This should have an impedance of about 4,000 ohms each winding, and the power transformers manufactured by the Sterling Telephone Company will be found excellent for this purpose. It will be seen that the coupling in the first stage is by means of an iron-core choke and low-frequency condenser. The choke may consist of the data given in the second table.

The coupling condenser can be of any value between ·01 and ·06 mfd., but ·05 gives extremely good results. The second stage coupling transformer may be of any standard make, but should work at a low flux density, and may, therefore, be of the Army pattern. The valves may be hard—the harder the better; small transmitting valves rated at about 20 watts would seem to give the clearest amplification. The resistance across the output side should be the same as that across the secondary of the microphone transformer, *i.e.*, 2 megohms. A standard grid-leak will serve excellently here. With the microphone just described this amplifier will be found to give about the right degree of modulation when used in a standard choke-control circuit, but the margin of control here is not great and care must be taken not to overdo it. The amplifying circuit will pick up the voice quite clearly from 20 ft. distant, with a minimum of room noises. The degree of control at this distance is, however, too deep, and the best working ranges are as previously mentioned. The amplifier is perfectly silent with correct values of H.T. and grid biasing batteries, and should prove useful for those experimenters who try a little land-line work on

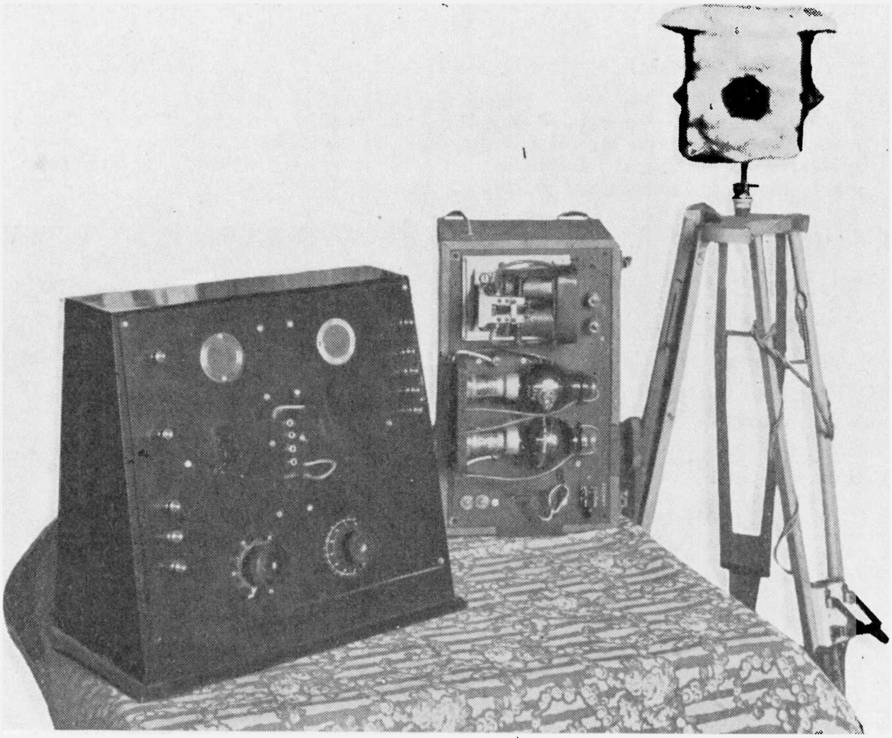


Fig. 7.—A general view of the converted microphone, amplifier, and control panels.

their own, or transmitting amateur theatricals and concerts. The flexibility of the amplifier when such a heavily-damped microphone is employed has enabled the writer to achieve considerable success with the above-mentioned enterprises.

Limitations as to space forbid my discussing the various types of microphone I had intended to, but why not an attempt at a microphone such as Fig. 5? This is a revised arrangement of the microphone employed at the London station, and should give excellent reproduction if carefully made. The great thing is to break away from the intermittent contact type of transmitter, and Fig. 5 presents one solution of the problem.

Then there is the electrostatic type. This is heavily laden with difficulties, but they could be overcome. The writer has used such an arrangement as is shown in Fig. 6, with great success at times, but it is very susceptible to "wash" from the main transmitter, and may do curious things if not suitably shielded. There is ample scope for research work on microphones, and I for one would welcome co-operation along these lines.

Directive Radio Telegraphy and Telephony.

By R. L. SMITH-ROSE, Ph.D., M.Sc., D.I.C., A.M.I.E.E.

During the last few years there has been considerable development in directional work, particularly with the use of extra short waves. There are obviously many applications of directional transmission, and we are giving below a general summary of modern methods and practice.

II.—DIRECTIONAL WIRELESS ON WAVE-LENGTHS ABOVE 100 METRES.

(a) The Theory of Direction-Finding Systems.

A DIRECTIVE system for either transmission or reception can be obtained by the use of vertical wire antennæ, making use of the instantaneous phase difference in space of the electro-magnetic field of an advancing wave. For example, if two vertical antennæ (Fig. 1) of height h, and separated by a distance d, are used for the reception of a wave of length λ arriving from a direction making an angle $90-\alpha$ with the plane of the two aerials, the E.M.F.'s induced in the two aerials will be—

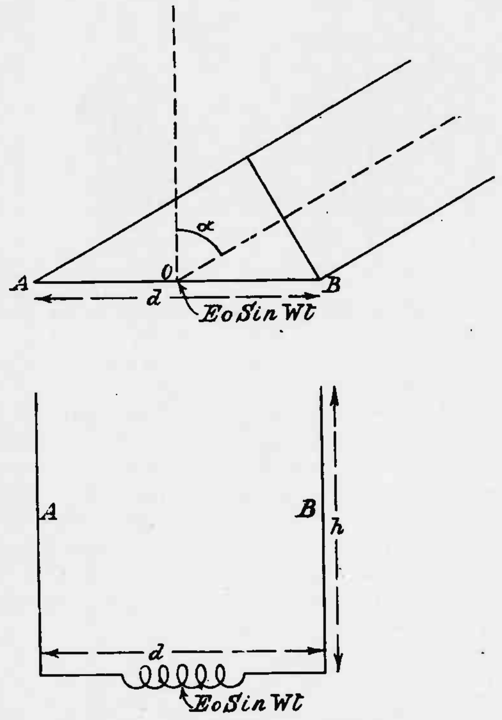


Fig. 1.—Two vertical aerials as a directional receiver.

$$\left.\begin{aligned} E_A &= h\,E_o \sin\left(\omega t - \frac{\pi d}{\lambda}\cos\alpha\right) \\ E_B &= h\,E_o \sin\left(\omega t + \frac{\pi d}{\lambda}\cos\alpha\right) \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where $E_o \sin \omega t$ is the vertical electric field at the centre point o.

The available E.M.F. in the horizontal limb connecting the lower ends of A and B is thus—

$$\begin{aligned} E_C &= E_A - E_B \\ &= hE_o \left(2\cos\omega t \sin\frac{\pi d}{\lambda}\cos\alpha\right) \end{aligned}$$

and when d is small compared with the wave-length λ, this reduces to—

$$E_c = 2\,h\,E_o \cos\omega t\,\frac{\pi d}{\lambda}\cos\alpha \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The signal E.M.F. E_c arising from such a pair of aerials is, therefore, dependent upon α, and passes through zero for the value $\alpha=90°$, *i.e.*, where the direction of the arriving waves is perpendicular to the plane of the aerials. The polar diagram of reception of such a system is shown in Fig. 2, where the vector r represents the intensity of signal received in the direction making an angle α with $O\,X$, the normal to the plane of the aerials.

Several experimenters worked on this method of spaced open aerials for both transmission and reception, and its principles were actually embodied in the original Bellini-Tosi direction-finder, using two pairs of such fixed antennæ and a radiogoniometer of a very similar pattern to that in use to-day.

In practice, however, it was found to be a great advantage to join the upper ends of the antenna A and B, making these into a closed loop, Fig. 3, representative of the modern coil antenna. In the above analysis it was assumed that the electric field of the advancing wave was vertical, and that the only sources of E.M.F. in the system were the vertical antennæ A and B. This is not strictly true in most practical cases, since the advancing wave-front is seldom vertical, and it is well known that signals may easily be received on a horizontal aerial, for example, of the Beverage type. The horizontal component of the electric field will induce E.M.F.'s in the horizontal sides of the loop shown in Fig. 3, and these must be taken into account in a complete calculation of the received signal. The latter, however, can be more easily obtained if we utilise the magnetic field of the wave as the basis of our calculation.

Assuming that the wave front of the incoming wave is sensibly plane, let it be inclined at any angle to the earth's surface, and let the magnetic field lie in any direction in the wave-front; this constituting the most general case for the arrival of a single wave. Let the magnetic field at the point where the loop is situated be resolved into two components at right angles—the one horizontal and the other vertical. Then, since the plane of the loop is vertical, the latter component can never link with it, and may, therefore, be neglected as regards its effect on the loop.

Let the direction of the horizontal component of the magnetic field make an angle of $90^\circ - \alpha$ with the plane of the loop, as in Fig. 4, and let its maximum value be H_m; also let E be the maximum value of the E.M.F. induced in the loop. Then, if the length of the waves be great compared to the linear dimensions of the loop—

$$E_m = KA \cos \alpha \qquad (3)$$

where A is the area of the loop and $K = \omega H_m$, ω being the periodicity corresponding to the waves.

When the loop is turned into such a direction that the E.M.F. induced in it is zero, we shall have $\alpha = 90^\circ$, and the loop will then lie in the vertical plane containing the direction of the resultant magnetic field in the wave-front. In certain common cases, subsequently discussed, this plane is perpendicular to the vertical plane containing the direction of travel of the waves, and from this fact arises the possibility of utilising the arrangement as a direction finder.

(b) The Single-Coil Direction-Finding System.

The single-coil system is a very close approximation to the simple theoretical case already discussed, its chief points of departure being as follows:—

(1) The coil usually has several turns instead of a single turn, and the separate turns cannot occupy the same space.

(2) A tuning condenser and detecting apparatus are usually connected in the circuit.

As regards the first point (1), if it could be assumed that the several turns were all

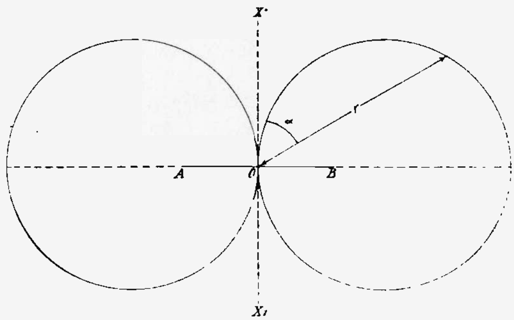


Fig. 2.—Polar curve diagram of reception of aerial system in Fig. 1.

condensed into the space occupied by a single turn we should simply get, instead of (3)—

$$E_m = KP \cos \alpha \qquad (4$$

where P is the quantity (area × turns) for the coil.

In practice, however, the turns cannot coincide. They are, therefore, spaced either in a series of equally dimensioned loops in nearly parallel planes (box type coil), or are wound spirally in the same plane (pancake-type coil).

In the case of the pancake winding the law expressed in equation (3) still holds good, but the quantity A must now stand for the effective or mean area of the coil.

In the case of the box coil this is usually wound spirally with a slight "skew" on the winding, which may give the effect of an equivalent turn in the plane of the coils' axis. The error so introduced, however, is usually only a fraction of a degree, and this may be entirely eliminated by a slight adjustment of the pointer on the coil, or by adopting a special mode of winding in which each turn is accurately located in a single plane.

As regards (2) above, in the practical use of such a single-coil system for the determination of direction, a variable condenser is introduced across the ends of the coil and adjusted to give resonance to the incoming waves. The resulting alternating potential difference across this condenser is then employed to operate the detecting amplifier arrangement to give audible response to the incoming waves (Fig. 5).

When the above condenser is connected to the loop and the resonance condition obtained, the current in the loop from equation (4) will be—

$$I_m = \frac{E_m}{R} = \frac{KP \cos \alpha}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

where R is the effective resistance of the loop under the prevailing radio conditions. The

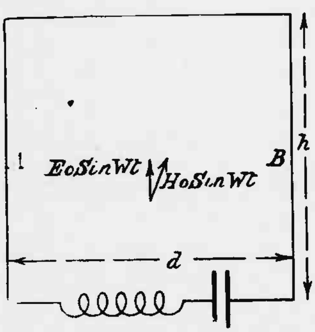


Fig. 3.—Closed loop directional receiver.

value of R depends not only upon the dimensions of the loop and the frequency being employed (*), but also upon the nature and circuit of the detecting arrangements (†).

The value of the P.D. across the condenser resulting from the current I_m will be—

$$V_m = \frac{I_m}{\omega C} = \frac{H_m P \cos \alpha}{RC} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

where C is the capacity of the condenser at resonance.

It is evident, therefore, that the alternating potential difference applied to the detector varies with the orientation of the coil in precisely the same manner as the E.M.F. induced in the coil.

Two disturbing features, however, arise from the connection of the detecting apparatus, usually a combined amplifying-detecting arrangement of triodes. Firstly, the leads and whole circuit of the latter may pick up a small E.M.F. from the incoming waves, which will be independent of the orientation of the coil. While this E.M.F. may be small compared with the maximum value of V_m (*i.e.*, when $\cos \alpha = 1$) it may be quite sufficient to give a very audible signal when $V_m = 0$

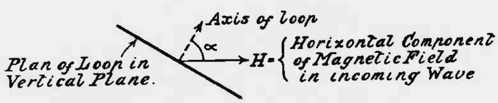


Fig. 4.—Plane vertical loop in path of electro-magnetic waves.

(*i.e.*, at $\cos \alpha = 0$). The result will, therefore, be a "blurring" of the zero of V_m into a more or less ill-defined minimum, which may considerably spoil the accuracy of the determination of the position of the coil for which $\alpha = 90°$. Secondly, due to the capacity to earth of the valve apparatus connected across the condenser, vertical capacity currents will flow to earth from the two vertical sides of the coil. In general, these currents will be unequal, due to the capacity to earth of the grid of the first valve being much smaller than that of the filament of the first valve with its associated batteries (compare Fig. 5). The inequality of these two currents results in a P.D. across the condenser G, even when there is no circulating current in the coil itself. Dependent also upon the inductance of the vertical sides of the loop and their capacity to earth, the phases of these currents will vary, but in general the resultant P.D. produced across the condenser by these currents is practically in quadrature with that produced by the circulating currents, as evidenced by the ill-defined zero of signal strength which is obtained on a coil possessing appreciable "vertical" or "antenna" effect. Another result of this vertical effect on a rotating coil system is that, in a complete rotation, the two minima of signal strength

* A. S. Blatterman, "Theory and Practical Attainments in the Design and Use of Radio Direction-Finding Apparatus Using Closed-coil Antennas," *Journal Franklin Institute*, Vol. 188, pp. 289–362, 1919.

† J. Hollingworth, "Notes on the Design of Closed-coil Receiving Sets," *Wireless World and Radio Review*, Vol. 10, pp. 351–354, 1922.

are not exactly 180° apart, due to the non-directional properties of the superimposed P.D. resulting from the above antenna currents.

Various means of overcoming this defect on the single coil direction-finder have been suggested, one of the most successful being the use of a compensating condenser connected between the grid of the first valve and earth, by which the smaller capacity C (Fig. 5) is increased to be equal to C_1. In this case the two "antenna" currents become equal and produce no resultant P.D. across condenser C. Another very effective method consists in the use of a suitable screen surrounding the whole of the coil receiver and operator.

(c) The "Bellini-Tosi" Direction-Finding System.

In this system two large loops, usually of a single turn and of rectangular or triangular shape, are erected with their planes at right angles. In series with each loop is connected a small field coil. These two field coils are also mounted with their planes at right angles and preferably parallel to the planes of their respective loops, and a small search coil is pivoted so as to rotate within them. The axis of the search coil carries a pointer which moves across a horizontal circular scale divided in degrees.

The aerial loops and field coils of such a system are represented diagrammatically in Fig. 6 (*a*) and (*b*). Consider a wave front of the same general type as assumed for the case of the single coil and let the horizontal component of its magnetic field make an angle $(90-\alpha)$ with the plane of the loop A. As before, the vertical component cannot affect either loop, and so may be neglected. Applying equation (1) above to this case, and employing the same notation, we have—

$$E_m{}^1 = KA \cos \alpha$$
$$E_m{}^{11} = KA \sin \alpha$$

where $E_m{}^1$ and $E_m{}^{11}$ are the circulating E.M.F.'s induced in the loops A and B respectively and the area A of each loop is assumed to be identical.

Now, the magnetic field produced by the two field coils will be in the direction of their axes and proportional in magnitude to the current in each loop; that is, assuming an identity of the electrical constants of the loops whether they be tuned or untuned, proportional to $E_m{}^1$ and $E_m{}^{11}$ respectively. Hence, assuming the search coil is so small that the field is sensibly uniform over its area, we have:—

$$\left.\begin{aligned} H_m{}^1 &= K^1 H_m \cos \alpha \\ H_m{}^{11} &= K^1 H_m \sin \alpha \end{aligned}\right\} \quad \ldots\ldots (7)$$

where $H_m{}^1$ and $H_m{}^{11}$ are the fields in question and K^1 is a constant depending on the area and constants of the loop circuits and the frequency of the waves. It is clear that the resultant of these two components $H_m{}^1$, $H_m{}^{11}$ will have a value—

$$H_m{}^{111} = K^1 H m \quad \ldots\ldots (8)$$

and will lie in direction making an angle α with the axis of the field coil A.

Thus a field is obtained from the field coils reproducing, as it were, in miniature the main field in which the two loops are situated, *i.e.*, the strength of the field is some definite fraction of the main field which is independent

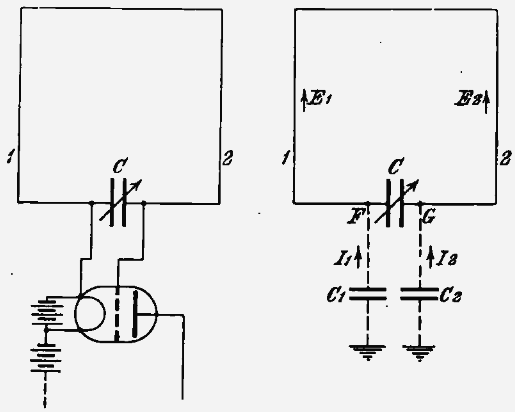


Fig. 5.—Arrangement of coil with tuning condenser illustrating capacity effect due to triode and its batteries.

of the direction of arrival of the waves relative to the loops, while the direction of this field makes, with the axis of the field coil A, the same angle which the main field makes with the loop A.

Hence, the search coil turning within the field coils is equivalent to a single rotating coil directly receiving the energy of the waves. It is thus possible to determine the direction of the waves by rotating the search coil to find the position where the currents induced in it are zero or a minimum.

The Bellini-Tosi system is thus in theory exactly equivalent to the ideal single-turn rotating loop. Like the rotating coil direction-finder, it is liable to a certain amount of " antenna " effect ; that is, the P.D. across the detector may not be entirely due to the circulating E.M.F.'s in the loops for the same reason, as in the case of the rotating coil. It may also be noted that the necessity with this system for exact similarity of the two loops, with their circuits and their accurate setting at right angles to one another, introduces a number of possible sources of error (due to non-fulfilment of these conditions) which are not present in the case of the rotating coil system.

(d) The Robinson System.

In this system the two coils A and B (Fig. 7) are fixed rigidly at right angles and pivoted about a vertical axis o.

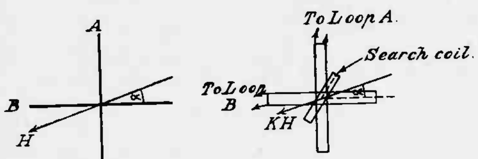


Fig. 6.—Schematic diagrams of Bellini-Tosi System.

The two coils are connected in series, and one of the coils can be reversed with regard to the other by means of a switch.

Let area turns of coil A be P.

Let area turns of coil B be Q.

Let H_m make an angle $(90-\beta)$ with the effective plane of the coil A. Then, if E_m^{1} and E_m^{11} be E.M.F.'s in A and B respectively, and there is no mutual induction between the two coils, we have—

$$E_m^{1} = KP \cos \beta$$
$$E_m^{11} = KQ \sin \beta$$

But since the two coils are in series, we have for the resultant E.M.F. in the circuit—

$$E_m^{111} = K \left[P \cos \beta \pm Q \sin \beta\right]$$

The sign in the bracket being negative or positive, according to the position of the reversing switch.

If now we choose an angle φ such that—

$$\tan \varphi = \frac{P}{Q}$$

we can write—

$$E_m^{111} = K \ (\cos \beta \ \cos \varphi \pm \sin \beta \sin \varphi) \ \sqrt{P^2+Q^2}$$

i.e., $E_m^{111} = K \ (\sqrt{P^2+Q^2}) \ \cos \ (\beta \pm \varphi)$ ....(9)

but this is of the same nature as the expression obtained in (3) for the single-turn loop, for it can be written—

$$E_m^{111} = KP^{11} \cos \alpha$$

where $P^{11} = \sqrt{(P^2)+(Q^2)}$; and $\alpha = (\beta \pm \varphi)$

From this it can be seen that the system is equivalent to a resultant single coil with area turns $= \sqrt{P^2+Q^2}$ displaced by a fixed angle $\pm \varphi$ from the coil A, where—

$$\varphi = \tan^{-1} \frac{P}{Q}$$

This movement of an imaginary single coi by operating a switch is very similar to the swinging of a single frame or search coil of a radiogoniometer.

The angle is changed from $+\varphi$ to $-\varphi$ with relation to the coil A as the switch is reversed.

This resultant coil may be obtained by adding vectorially the area turns of the two coils in the manner shown in Fig. 8.

It is then clear that each time the switch is reversed it is equivalent to displacing a single coil suddenly through an angle of 2φ. If then, as in the method of operating the direction-finder, the whole system be rotated until a position is found in which the signal strength is equal in both positions of the switch, the resultant coil will be alternating between two positions symmetrical about its maximum or minimum position ; that is to say, the coil must then lie with its plane parallel to H_m. In this way, therefore, it is possible to determine the direction of arrival of simple types of wave fronts. The angle of " swing " (2φ) of the resultant coil can be made the most suitable value by correctly choosing the ratio of P/Q.

(e) The Use of the Three Systems.

On account of the similarity in fundamental principle of these three systems of direction finding it is, therefore, to be expected that the results obtained by them are of a similar order of accuracy. Concentration on the details of design and construction of the apparatus, and judicious application of the principles of screening, has resulted in the elimination of many spurious effects leading to instrumental errors, which can now be reduced to a negligible magnitude for most practical purposes. The Bellini-Tosi system appears to have received most attention in this respect, and in many cases for shore station work it has superiority in regard to robustness, ease and quickness of operation and detection of unreliability of the readings obtained. Where, however, portability and low cost are of great importance the single rotating frame is an excellent substitute. In many cases the Robinson system can be used with equal advantage, and it is greatly superior

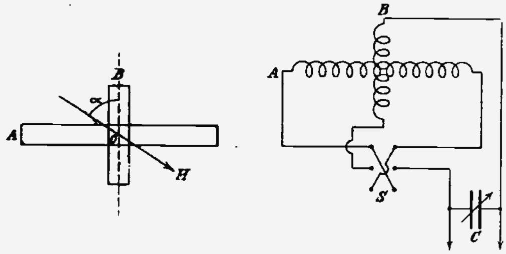


Fig. 7.—Plan of coils and diagram of connections of Robinson System of D.F.

to the other two systems in the presence of a large external noise which makes the detection of the minimum very obscure. For further details of the arrangements and uses of these directive systems the reader may be referred to text-books on the subject.§ Also in a recently published report of the Radio Research Board,¶ the above theory of the systems is considered in somewhat greater detail, and the conclusions are confirmed by a large number of results obtained in an experimental comparison of direction-finders.

(f) What is Indicated by a D.F. Coil.

From the theory of the closed-loop direction-finder given above it is seen that when the coil is rotated about a vertical axis until the strength of the signal in the telephones becomes zero or is reduced to its minimum value, the coil is then set with its plane parallel to the horizontal component of the magnetic field of the arriving wave. What is required in practice, however, is to determine the horizontal direction along the earth's surface from which waves arrive. Now, in the arriving electro-magnetic wave we know that the plane of the wave-front is perpendicular to the direction of propagation, and also that both the electric and magnetic fields lie in the wave-front and are at right angles to each other. If the direction of propagation of the waves is horizontal, then the wave-front is vertical, and all components of the magnetic field lie in the wave-front. The vertical coil placed in the position of minimum signal strength will, therefore, have its plane parallel to the wave-front, and the direction of the incoming waves will, therefore, be perpendicular to the plane of the coil. Hence, in this case the D.F. coil will indicate the direction of the arriving waves, whatever may be the direction of the magnetic field in the wave-front. The above condition of a vertical wave-front and horizontal propagation applies to the case of waves travelling over the surface of a perfect conductor, and for most practical purposes it is applicable to the propagation of wireless waves over sea-water.

When, however, the waves are travelling over a bad conductor such as dry earth eddy currents are set up which involve losses, and there is consequently a continual feeding of energy into the ground material. Resulting from this, the direction of propagation is inclined slightly downwards below the

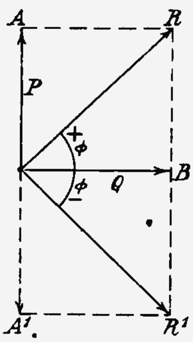


Fig. 8.—Direction and relative magnitude of resultant coil in Robinson System.

true horizontal, and the wave-front is consequently tilted forward in the direction of travel. Unless the magnetic field in this wave-front is entirely horizontal the horizontal component will not be perpendicular to the direction of travel of the waves, and the rotating coil will not necessarily indicate the direction of the arriving waves.

§ L. H. Walter, "Directive Wireless Telegraphy," 1921. (Sir Isaac Pitman & Sons, Ltd.) R. Keen, "Direction and Position-Finding Wireless," 1922. (The Wireless Press, Ltd.)

¶ R. L. Smith-Rose and R. H. Barfield, "A Discussion of the Practical Systems of Direction-Finding by Reception," Radio Research Board, Special Report No. 1, 1923. (H.M. Stationery Office.)

Generalising from the above, it is seen that what is actually determined from the rotation of a coil about a vertical axis is the direction of the horizontal component H of the magnetic field of the arriving waves. To determine the horizontal direction D from which the waves arrive it is necessary to know the angle between D and H. Practical experience with direction-finding has shown that in the majority of instances it is justifiable to assume that D and H are at right angles. This condition, however, can only hold for the two cases discussed above, *viz.*, first that the direction of propagation is strictly horizontal, or, second, that the wave is polarised such that the magnetic field is horizontal. The former case implies that the wave-front is vertical, whereas the latter imposes no condition as to the inclination of the wave-front.

It is evident, therefore, that absence of directional error in the readings of a frame coil direction-finder does not indicate anything very precise about the advancing wave-front or the inclination of the magnetic and electric vectors therein. The wave-front may be tilted forward at any angle, provided that magnetic field remains horizontal, or if the wave-front remains vertical the magnetic field may be inclined at any angle therein without giving rise to any error in the indications of the direction-finder. From the theoretical discussion correlating the systems of direction-finding it is evident that the above remarks in reference to a single frame coil apply equally well to the Bellini-Tosi and Robinson systems.

[*To be continued.*]

Radio Station 6UV

Amateur transmission stations usually show a marked dissimilarity in circuits, systems, and apparatus employed. This is due no doubt to the fact that many experimenters build their sets as a result of their own investigations. In order that experimenters may become acquainted with the work of others, details of stations embodying novel methods and circuits would be welcomed in these pages.

THIS station is located in Berkhampsted, Hertfordshire, at an elevation 500 feet above sea-level on the ridge of the Chiltern Hills, and is so placed that it is almost entirely free from screening either by natural or artificial objects.

Until the early part of the current year the station, which was first erected in 1912, and was equipped for reception only, was situated in a lower part of the town in a position far from ideal for transmission purposes.

This is mentioned because at this time the writer, in considering a site upon which to build a house, was fortunate enough to secure a position on the highest ground in the neighbourhood, giving considerable facilities for serious radio work.

The aerial, which is designed primarily for 200 ms. transmission, is of the twin inverted L-type, consisting of 7/20 H.D. copper, each strand being enamel insulated, and runs due North and South, each wire being insulated with three large porcelain insulators in series, the bridles of each of the 10 ft. spreaders being also broken with insulators.

The total length from free end to lead-in terminal is 120 ft., the measured fundamental wave-length being 175 metres, which in practice, owing to the employment of a counterpoise, is reduced to approximately 170 metres.

The aerial is slung from a 40 ft. wooden mast at the N end (shown in Fig. 1), and by a similar mast 45 ft. high at the S end. Each mast is stayed with ½-inch wire rope, the anchor blocks for the stays and also the mast housings being concrete, sunk to a depth of 3 ft. This is necessary owing to the exposed position of the station and prevalent N.-W. gales.

A six-wire counterpoise is used directly under the aerial roof, each wire being spaced 2 ft. and 8 ft. above ground, and the whole fanned out to a distance of 20 ft. beyond each mast. The counterpoise lead can be seen in Fig. 1 alongside the main mast, but the counterpoise itself is not shown, as the photograph was taken before this was constructed.

Owing to the absence of earthed bodies the mean effective height of the aerial is 11·4 metres, and the capacity works out at approximately 0·00032 mfds.

The actual lead-in and main earthing switch are shown in Fig. 2, which also shows the 2-inch diameter mica tubes built into the wall as lead-in tubes. This photo also shows clearly the protection afforded to the lead-in insulators against rain by the overhanging gable.

On 195 metres, which is the normal operating wave-length, the radiation resistance is 4·8 ohms, and on 440 metres—the alternative wave for which the station is licensed—1·15 ohms. These combined with the ohmic and absorption losses give a total aerial resistance for the two wave-

Fig. 1. 40 ft. mast and counterpoise lead.

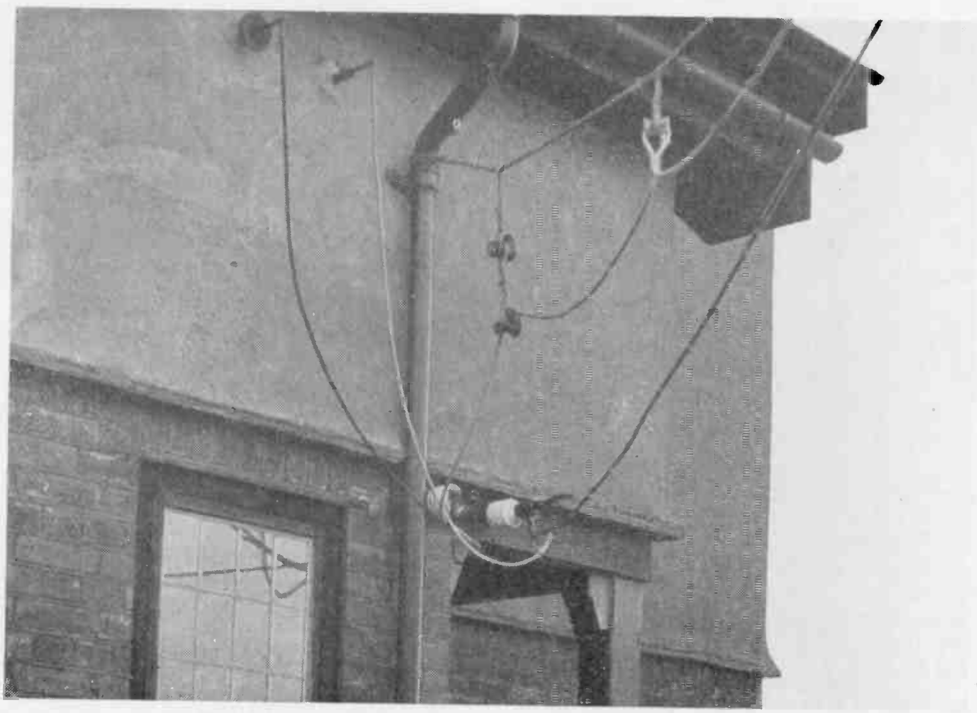


Fig. 2.—Aerial and counterpoise leads in, showing earthing switch.

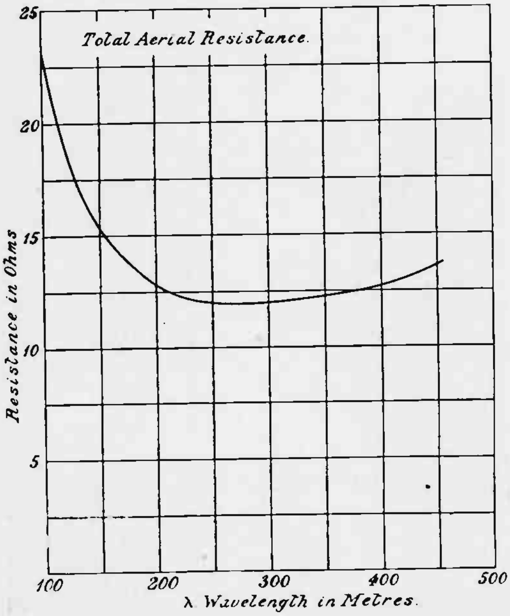


Fig. 3.—Total aerial resistance curve.

lengths of 13 and 13·4 ohms respectively, and as a matter of interest the total aerial resistance curve is given in Fig. 3.

Power for transmission is taken from a B.T.-H. 1,000 V.D.C. generator illustrated

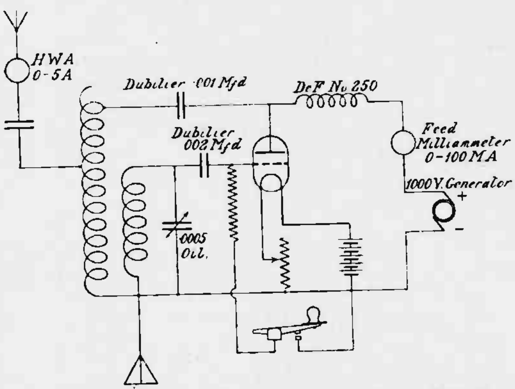


Fig. 4.—The circuit employed for transmission on 440 ms.

in Fig. 6, which is capable of giving 100 watts on continuous rating. This machine, originally an R.A.F. wind-driven plant, is run as a motor-generator from the house-lighting system, taking 8 amps. 16 volts on full load.

The transmitter itself is shown in Fig. 5, and is of the reversed feed-back type, the circuit diagram being shown in Fig. 4. All condensers used are of Dubilier manufacture with the exception of the oil immersed grid variable, which is ex-Navy, calibrated direct in jars. The radiation meter is a Sullivan 0—5 amp.

As a stand-by against failure of the main generator, an ex-Army T.v.T. unit is installed—seen on the extreme right of Fig. 5—for Tonic Train work, and will give

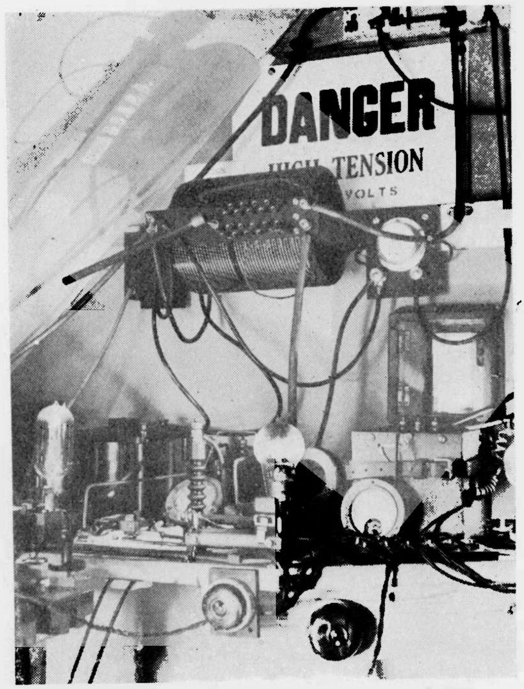


Fig. 5.—Near view of the transmitter in use at 6UV.

0·5 amp. in the aerial at 440 ms. The main inductance, with interior rotating grid coil, can be seen on the wall, and a "close up" of this unit is given in Fig. 7.

For straight C.W. a 40-watt oscillator valve is employed, the output of which can be modulated for speech by means of another 40-watt valve, the choke control shunt feed method being employed. When changing over from speech to C.W., the modulating valve is automatically cut out of circuit, the speech choke being at the same time short-circuited. A continuously variable grid-leak of the liquid type is used, giving very critical values of radiated power.

With a measured 10-watts input to the

valve, 0·8 is radiated on 195 metres, and 0·85 on 440 ms., both these figures being for straight C.W.

The receiving equipment, which is not shown in the illustrations, consists of a standard Mark III * tuner and 3-valve receiver (1 H.F. Det. and Note Mag.) for general work; a Marconi-type 55—7 valve amplifier arranged for supersonic working being used for long-distance traffic, and when QRM is bad a 3-valve receiver is employed of the type described by the writer in the December issue of EXPERIMENTAL WIRELESS.

Within the last month extensive trials of the Colpitts circuit have been carried out on 195 metres, with the result that it is proposed in future to use this circuit on the short wave, retaining the present transmitter solely for 440 ms. traffic.

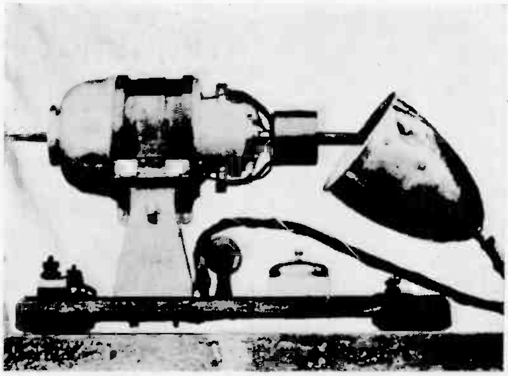


Fig. 6.—B.T.-H. 1,000-v. generator, showing main H-T. condenser.

In conclusion the writer would welcome reports from other stations who may hear 6UV.

G. L. MORROW.

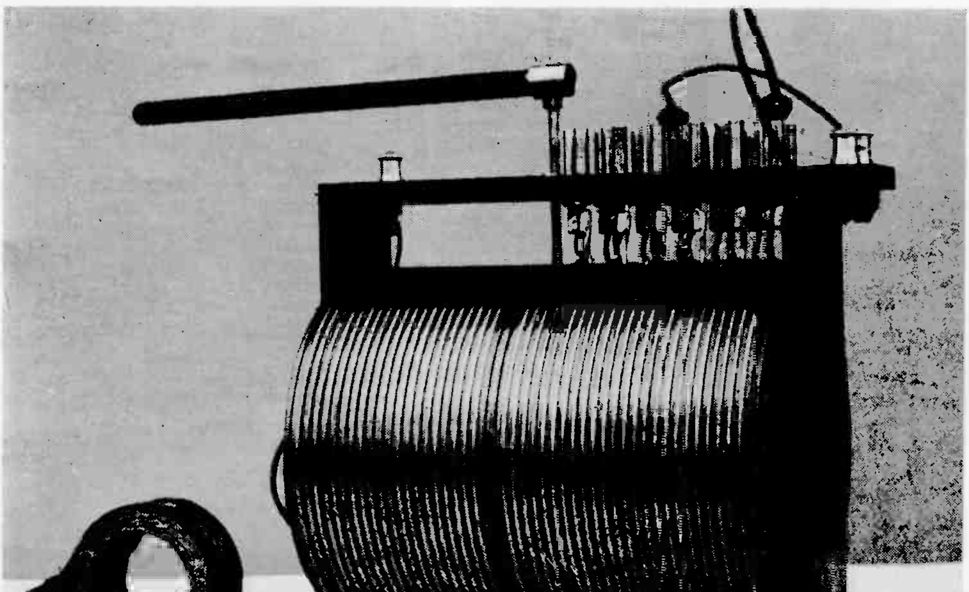


Fig. 7.—Transmitting inductance with 250 Igranic coil, showing relative sizes.

Frequency Transformers.

BY H. T. DAVIDGE.

Although the problem of frequency multiplication presents many difficulties from a practical point of view it occurs in many branches of radio work, and the following summary should be of great interest.

THE problem of conversion of an alternating current at one frequency into alternating current of another frequency arose long ago. It has never been an easy problem, and only partial solutions exist even now if variation of frequency and economy are both essential. An obvious method for a constant ratio of the two frequencies is to use an A.C. motor

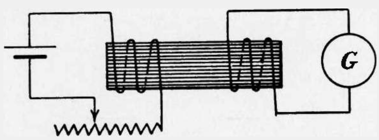


Fig. 1.—An alteration of the rheostat causes a current to flow through G.

coupled to an A.C. generator having the different required frequency, but this is cumbrous, expensive and invariable. The generator poles might, however, be in groups giving a twofold or higher ratio if desired. One method, which is in a sense frequency transformation, is the well-known heterodyne method for the reception of continuous wave signals. As an analogy a tuning-fork, for example, may be sounding a note of frequency 500 per second, and, audible with it, another fork having a frequency of 480 per second. The result of the combination of the two oscillations is a resultant wave which has peaks and hollows greater than either of the constituent waves, the peaks occurring with a frequency of 20 per second. Thus we have converted by this arrangement two different high-frequency oscillations into one of a very much lower frequency. The frequency of the beat note is simply the difference between the frequencies of the two given notes, and it is obvious that the same beat frequency may be obtained when one of the given notes is either above or below the other by the same amount. This method is now applied to detect an inaudible frequency by locally generating another inaudible frequency, but differing somewhat from the incoming one so as to produce an audible beat frequency so long as the other two are oscillating together. To thus cause two oscillations, both above the upper limit of human audition, to combine together and make a note of a musical character is one of the most ingenious methods for detecting ether waves. It, of course, necessitates an apparatus for making with certainty waves of nearly the same frequency and amplitude as those we wish to receive. Frequency changers however are in practice made on quite different principles which need no local generator to co-operate with the incoming current and the usual effect made use of is the magnetisation of an iron core by an electric current. In connection with the early days of telephony it will be remembered that if we take two ordinary

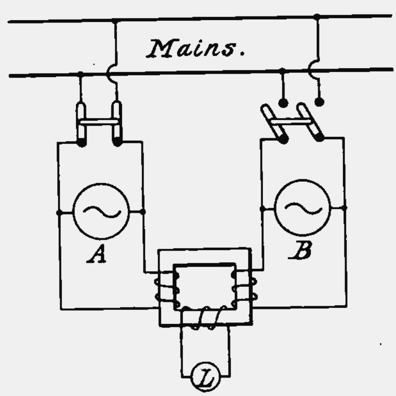


Fig. 2.—An arrangement for synchronising two alternators.

telephone receivers and connect them by lines without any battery, then on speaking into one, the other repeats the sounds at the distant end. The motion of the iron diaphragm at the one end generates *alternating* currents which cause corresponding motions of the diaphragm at the other end. When the microphone and induction coil are added, at the sending end only, the process involves a *continuous* current in the microphone circuit, varied in strength by variation of resistance of the carbon granules. This current never reverses, but passing through the primary of an induction coil it causes strengthening and weakening of the flux in the iron core, and thus generates *alternating* current in

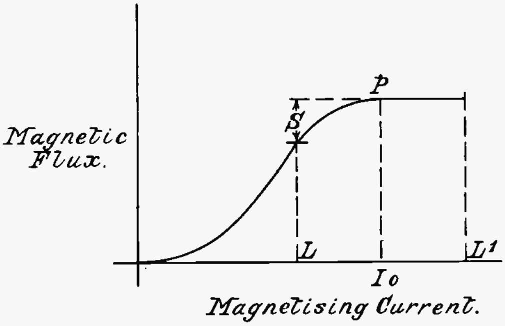


Fig. 3.—A typical magnetisation curve for iron.

the secondary or line circuit. Thus variation of magnetic flux always leads us to an alternating current. The same effect is found in the armature of a D.C. dynamo, but the brushes so arrange matters that unidirectional current only comes outside. This effect of change of flux may be made clear by a simple experiment. If an iron core (Fig. 1) has two coils upon it, one connected through a rheostat to a battery and the other to a galvanometer, we find that when the rheostat slider moves so as to increase the battery current there will be a current in G in one direction, while when the rheostat slider moves so as to diminish the battery current there will be the opposite current in the galvanometer. Thus variations up and down in a continuous current by the use of an intermediary magnetic flux cause alternating current in another circuit.

An application of the principles of the magnetic flux in a transformer and the beats due to two slightly different oscillations occurring together is found in the synchroniser used for coupling two alternators in parallel to the same mains on a switchboard. Suppose the frequency of the station to be 50 and machine A is already running. The load is increasing and it is necessary to insert B in parallel with A. Before a second alternator can be connected in parallel to the mains, not only must the voltage of the second machine equal that of the first—as in direct-current machines—but the phase of each must be the same; hence the need for a synchroniser. The type which illustrates our present problem is connected as follows: A transformer has three windings on its core, one connected to machine A, one to machine B, and a small secondary to a pilot lamp.

The two primary coils may be either wound similarly or oppositely. The connections are shown in Fig. 2. If similarly connected then when machines A and B are in phase the magnetic flux swings to and fro round the core with maximum energy, and the pilot lamp gives maximum light. If the two coils are oppositely wound then when A and B are in phase the magnetic flux due to one is exactly equal to that due to the other and the lamp remains dark. The procedure is then, using the bright lamp method, as follows: Machine A alone causes the lamp to glow, but when B is put on, out of phase to begin with, the light of the lamp oscillates. The attendant then adjusts the phase of B, and as it becomes nearer the right position beats of light occur as in sound, the frequency of the beats

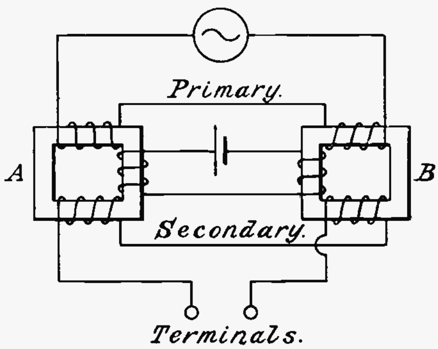


Fig. 4.—A frequency raiser due to Arco and Meisner.

growing less and less until the lamp remains steadily very bright. At that moment the main switch connecting B to the mains is closed. This quite old method of synchronisation suggests the use of the transformer with magnetic fluxes more or less in opposition as in those newer methods for frequency-raising now to be described.

The magnetisation curve of iron is as shown in Fig. 3. When the curve becomes horizontal at P the iron is saturated. If the magnetising current alters on either side of the mean value at I_0 to L or L^1, then in one case we obtain no increase of

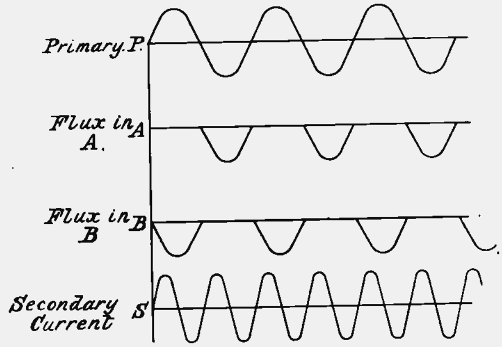


Fig. 5.—Illustrating the operation of the Arco and Meisner frequency raiser.

magnetisation while in the other the magnetisation drops by the value S.

The frequency-raiser of Arco and Meisner operates as follows :—

In Fig. 4 A and B are two transformers, the core of each of these being magnetised

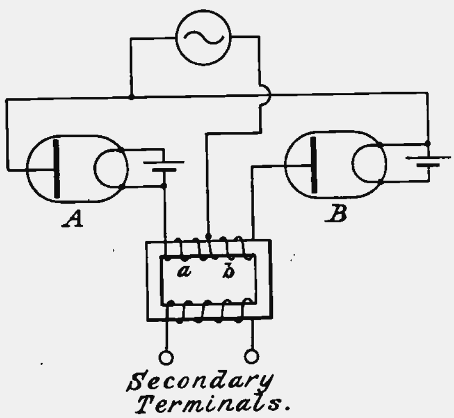


Fig. 6.—Showing the use of diodes for frequency multiplication.

just to saturation by the battery between them. The supplied alternating current passing through the primary of each transformer, in one half wave causes no change of flux, and in the other half wave a decided change of flux. Hence the secondary coil at the bottom of each in the figure has an e.m.f. in it due to this change of flux, the nature of the e.m.f. depending on the rise or fall of the flux.

The two primary windings are wound oppositely to each other and may be either in series or in parallel, while the two secondaries may be connected, either opposing each other or assisting each other. When opposing each other the resulting secondary current has a frequency double that of the primary. When the secondaries assist each other the secondary frequency is three times that of the primary.

Fig. 5 shows the effect graphically, the primary oscillations being shown at P, the flux change in A at A, and that in B at B, while the resulting secondary current of double frequency is shown below.

The soft iron core, when at saturation, is made use of in this ingenious method because of the property it thereby possesses of giving a result when the applied current is in one direction and giving no result when the current is in the opposite direction. Since a valve has unilateral conductivity

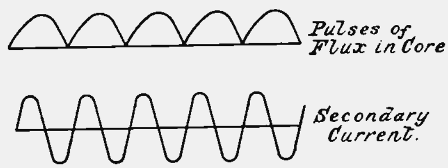


Fig. 7—Illustrating the relation between flux and secondary current.

it suggests itself as another appliance suitable for frequency conversion, and it has been so applied.

The arrangement is shown in Fig. 6 in which a source of alternating current is coupled to two 2-electrode valves. One pole of the supply is connected to the plate of one valve and the filament of the other, and the other pole of supply is connected *vice-versa* through a primary winding of a transformer. The effect is that during one half period the current can flow through the first valve and not through the second, while during the second half period the current flows through the second and not through the first.

Considering the moment when the supply voltage is causing electrons to flow in valve A, then there is no flow in valve B, but it will be seen that the electron current in the transformer coil *a* is to the left. Half a period later when the electrons are flowing in B but not in A the electron current in the half of the transformer *b* is also to the left. Hence each half period causes a magnetic pulse of the same kind.

Fig. 7 shows the effect of these on the secondary where rising magnetic flux causes a current in one direction, while falling magnetic flux causes the opposite current. Hence the frequency of the secondary current is double that of the primary current. The diagrams of the two methods here given are made as simple as possible, and it should be noted that there are in reality inductances included in the battery circuits to keep the oscillations out of the batteries, and as induced effects are always enhanced in the secondary circuit when this is tuned, in practice the secondary is tuned by inductance and capacity to the required double or treble frequency of the primary current.

A frequency-raiser giving a treble frequency has also been designed by Kujirai.

The principle of the saturated transformer core is used, but he uses three transformers, two only of which are saturated by a battery current. The principle of the apparatus is shown in Fig. 8 in which the primary circuit is the upper line, and the secondary the lower line, the current in this

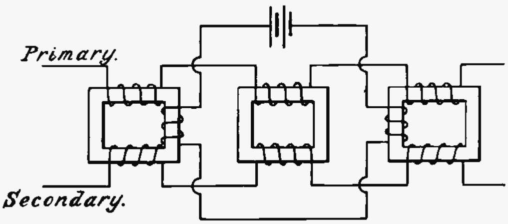


Fig. 8.—A saturated iron core frequency raiser.

latter having three times the frequency of that supplied.

An electrolytic valve as used in various forms for charging accumulators from alternating supply is another unidirectional piece of apparatus which conceivably might be embodied in a form of frequency changer, but the writer is not aware of any method employing this.

Both-way Amplification.

By ALEXANDER J. GAYES.

Although uni-directional amplification is normally employed for most wireless purposes the valve is frequently used so as to amplify from either end of a line. The following summary of the principles employed should provide useful data for experimental work.

THE introduction of one or two stages of L.F. amplification to a circuit carrying speech currents does not present any particular difficulty to the average wireless experimenter. He will arrange his valves, inter-valve transformers or resistance capacity couplings and quickly produce a circuit which will give the desired increase in volume. True, there is more in L.F amplification than is implied by the above remarks, but that is a subject in itself, and it is proposed to consider here, not so much the method of amplifying as the application of amplifiers to ordinary speech circuits.

L.F. amplification as applied to a wireless-receiving circuit is, when all is said and done, only a one-way device. It is a talking channel through which speech can be transmitted from one end only. Imagine a telephone which will "speak" only one way and it will be seen at once how limited is its application. Endless possibilities arise in the application of an amplifier which will function in both directions. That is, an apparatus such that it will give "B" an amplified reproduction of "A's" speech and conversely give "A" an amplified reproduction of "B's" speech. The subject forms an interesting study and gives scope for experimenting in an application of valve amplifiers which has so far received little or no attention from those outside any direct commercial application such as the introduction of amplifiers in the lines of the Public Telephone Service. Incidentally it should be mentioned that the experimenter must not interfere in any way with the public service : to tamper with, or to attach

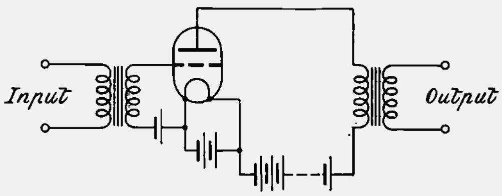


Fig. 1.—The input and output must be independent of external batteries.

to, the public telephone, apparatus of any description is quite illegal, and any mention here of a telephone line refers to a purely private line or the line of a domestic telephone system not associated with the public service. There are many domestic inter-communication schemes, hotel service and the like, where amplified speech might be appreciated. By its aid people with defective hearing could use a telephone. In fact, by the introduction of a both-way amplifier, the improbable but nevertheless possible desire of two partially deaf people to converse over a pair of wires without unduly raising the voice could be accomplished. Loud speakers could be used to replace ordinary telephone receivers, and such apparatus used with microphones in conjunction with both-way amplifiers would give inter-communication facilities over and above those at present at our disposal. Such a scheme might be particularly welcome between patients and nurse, for example, where the former might be quite unable to use the ordinary telephone.

In attempting both-way amplification we are faced with the problem of introducing the amplifier in an existing circuit in such a way as will avoid the magnified output current reacting on the input current. Should any such coupling occur a sustained howl will be the inevitable result. Another point of importance is to so arrange the amplifier as to leave both input and output circuits independent of external batteries. This can easily be accomplished by using a circuit as shown in Fig. 1 : the number of valves and the internal arrangement being open to modification so long as the circuits terminate with transformer windings as shown.

Referring now to Fig. 2. If "A" and "B" represent telephone apparatus at two distant points between which amplified inter-communication is desired, it would be possible to insert the amplifier, which we will indicate by a rectangle and designate "C," at a mid-point such that the electrical properties of circuit A, C, simulate those of circuit B, C. With the input terminals bridged across the telephone lines in this manner, it will be seen that a certain portion of the speech currents from either "A" or "B" will pass into the amplifier. This will give rise to amplified output currents which have now to be impressed on the original circuit. A method of doing this is shown in Fig. 3. It will be seen that, broadly speaking, the output energy is divided and a portion applied to circuit A, C, whilst the remainder is applied to circuit C, B. This is a form of bridge circuit, and provided the transformers are correctly connected, and provided also the circuits are electrically balanced, the input circuit of the amplifier will be unaffected by the amplified output current. Consideration of the reverse action will show that the feeble currents from "B" will also be amplified, so we have now the essential and necessary conditions for satisfactory both-way amplification.

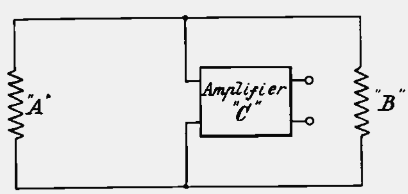


Fig. 2.—Illustrating the fundamental principles involved in two-way amplification.

The successful operation of this circuit depends entirely upon the degree of balance between the "A" and the "B" end. This is clearly shown in Fig. 3, where the dotted arrows are intended to represent the initial speech currents and the ordinary arrows the amplified speech currents. It will be seen that "D" and "E" must be equal and opposite in effect to avoid reaction and consequent howling. The arrangement is slightly inefficient in that one-half of the degree of amplification is lost, but this is practically unavoidable, and the amplification factor can usually be made such that this loss is of little importance.

In conclusion it should be stated that for such important purposes as the amplification of speech on telephone trunk lines, two amplifiers are used, one working in each direction, and the necessary balance is obtained by means of carefully constructed artificial cables, but that is a telephone problem rather beyond the scope of this article.

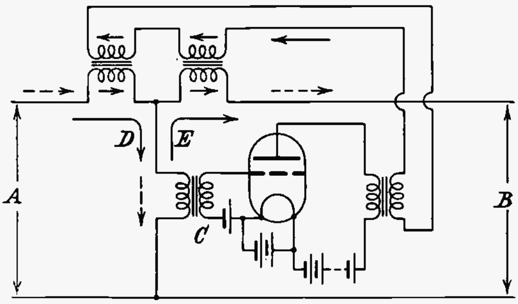


Fig. 3.—A practical amplifier circuit.

Alternating Currents and Wireless.

By Capt. P. P. ECKERSLEY.

It is practically impossible to conduct any serious quantitative investigations without some knowledge of the fundamental principles underlying alternating current calculations. Below will be found a method which reduces the necessary mathematical calculations to little more than simple arithmetic.

IT seems to me that many of us make the mistake of trying to discuss wireless problems without knowing enough of the basic laws. I may, in this journal, be insulting a number of people who live to love pLI and j, but I do hope there may be those among my readers who, though vaguely knowing that "one puts a tuning condenser there," do not quite understand what "resistance" a condenser offers to an alternating current. It is so easy to drop into the jargon, so rare to find one who ever calculates; though never let it be said that I decry the "fool experiment" and would do away with all except calculations.

But a little fundamental knowledge of alternating currents is a useful tool to one who would go a little further than the hobby stage, and as I have, personally, had such intense and awful difficulties in trying to use mathematics, however childish, I have felt that a little article telling of some of the useful hints and tips for use in alternating current work might be useful to many readers.

Wireless problems, thanks to the valve, are, in essence, far simpler than they used to be. The mathematics of the spark, with horrible decrements and logs and so on, was simply hopeless; now it is purely alternating current work, such as can be studied in any text-book on the subject. The frequency only is different—there is no bother about iron and permeability, and often $pL=\frac{1}{pK}$ and one is left with Ohm's law.

If a battery is connected, as in Fig. 1, across a number of resistances R_1, R_2, R_3 a current I will flow. The same current flows through all the resistances. If one wishes to work out the resistance of the whole circuit and calculate the current, one says that—

$$I=\frac{E}{R_1+R_2+R_3}$$

This is perfectly childish.

Replace now the resistances R_1, R_2, R_3 by a resistance R1, an inductance L, and capacity C. Apply now an alternating voltage. The total impedance of the circuit is made of the impedance of the resistance and the impedance of the inductance and the impedance of the condenser.

Now, the impedance of an inductance is given by pL, where p is 2π times the frequency of the current trying to get through it and L is the inductance. The impedance of the condenser is given by $\frac{1}{pK}$, where p is as above and K is the value of the condenser. This fact can be verified by reference

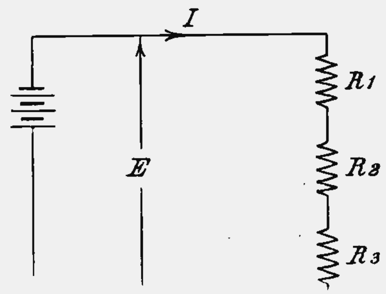


Fig. 1.—The battery E causes a current I to flow through the three resistances.

to various text-books, and it would seem redundant to argue why here.

One might, therefore, say that the total current I that could be pushed from the alternator of Fig. 2 through the circuit was given by the voltage divided by the impedance (or alternating current resistance —Ohm's law). One would then write—

$$I = \frac{E}{R + pL + \frac{1}{pK}}$$

and very simple, but unfortunately wrong.

The voltage produced in an inductance with alternating current flowing through it is a maximum when the current is a minimum (or volts and current are 90° out of phase—and it is a lagging phase); you switch on a voltage suddenly across an inductance—the current does not rise immediately, the current lags behind the voltage; switch on a voltage across a condenser and immediately a current starts flowing, pouring into the tank of the condenser, as it were. The tank does not get full until some while afterwards; the current in the condenser leads the voltage. Thus, again, when the voltage across the condenser is maximum the current is zero in it; always remember, the current leads in a condenser and lags in an inductance. In a resistance, obviously, the currents and volts are in phase. Thus, instead of adding our impedances together arithmetically, we have to add them together vectorially; this is always where so many people get worried.

The thing to do is to get some simple method and stick to it, and I, personally, rather than use anything else, prefer to add the vectors together by the use of j. In Fig. 3, then, from what I have said above, we have three vectors to add together—R resistance, pL inductance, and $\frac{1}{pK}$ condenser. The same current flows in all these parts of the circuit (Fig. 2), and hence we can draw the three vectors as proportional to R, pL, $\frac{1}{pK}$.

It now remains to add them together, and, of course, with a pencil, dividers and so on the eventual vector Z can be drawn, which represents their sum. But how, without recourse to such obvious methods? Suppose, for the sake of argument, instead of writing pL, we write jpL, and instead of $\frac{1}{pK}$ we write $\frac{-j}{pK}$ or $\frac{1}{jpK}$, and we call j the square root of minus 1. Why? I have not the faintest idea. Ask a mathematician. Meanwhile, follow me.

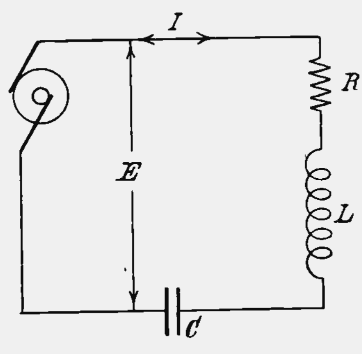


Fig. 2.—How two of the resistances are replaced by a condenser and an inductance.

Now j simply means any vector that is turned at right angles to the vertical line in Fig. 3 in a lagging direction (see the arrow in Fig. 4), and $-j$ or $\frac{1}{j}$ means anything that is turned at right angles in a leading direction. Obviously, terms having j in front of them can be added together arithmetically, because they are all in the same straight line.

So, in a complicated formula, the obvious thing is to collect all the terms in j together, and add them together arithmetically, and then to take all the terms without j and add them together arithmetically, and write down

$$Z=ja-jc+d-b$$
$$\text{or } Z=j\,(a-c)+(d-b)$$

as an example (Fig. 4).

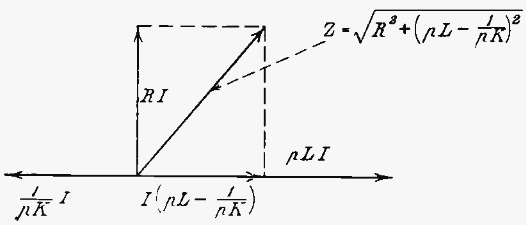


Fig. 3.—A simple alternating current vector diagram.

This means that a and c are all in one straight line, and that d and b are all in one straight line, but the resultant two straight lines $(a—c)$ and $(d—b)$ so formed are at right angles. Obviously, we can now use Pythagoras and vector addition theorem, and say that the sum of the two vectors $(a—c)$ and $(d—b)$ at right angles is—

$$\sqrt{(a-c)^2+(d-b)^2}$$

The imaginary and rather frightening j has disappeared.

Thus the simple rules: collect all terms in j and add them together in one lot; collect all terms without j and add them together in another lot. Forget j, square both the terms that were in j and the terms that were without j, put a square root sign over the lot, and that is the answer.

Never write pL for an impedance of an inductance if you have got to add it to something else. Always write jpL. Write: $\frac{-j}{pK}$ or $\frac{1}{jpK}$ for a condenser. For all terms in resistances, don't worry about j.

Now turn again to Fig. 2, where the alternator was connected across a resistance, an inductance and a capacity. So as to go very gently, treat them first as pure resistances. You know the voltage of the alternator, but you want to find out how much alternating current you can push through the circuit. If it were D.C. :—

$$I=\frac{E}{\text{Total Resistance}}$$
$$=\frac{E}{R_1+R_2+R_3}$$

but $R_1=R$ (the pure D.C. resistance)

$$R_2=jpL$$
$$R_3=\frac{-j}{pK} \text{ or } \frac{1}{jpK}$$
$$\text{Then } I=\frac{E}{R+jpL-\frac{j}{pK}}$$
$$=\frac{E}{R+j\left(pL-\frac{1}{pK}\right)}$$
$$=\frac{E}{\sqrt{R^2+\left(pL-\frac{1}{pK}\right)^2}}$$

This is the ordinary Ohm's law for alternating currents, which you probably know already, but I give it to you to show how j helps.

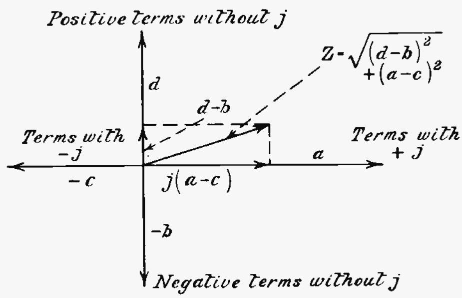


Fig. 4.—Illustrating how the problem could be solved graphically by the aid of a vector diagram drawn to scale.

But before I close I will take one more example, a circuit of Fig. 4. First assume the alternator is D.C. and has a voltage E, and that the three impedances are resistances R_1, R_2, R_3, as marked :—

$$\text{Now } I=\frac{E}{R_0}, \text{ where } R_0 \text{ is total resistance.}$$
$$\text{Then } \frac{1}{R_0}=\frac{1}{R_1}+\frac{1}{(R_2+R_3)}$$
$$=\frac{R_1+R_2+R_3}{R_1\,(R_2+R_3)}$$
$$\therefore\quad R_0=\frac{R_1\,(R_2+R_3)}{R_1+R_2+R_3}$$
$$\text{and } I=\frac{E(R_1+R_2+R_3)}{R_1(R_2+R_3)}$$

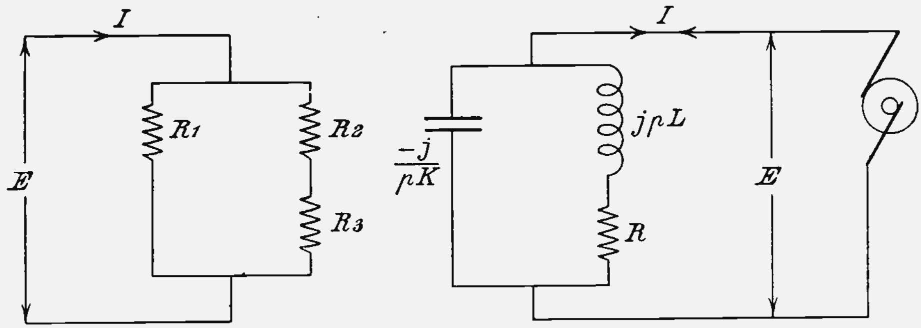


Fig. 5.—Illustrating the similarity between the direct and alternating current circuits.

Turning this into A.C. we have—

$$I = \frac{E\left(\frac{-j}{pK} + jpL + R\right)}{\frac{-j}{pK}(R + jpL)}$$

$$= \frac{pKE\sqrt{R^2 + \left(pL - \frac{1}{pK}\right)^2}}{-jR + pL}$$

$$= E\left\{\frac{pK\sqrt{R^2 + \left(pL - \frac{1}{pK}\right)^2}}{\sqrt{R^2 + p^2L^2}}\right\}$$

(Note if $pL = \frac{1}{pK}$ and $pL > R$

$\frac{\sqrt{R^2 + p^2L^2}}{\sqrt{R^2 + \left(pL - \frac{1}{pK}\right)^2}}$ is the impedance)

Then $I = \frac{ERpK}{pL}$

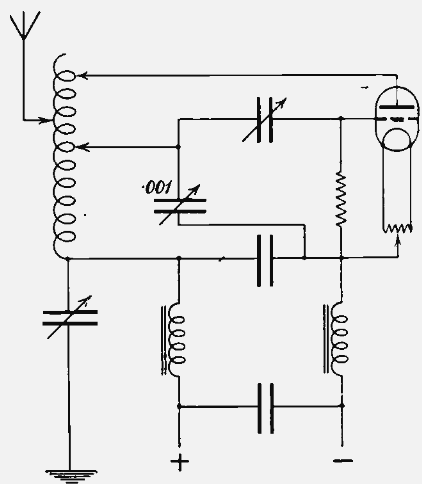
$= \frac{ER}{p^2L^2}$

This is the case where the circuit is in resonance, or the impedance of the circuit is—

$$\frac{p^2L^2}{R}$$

Experimental Station oMX.

In the November issue of Experimental Wireless there appeared an article entitled "Amateur Radio Work in Holland," by J. Westerhoud. Many details of apparatus and circuits employed by Dutch experimenters were given, including that used by oMX. As considerable interest has been aroused, and also some little confusion, we are reproducing a diagram of the actual circuit employed, which, it will be noticed, is of a rather peculiar type.



Circuit used by OMX.

The "Old Vic" Wireless Relay.

By A. G. D. WEST, B.A. B.Sc., Assistant Chief Engineer B.B.C.

In the last issue of "Experimental Wireless," details were given of the system used for land line connection of microphone to transmitter. When this is impracticable a relay transmitter is used as described below.

ALTHOUGH the relaying of music by wireless for transmission appears quite simple in principle (as shown in Fig. 1) many difficulties cropped up when this method was first attempted and in this article I propose to deal with some of the special problems connected with this kind of work.

The aim is to produce for the operation of the control valves of the broadcasting station a replica in tone value and balance of the original music, without any loss of quality; and in the case of the broadcasting of opera there are intrinsic difficulties of maintaining a correct balance between the orchestra which is fixed and the artistes who are always moving about, and of keeping the average strength of music arriving at the broadcasting transmitter between the limits which determine its efficient operation.

It is well known that for the transmission of music along ordinary telephone lines, these lines must be capable of carrying low-frequency currents of between 30 and 8,000 cycles a second with equal efficiency to retain the original quality of the music. Overhead wires of considerable length satisfy this condition, but when underground wires are used for a distance greater than three or four miles a loss of quality is apparent, because, owing to the large capacity between the two wires of the system, the higher tones do not get through relatively so well as the lower tones, and it is the higher frequencies that give to music its essential qualities.

Although it is under a mile from the "Old Vic" Theatre to Savoy Hill, it was found to be impossible to provide a direct landline connecting the two, and the best that could be supplied was a line (underground of course) of some seven miles in length. Hence the original reason for the attempt at a wireless link.

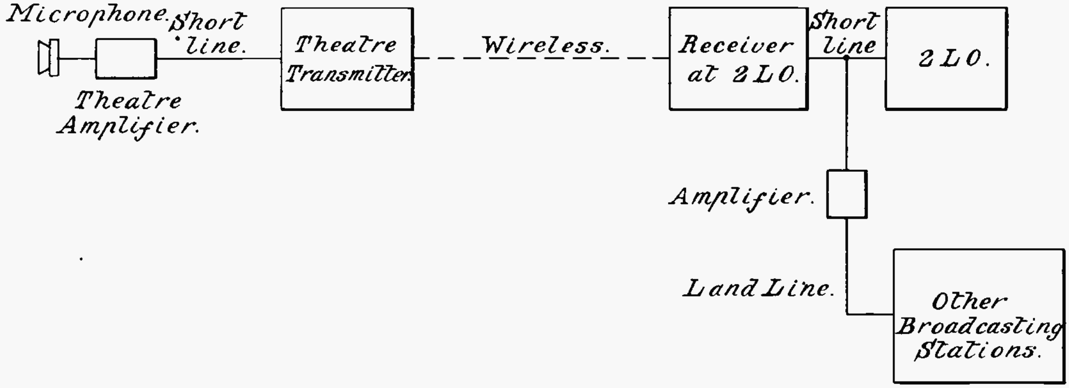


Fig. 1.—Schematic representation of system used in wireless relay.

The chief technical difficulties to overcome were as follows. First of all a suitable transmitter had to be designed to suit the conditions of theatre work; one that would deal effectively with the weakest and the strongest sounds without loss of quality and that would bring them all to much the same level. Secondly, in receiving the transmission from the theatre to the London Station all possibility of interference from the latter must be avoided. Thirdly, in passing through the whole series of valves from the microphone to the London transmitter, special precautions must be taken against distortion which might not be apparent if the chain consisted of a few transformations, but which only too easily exists when a large number of steps of valve magnification are employed. The following description will show how these difficulties were overcome.

Transmitter.

The standard type of theatre microphone was used and placed on the front edge of the stage in the centre, the place which has generally proved to be most effective for the transmission of operas and giving the best balance. The currents through the microphone after being magnified by a two-valve low-frequency transformer amplifier at the back of the stage are of sufficient strength to control the transmitter which is situated in the building next door. It is in this amplifier that the strength of the music is controlled by a grid potentiometer and is kept within the proper limits. It is a very difficult matter to do this well; an artiste may turn away or move to the back of the stage, and whereas a listener in the audience would notice no difference in volume of sound on account of the adaptability of his ears and of his nearly equal difference from all parts of the stage the microphone only deals with what it gets: lack of strength must be made up for in the stage amplifier and movements on the stage must be if possible anticipated.

At the last valve of this amplifier the potential is transformed down on to the line to the transmitter, and then up again to operate the grid of the subcontrol valve which is a 50-watt valve and in turn feeds the control valves (200-watt valve) the connection being by the usual resistance capacity method. These large valves are specially chosen so that with suitable negative grid potentials we operate on the straight parts of their characteristics. Furthermore, sensitive galvanometers are placed in series with the grids of control and subcontrol valves to indicate the existence of grid current; and the engineer in charge operates a variable shunt across the line from the theatre by means of which he reduces the strength entering the transmitter if there is any likelihood of grid current. The oscillator valve is a 50-watt valve, very much under loaded.

Such a transmitter may appear very uneconomical, but the choke control method always has the advantage that with suitable instruments we know "where we are." For low-powered sets where economy is the chief consideration and quality comes second the grid method of control is very effective, provided that stable conditions exist in the high-frequency circuits, but in this set quality is the first consideration, so choke control is used. Another point that is of the utmost importance in low-powered circuits is the efficiency of the aerial-earth circuit, especially when working on very short waves. The difficulty of finding a suitable earth connection in the top story of the building necessitated the use of a coupled circuit and

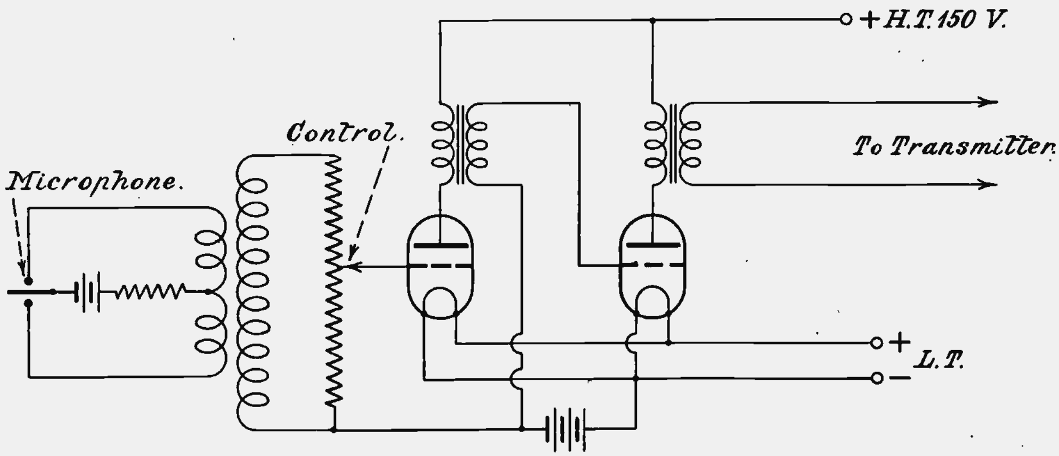


Fig. 2.—Theatre microphone and amplifier circuits.

earth screen, and there is no doubt that when short waves are used this method is generally the best. Again it is a case of knowing " where we are " as regards tuning. All the circuits can be buzzed seperately and some idea obtained of the number of turns required on each coil. On short wave-lengths with doubtful earth connections auto-coupling is sometimes difficult to manage. With regard to modulation in this particular transmitter as a result of all the precautions taken to ensure no " blasting " in any circuit at maximum strength of music from the theatre, it can be understood that the modulation is really very small, probably averaging out at about a tenth of the maximum. With regard to aerial, this is a single wire about 25 feet long and 20 feet above the roof of the house. This type is in many respects more satisfactory than any other for telephony on low wave-lengths.

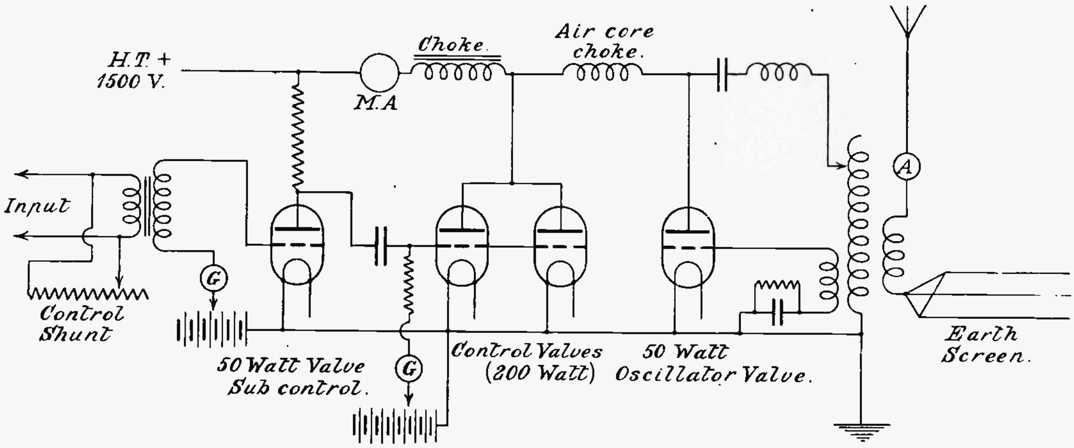


Fig. 3.—The actual choke control circuit used for the theatre transmission.

The transmitter is, except for the aerial and earth screen, quite self-contained, the generator and filaments being all run off accumulators.

The Receiver at 2LO.

To ensure sensitivity and selectivity, and freedom from interference from the London transmitter, a super-heterodyne receiver is used with a small single-wire aerial. For short wave-lengths the super-heterodyne receiver certainly has no equal as it offers three distinct methods of magnification—original high-frequency, beat-note and low-frequency—and the combination of these three is extremely effective. Usually sufficient sensitivity is obtained without the first, connecting the aerial circuit direct on to the first detector valve. This receiver is just as remarkable from the point of view of selectivity, and immunity from interference by near-by stations when it is properly designed. It is important to get the strength of the heterodyne right for best results, the easiest way of doing this being to use a variable coupling with the closed circuit of the receiver. If it is required to cut out a near station working on a wave-length of reception, a power valve must be used closely coupled to the receiver. Care must be taken when receiving telephony that if necessary sufficient damping is introduced so that the higher speech frequencies are not cut out, thus giving distortion. This can be done by using a suitable transformer, wound to the beat note wave-length, in the anode circuit of the first detector valve and the beat-note amplifier must be kept well under control and right off the point of oscillation. Any of the usual forms of high and low-frequency magnification may be used in this circuit. In the particular receiver we are considering resistance capacity coupling is used for both high-frequency and low-frequency amplification, and in the latter there is no distortion if the resistances and capacities have correct values and it is ensured that no grid current flows by using

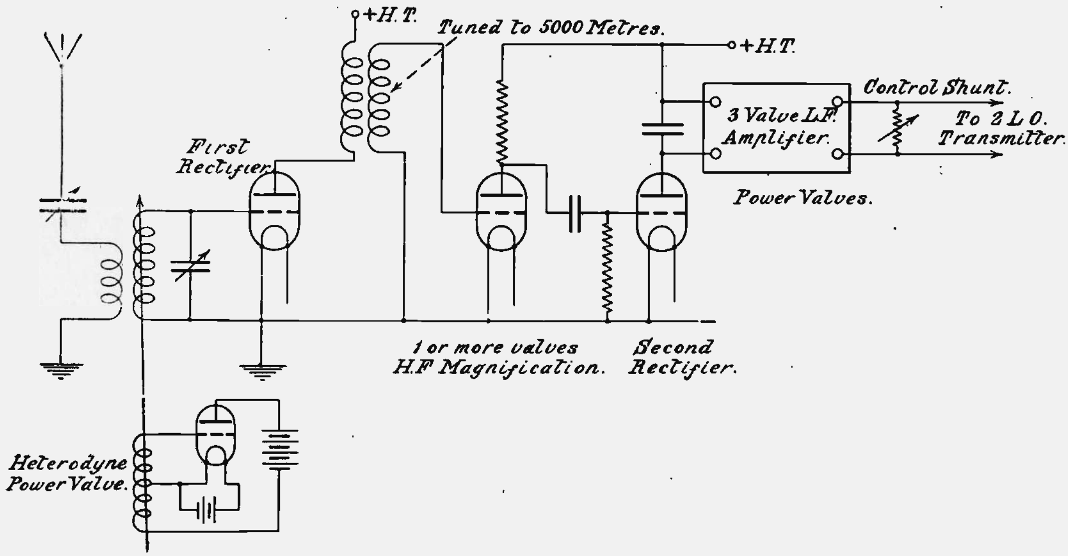


Fig. 4.—The supersonic receiver and amplifier which is coupled to the 2LO transmitter.

sufficient high tension, and negative potential on the grids for the valves in use.

It is best to screen the beat-note frequency amplifier with copper foil which is earthed, as it very easily picks up carrier waves and harmonics of commercial stations. The music is thus received and brought up to sufficient strength to operate the London transmitter and if necessary the transmitters of the other stations through the amplifiers controlling the various simultaneous lines. The various units in the photograph of the receiver, reading from left to right, are as follows: heterodyne with fine adjustment, aerial and closed circuit condensers, first detector valve, screened transformer, beat-note amplifier, low-frequency amplifier, controlling potentiometer.

So much for the apparatus actually in use for the wireless link, but there are still many minor difficulties which still await solution.

Although the London Station has been eliminated in the receiver, now and then a harmonic of a C.W. station or the oscillation of a neighbouring receiver is picked up and sometimes noticeable in a weak part of the music. Generally these can be tuned out by adjusting the heterodyne without affecting the reception from the theatre. Sometimes faint interference is experienced from an electric motor or a lift in another building and this is only to be expected when using a sensitive receiver in the heart of London. So far such interference is not really serious, but when the wireless link is extended up to a distance of ten miles or more it will be a difficult matter to keep the reception pure and free from interference and atmospherics without a corresponding increase of power in the transmitter. An interesting fact is the absorption of certain very short waves in passing over London. On one low wave-length tried for this wireless link of only a mile, very poor results were obtained, while a slightly higher wave-length was much more successful; and while picking and choosing among wave-lengths it is, of course, necessary to steer clear of harmonics of 2LO.

In extending this wireless form of relaying up to a large distance, there is no doubt that much greater difficulties will be experienced, but it is hoped that these will be overcome in time, so that the transmitter can be made a portable one (that is installed in a car) and then this method will be available for the broadcasting of any form of programme from anywhere in the London district at more or less a moment's notice.

Notes on Sources of Energy Loss in Condensers.—II.

By PHILIP R. COURSEY, B.Sc., F.Inst.P., A.M.I.E.E.

THE possible sources of energy loss in condensers which we have so far been considering should in any well-constructed condenser represent only an almost negligible amount of energy. There are, however, many other uses to which condensers can be put other than those mentioned, and in some of them not only are there more possible sources of loss, but the order of magnitude of these losses may be much greater. These additional losses will often be added to whatever loss may exist of the types that have already been discussed.

For example, consider a condenser connected to an A.C. circuit so that it is subjected to a high alternating voltage of low frequency, such as 50 cycles.

There will, in the first place, be a direct breakage of current through and over the surface of the dielectric. This loss will not be a constant one, but will vary both with the frequency of the A.C. and with the voltage applied to the condenser, as has already been indicated. This A.C. leakage—the "leak-over" of the telephone engineer —may frequently be much greater than might be

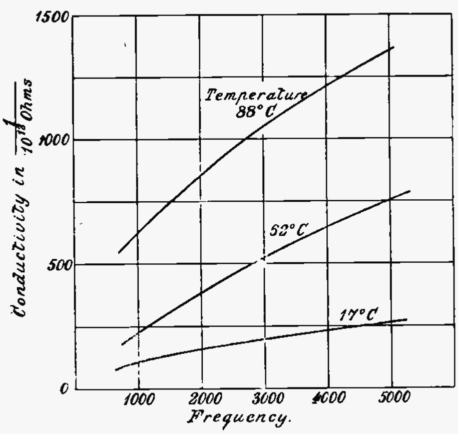


Fig. 1.—Leakance through glass at different temperatures.

anticipated from the D.C. tests on the dielectric in question. Some idea of the increase may be gathered from Fig. 1 which is typical of the type of result obtainable when the tests are made at telephonic frequencies. From such tests as these one is led to the conclusion that the leakage loss in watts may become, in a condenser subjected to an A.C. voltage, a loss which it is of importance to consider. It is of interest also to note that the loss increases with the temperature of the dielectric.

In the second place we have an actual energy loss in the dielectric, consequent upon the alternating electrical stress to which it is subjected—this loss being usually

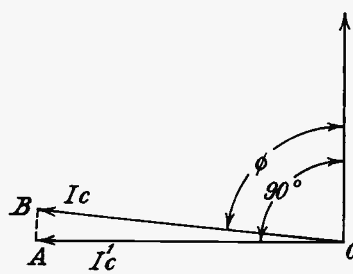


Fig. 2.—Vector diagram showing effect of losses.

attributed to dielectric hysteresis. And in the third place we may have an augmented loss due to the formation of corona or "brushing" where the voltage on the condenser is at all high.

These three sources of loss are, generally, in the case of a condenser subjected to an A.C. voltage, summed up in the quantity known as the "power-factor" of the condenser. The normal "capacity-current," which glows through a condenser of capacity C microfarads when it is subjected to a sine-wave alternating voltage of V volts at a frequency of f cycles per second is

$$I_c^v = \frac{2\pi C f V}{10^6} \text{ amperes.}$$

If the condenser is a perfect one this current I_c^v will be 90° out of phase, with the voltage V as sketched in Fig. 8, but in actual practice there must be some losses, although these may, and should, be very small. The actual current which passes through the condenser should therefore not be represented by the vector OA but by the vector OB, which is marked I_c in Fig. 8, making an angle ϕ with OV, ϕ being slightly less than 90°. The power-factor of the condenser is the same given to the quantity numerically expressed by the cosine of the angle between OB and OV, *i.e.*, by cos ϕ. It is, therefore, the ratio of the lengths of the vectors AB and OB.

This ratio expresses the ratio of the power-expended in the condenser, *i.e.*, the energy losses—to the apparent, or wattless power, in the circuit. Numerically, if W is this energy loss, the power-factor is expressed by

$$\frac{W}{I_c V} = \frac{I_c^2 R}{I_c V} = \frac{I_c \, _2 R}{I_{c2} / (2 \pi c 1)}$$
$$= 2 \pi R C f$$

This relation is only true when the losses are small. In this expression R is the effective resistance of the condenser, which is the resistance value in ohms which expresses the loss in the condenser. It is a quantity that can often be measured directly by certain capacity measuring bridges, but is only determinable with ease at audio frequencies. The relative size of the "loss vector" AB

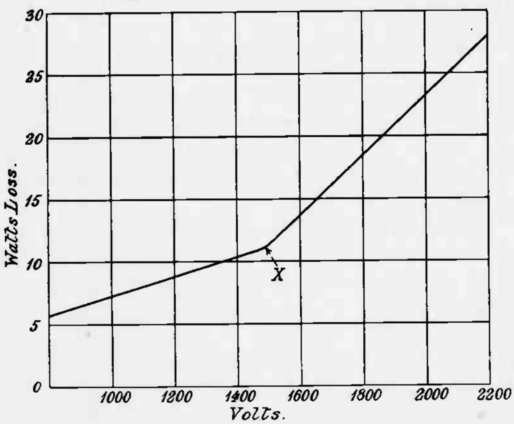


Fig. 3.—Curve of energy loss as function of voltage on condenser.

in Fig. 8 has been much exaggerated, as in a good condenser its length is a very minute fraction of the lengths of the other vectors. It is this fact which renders its measurement difficult.

The power factor of a condenser having a solid dielectric should be quite a small quantity (less than one-tenth of one per cent.) when measured at audio frequencies,

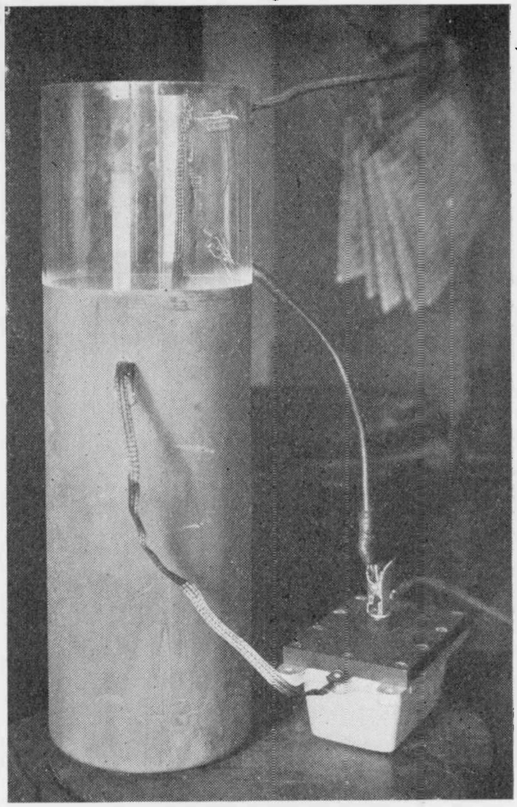


Fig. 4.—Brush discharge on glass dielectric condenser.

with only a low voltage on the condenser terminals, but the production of a condenser that will have an equally low power factor when operating in a high voltage radio frequency circuit is not a particularly easy matter. There are many reasons for this difference between the results obtainable at low audio frequency voltages and those at high voltage radio frequencies. In the first place, the loss due to dielectric hysteresis increases usually very rapidly with the frequency, while, secondly, the extra losses due to corona, which are non-existent at low voltages, become serious at high voltages, and especially so at high radio frequencies. Measurements of energy loss in condensers, as the voltage on the condenser is raised, show up the effect—Fig. 9. It will be seen that there is almost a discontinuity at the point X in the curve of watts loss, this point marking the formation of corona, or a brush discharge at the electrodes of the condenser. Energy loss, due apparently to this cause, may actually begin before there is any visible sign of corona on the plates—the loss being probably due to the generation of a number of extremely minute discharges. Once visible corona commences, however, the loss may become very serious and lead to a rapid heating up of the whole condenser.

A well known example of the effects of brushing at the edges of a condenser plate is provided by the glass plate condensers commonly used as part of a ship's radio installation. If one of these condensers is examined after it has been in operation for some time, there will frequently be found a distinct groove in the surface of the glass sheet corresponding with the edge of the condenser plate which has been in contact with the glass. This groove is entirely due to the brushing that has taken place off the edge of the metal, the brush discharge gradually melting its way into the material of the dielectric. This brushing takes place in these condensers, even although they are operating on a spark transmitter, but the effects would be much worse if the condenser were in a circuit. A brush discharge from the edge of the metal electrode will gradually spread into the material of the dielectric until an actual puncture occurs.

The old fashioned Leyden-jar type of condenser showed the same efiect—Fig. 4—and consequently often broke down for this reason. The photograph shows a Leyden jar subjected to the same test voltage as a small mica dielectric condenser, of the same capacity, and illustrates the brushing taking place round the edge of the metal coating of the jar, while no such luminosity is to be seen on the mica condenser.

This brushing, or corona, brings about considerable heating of the dielectric, as is emphasised by the curves in Fig. 5, which show the energy losses for a Leyden jar and for a mica condenser, both condensers having a capacity of 0.004 microfarad. The rapid increase of loss with rise of voltage should be noted.

Losses of this type are by no means entirely confined to condensers having a solid dielectric, and although it is frequently stated rare air, is a perfect dielectric and that therefore an air condenser cannot have any losses, such is in practice far from being the case. Even a variable air condenser used in quite low voltage radio frequency circuits may have in it appreciable energy losses, due apparently to the excessive value of the electric stress in the air. Some of the variable air condensers having extremely close plate spacings are bad in this respect, and even when subjected to a radio-frequency voltage of 20-30 volts only may have a loss resistance of several ohms introduced by this cause. When the radio-frequency voltage is high an air condenser may have a considerable loss. Under these conditions a condenser properly designed for operating on high C.W. voltages, with a good solid dielectric such as mica (Fig. 6), may be superior to an air condenser in this respect, besides being much smaller in

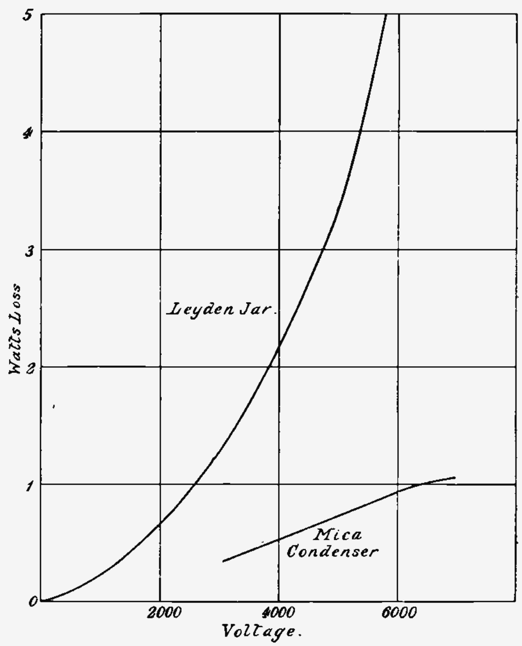
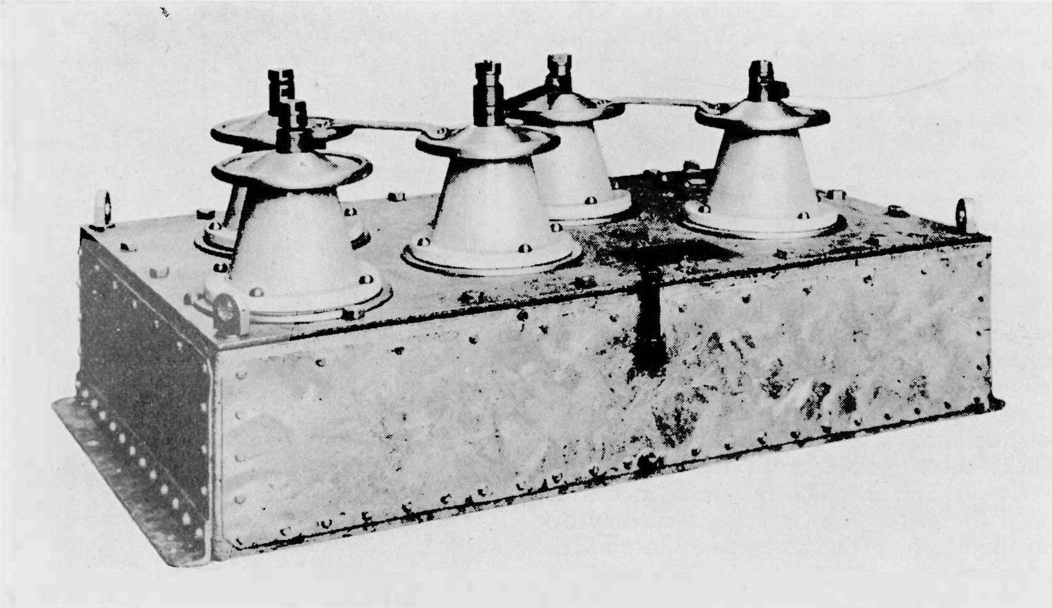


Fig. 5.—Energy loss in glass and mica condensers.

bulk. For instance, the power factor of the condenser illustrated in Fig. 6, which has a mica dielectric, is only of the order of 0.00006. This result has only been obtained through many years of research in the methods of manufacture of such condensers.

The small value of the power factor possible in such condensers emphasises the freedom from corona effect and other similar



F. 6.—A modern mica condenser for operation on high radio frequency voltages. [By courtesy of Dubilier Condenser Co., Ltd.]

sources of loss, as the large radio-frequency voltages to which these condensers are subjected so readily give rise to such losses, especially at the short wave lengths where the frequency is high and the currents also large.

Anyone who has experimented with the use of dielectrics in intense radio-frequency fields cannot fail to have been impressed with the extraordinary heating effects to which such fields can give rise. Quite large masses of dielectric can be heated up by the application of a high radio-frequency voltage for a few moments only, if the shape of the dielectric and the mode of application of the electric field to it are unsuitable. These effects accentuate the difficulty of leading the current into and out of the condenser, unless the terminal insulators are suitable. It is easy to have a greater loss in the terminal insulators than in the condenser itself, if they are improperly designed for radio frequencies. These losses are more due to the so-called dielectric hysteresis than to corona effects.

Apart, altogether, from the disadvantage of the existence of losses in a condenser from the point of view of the energy wastage involved, and the possible augmented cooling means which may be necessary to dissipate this energy wastage, there is the more serious side of the matter due to the fact that most dielectrics become weaker as their temperature is raised. Referring again to Fig. 1, it will be noted that the leakage loss increases with the temperature of the dielectric. All other dielectric losses usually similarly increase with the temperature, so that an initial energy loss in the condenser which causes a rise of temperature may as a consequence bring about an increased rate of energy loss, due to the effect of temperature rise on the dielectric losses, and consequently a further temperature rise results. This effect may in a poor condenser ultimately cause a breakdown of the dielectric, but should not occur in a well-designed one.

These few notes on the different types of energy loss which may occur in a condenser may serve to emphasise the great difference between the problems encountered to-day in producing an efficient condenser for operating in C.W. circuits, from those met in condensers for spark, or "damped wave," transmitters. It is perhaps not too much to say that the revolution that has been brought about in radio frequency condenser design by the extended use of continuous waves radio transmitters is hardly less than that caused by the introduction of the thermionic valve into the radio receiver.

The Month's "DX."

Recorded by HUGH N. RYAN (5BV).

The increasing efficiency of amateur transmitters and receivers is resulting in the creation of many new long-distance records which are undoubtedly worthy of mention. It is proposed to record month by month work in this direction, and the Editor will be pleased to receive details for inclusion in these pages.

SINCE last month's notes the DX world has awakened well and truly. Last month the all-night listener for Americans heard nothing but Americans and a few hetrodynes (the number of Americans logged varying inversely as the umpteenth power of the number of hetrodynes.)

Now, however, most of the long-awaited high-power transmitters are in action, and, judging by the awful row that goes on in the small hours, the power really is high.

The time for producing long lists of "Yanks heard" is past, and everyone is striving to be the first to "get over" or, better still, accomplish two-way working with the States.

Since there are few very good logs this month, I will deal with the few first. The fact that anyone can get so many Yanks through the QRM shows that conditions are splendid. The small number of logs is due entirely to the fact that most of the best men are engaged chiefly in transmitting. By far the best night yet was that of December 1-2. Conditions on that night were not very good until about 6.50 a.m. on the 2nd, when Americans started to come in as fast as they could be logged, and were still coming in at 8 a.m. in broad daylight!

Between 7 a.m and 8 a.m. 2AAH logged twenty-six complete calls (*i.e.*, call-sign of both calling and called stations), as well as many other single call-signs logged, on one valve—a very fine performance. On the same morning, between 6 a.m. and 8 a.m., 6LJ, another London man, logged thirty-seven Americans, calls being received from every district except the seventh—another excellent piece of work.

Mr. Rogers, a receiving man at Ashford, has logged some fifty Americans on one and two valves.

No reports from the north are to hand.

The excellent conditions indicated by these results give us great hopes for the official tests in the near future.

On that splendid morning, December 2, I answered a CQ from 8AJW, and received a reply asking for a repetition of call-sign and more power. Unfortunately, the rest of the working was spoilt by a humorist with a hetrodyne who appeared to think that his call-sign was 8AJW!

The reception of PCII by 7ACM, reported in last month's notes, was, unfortunately, not true, being due to a similar hetrodyne masquerading as 7ACM. It is most unsporting behaviour on the part of the stations who do this sort of thing with their hetrodynes, and it is to be hoped that they will have the decency to refrain from it in future. In this case, PCII has our entire sympathy, and we wish him all the better luck in the near future.

8AB, of Nice, whose 25-cycle note was so familiar last year, has been in America ever since the end of last year's tests, and has only just returned. Not many people have noticed his return, however, as he now works on 130 metres! He has already worked with two American amateurs, who appear to get him very well on that short wave-length.

Many of the Americans are also down on that wave, and come in very loudly indeed. The great advantage of going down there is that horrible fading which characterises all 200 metre work is almost entirely absent. After being used to the effect, it sounds quite uncanny to hear a weak distant station staying at a constant strength. Low power signals also seem to carry very well indeed on this wave-length. I think that by the time we are working regularly with the States (and may it be soon), it will be on about 150 metres. It promises to be the wave-length for DX as soon as the majority of stations can receive it efficiently.

That practically completes the American news.

The R.S.G.B. station, 5AT, is now going strong. It has sent out some very useful calibration waves, for the benefit of the many who do not quite know where 200 metres is, and the knowledge of the exact position of this and the other waves sent will be of great benefit to many who do not possess wave meters.

Also 5AT has recently been working in the small hours trying, like the rest of us, to "get over the Pond." He has also been calling the elusive WNP, but with, unfortunately, no more success than we have had.

We have this month had the unusual experience of hearing our friends the broadcasters engaged in perfectly good DX. The tests have been so widely reported in the technical press, that no more than a passing mention is necessary here. Nevertheless, we congratulate them upon their temporary entry into our nocturnal activities. (By the way, we know now what Uncle Arthur means by "The night shall be filled with music!")

The tests showed, at any rate, that the B.B.C. are no more immune than we are from the spells of bad conditions which always come when they are least wanted.

European DX has rather been overshadowed by the American work, but several interesting results have been obtained.

On December 4 signals from 6DW of London were received at good strength by 5US of Yorkshire, on a 4-foot frame and single-valve super. The input at 6DW was about 2 watts, and aerial current ·13 amps. The distance between 6DW and 5US is approximately 190 miles.

5DN of Sheffield, whose call-sign is familiar to many London amateurs, has been heard in Switzerland. He was using 10 watts, and his aerial current was ·42 amps. This is an interesting example of what can be done with a small aerial current, as even though ·45 is not a good aerial current for 10 watts, it travels as well as the ampere obtained by some stations more technically "efficient."

Mr. F. R. Neill, of Belfast, has contributed greatly to the interest of DX recently by his excellent reception of many English stations. His usual receiver comprises $_2$HF and $_1$LF stages, and on that, for example, he can read my own signals all over the room.

I believe he has received very good telephony from 2OD. It would be interesting to know if there is a place where 2OD's telephony cannot be heard. His transmission is extraordinarily good, and seems to carry everywhere.

On December 9, between 2 a.m. and 3 a.m., 2AAH and myself received KDKA (Pittsburg Broadcast) very loudly indeed on approximately 100 metres. It seems impossible that this could have been a harmonic, especially as the fundamental was very weak indeed that night. It also appears impossible that it could have been a retransmission from a station in this country, as the music and speech was absolutely pure, and seemed quite evidently a first-hand transmission. Also, it was not fading in the least, as was the fundamental, so it could not have been picked up on a super-receiver and retransmitted.

KDKA was probably experimenting with transmission on two wave-lengths simultaneously, as I believe several American stations have been doing recently. Single-valve receivers were used in both cases.

The new "A" code of signal strengths published in these notes last month has "caught on" to some extent already. I have heard it used several times by DX stations, and at least one station has had the code incorporated in his printed report cards.

A number of experimenters have approved of the code, and asked me to "boost" it further, so let's hear it used more!

Just before going to press comes the great news that 2KF has, on several consecutive nights, worked with American 1MO. The results are fully authenticated, and 2KF has our heartiest congratulations. The wave-length used by 2KF was very low, as was his power (aerial current being under 2 amps.)

This achievement has just been followed up by some excellent work by 2SH who has for several hours established two-way communication with 1MO, 2AGB and Canadian 3BP, which it is understood is located in Ontario. 2SH has also been reported by 5XD of New Mexico, about 600 miles from the Pacific.

The Construction of a Tuned Reed Rectifier for 200-volt 50-cycle Supply.

By E. J. SIMMONDS.

One of the most useful methods of rectifying alternating current is by means of the vibrating reed. The success of the apparatus is dependent upon correct design and adjustment, details of which are given below.

THE following article describes the construction of a simple but efficient type of tuned reed rectifier for accumulator charging from A.C. mains. The instrument is built on well known-lines, but with the addition of several adjustments, which increase the flexibility and control. It consists broadly of a step-down trans-

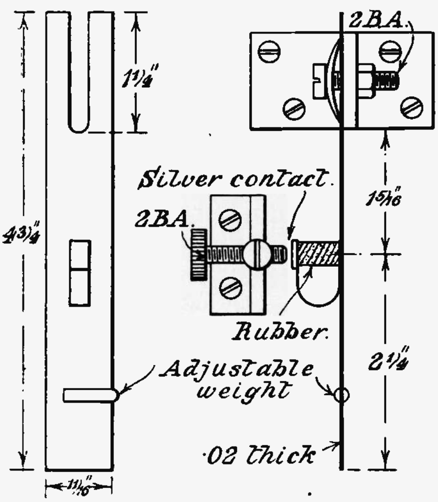


Fig. 1.—Details of tuned reed.

former, rectifier panel, with steel reed, permanent magnet, exciting coil and potentiometer.

This rectifier can safely be left to recharge the cells overnight up to a 5-amp. rate, and has been in use at the writer's station for two years, giving every satisfaction; also the first cost is very low.

The most important point is undoubtedly the tuned reed, and care should be taken to adhere to the dimensions given, which are the result of much experiment. The reed is a strip of spring steel 11-16th" wide ·02" thick and 4¾" long. This may be conveniently obtained from a broken gramophone spring (the springs of H.M.V. machines are of correct thickness). If a piece of this spring

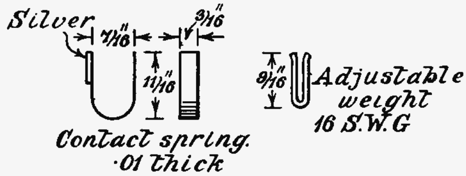


Fig. 2.—Details of spring and weight.

is used it will be too wide, but can be reduced to correct dimensions by gripping in a vice with the unused part protruding. If this is now firmly held by a pair of pincers it can readily be torn off. The resulting rough edge should be ground smooth on a carborundum wheel or stone. The steel could of course be softened and cut in the usual way, but the process of rehardening and tempering requires considerable skill. By my

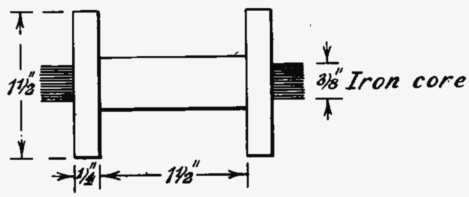


Fig. 3.—Dimensions of exciting coil.

method the original temper of the steel is preserved.

The next point to which attention is directed is the U-shaped contact spring.

The alarm spring from the average drum clock will be suitable, the actual dimensions are thickness ·01" width 3-16th". This is

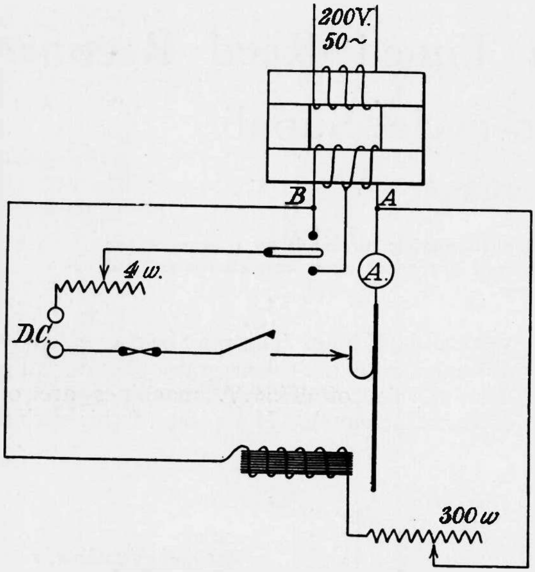


Fig. 4.—The connections of the rectifier.

soldered in position indicated on the reed. Here will be noticed an unusual arrangement.

This spring is effectually damped by a column of soft rubber, with its base fixed to reed. In practice, the effect of this damping is to render the instrument more accomodating to irregularities in the wave-form of the power supply. Considerable difficulties were encountered in the early experiments with the rectifier, until this simple damping

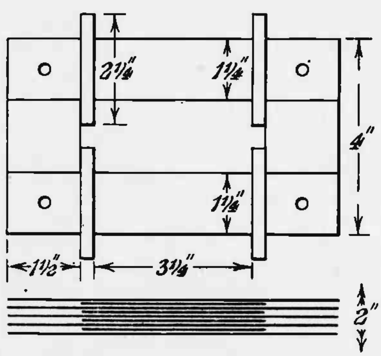


Fig. 5.—Details of transformer coil.

device was added. Soft indiarubber as used for erasing will be found excellent for this purpose. It should be noted that a spiral spring would not be suitable, as it would have its own natural period.

The contacts on both U-shaped spring and contact screw are of silver, soldered in position. Tungsten may of course be used, but is quite unnecessary.

After about 100 hours use at 3-4 amp. rate the contacts may be trimmed up with a dead smooth file. Another useful addition is the small sliding weight on the reed. By this means accommodation may be obtained for temperature changes, and also slight fluctuations in the frequency of the supply. This weight is made of spring brass or steel wire, about 16 S.W.G., bent to shape as shown, and should grip reed tightly, although capable of being slid up or down. The dimensions of the permanent magnet are not critical; one from an old magneto will be suitable.

The exciting coil consists of a former

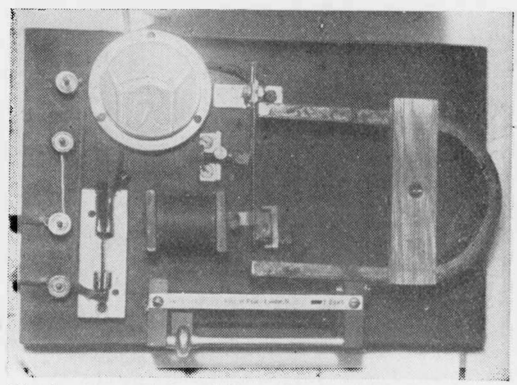


Fig. 6.—A general view of the rectifier with switchgear.

$2 \times 1\frac{1}{2} \times 1\frac{1}{2}''$ layer wound full of 30 D.S.C. copper wire. The core is a bundle of soft iron wires, and made a nice sliding fit in the tube to allow for final adjustment. It will be noticed that in series with this coil is a potentiometer of 300 ohms. By suitable adjustment of the slider the reed may be arranged to break contact when the E.M.F. of charging current is at any required value between 2 volts and 10 volts.

It is of course clear that to obtain sparkless operation the contact must be opened when the E.M.F. of charging current equals the opposing voltage of the cells on charge; at that moment no current will be passing at the contact.

The potentiometer control gives a ready means of obtaining the critical adjustment, without any alteration of contact screw, and is a most important point in the successful operation of the rectifier. When charging a 10-volt battery practically all the resistance will be included in the circuit; more and more resistance will be cut out when charging cells of less voltage.

Several points of importance should be noted in the bracket support for the reed. This is made from two pieces of angle brass ⅃ L, sweated together, and is firmly screwed to the hardwood base. The reed is clamped by a clamping plate and 2-B.A. screw and nut. It should be observed that the small clamping plate is slightly curved, the concave face being placed next to reed, and it is important that the lower edge of the clamping plate, and also the edge of the bracket, should be truly square and in line, so as to grip the reed from its operating point firmly.

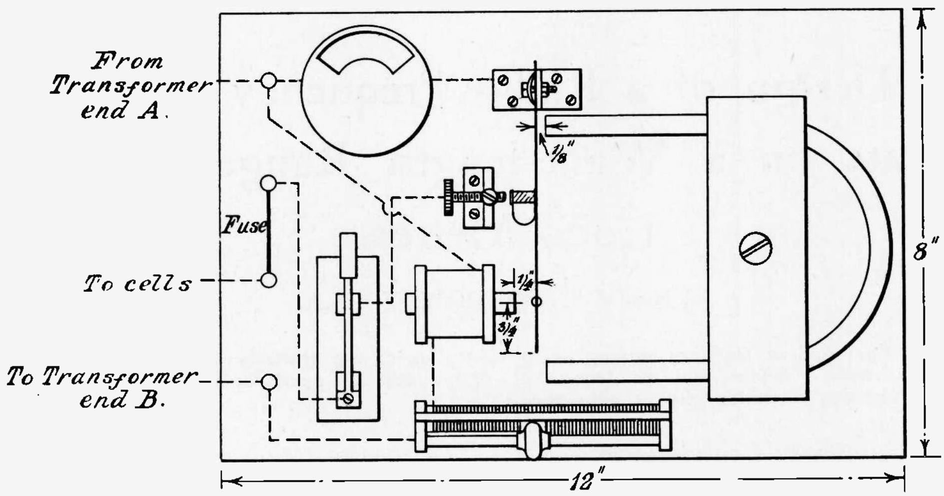


Fig. 7.—The lay-out of the rectifier and controls.

A transformer is necessary to step the line voltage down, and is of closed-core type. Many excellent transformers can be picked up cheaply second-hand, which may be easily adapted. The construction of an efficient type will, however, be dealt with. It should be made from a good grade of transformer iron, preferably stalloy, the laminations being about ·016" thick. Each sheet should be japanned or shellacked before assembly, to prevent eddy currents.

The core is built up to dimensions shown on drawing. Note carefully the method employed to interlock the corners to complete the magnetic circuit. The two limbs carrying the primary and secondary are made up from alternate long and short sections, and the cheeks which are of vulcanised fibre are then attached.

The core is carefully insulated with empire cloth or thin vulcanised fibre, and the primary and secondary coils wound. The primary consists of 500 turns of 20 D.C.C., and is wound on one limb as indicated.

The secondary, which is 50 turns of 14 D.C.C., is wound on the other limb. The secondary coil has a tap brought out at the 25th turn, and is connected to a 2-point switch. This permits of voltage regulation when charging cells of low voltage. If desired, the coils can be former wound, taped, and then slipped over cores. The coils should be well shellacked and baked in a warm oven.

The transformer is now assembled by attaching the yokes, which are also made up of alternate long and short sections. The whole of the laminations must be tightly clamped to avoid noise in operation.

The ammeter for indicating charging rate should be of the moving coil type, preferably with central zero.

Moving iron and hot wire instruments give incorrect readings, owing to the fact that the charging current is a pulsating one.

The resistance to regulate the rate of charge should be wound with 18 S.W.G. to a resistance of 4 ohms, on a slate base, and fitted with a slider. The 4-amp. 3-ohm type supplied by the Zenith Co. is excellent for this purpose. This regulating resistance and the 2-point switch are mounted on the transformer.

Considerable charging rate control is obtained by the adjustment of the contact. 1-16th" is the usual allowance between contact screw and contact on reed, when the latter is at rest. In the preliminary tuning up of the instrument all the resistance should be included, until sparkless operation is obtained. Otherwise, if the reed falls out of step a very destructive arc will be set up at the contact, which will be speedily destroyed. Rough tuning of reed is accomplished by alteration of effective length at supporting bracket, fine tuning by sliding weight.

The polarity of D.C. terminals must be found, either with pole finding paper or by immersing the two wires in slightly acidulated water, noting wire which gasses most, that being the negative.

In conclusion, it is hoped that all the essential details have been adequately dealt with, and the writer is confident that the instrument will give satisfaction if these instructions are adhered to.

The Design of a Radio Frequency Amplifier to Operate on a Wave-length Range of 300 to 1,000 Metres.

By G. L. MORROW, F.R.S.A.

The modern tendency among experimenters is to use critically tuned amplifier circuits. Below will be found the design for an aperiodic amplifier which obviates a multiplicity of adjustments.

Preliminary Consideration.

A RECEIVER was desired to operate with the maximum degree of efficiency combined with high sensitivity, on a wave-length range of approximately 300 to 1,000 metres, being primarily required to give high and sustained amplification on 300, 450, 600, and 900 metres ship and shore spark traffic. Other considerations were in the order of importance that the amplifier should

1. Possess the highest degree of sustained amplification over the above band of wave-lengths combined with the fewest number of critical adjustments.

2. On an average amateur aerial (confined to the standard G.P.O. aerial limits) be capable of receiving 600 m. ship spark traffic up to 1,000 miles radius. This last figure being the night range under normal atmospheric and climatic conditions.

3. Be capable of
   A. Sustained amplification with
   B. Quick "search" properties.

When used for 450 ms. spark D.F. work with either a frame or open Bellini-Tosi D.F. aerial.

4. Be of reasonable dimensions and weight with regard to portability.

Dealing with these requirements in order, and in fairly full detail, two outstanding points had a considerable bearing on the design. These two points are, first, owing to the fact that the station is situated in a country locality with somewhat poor facilities for charging accumulators, it was desired that as few valves should be employed compatible with the degree of amplification aimed at. This necessitated the employment of valves with a low current consumption, and in passing it should be noticed that at the time when the amplifier was designed Dull Emitting valves were still in an experimental stage. Secondly, owing to the locality of the station, facilities for obtaining spare high tension units were poor, especially when it is remembered that a high-tension battery often fails at a moment's notice. This consideration, apart from reasons of economy in maintenance, had considerable influence on the design, since the total anode feed current was required to be as low as possible.

B. The tuned anode system.

C. Aperiodic transformers, *i.e.* transformers wound with resistance wire.

Undoubtedly method (A) would give the high degree of sensitivity and therefore amplification with the smallest number of valves, but it was considered that in order to operate efficiently over the band of wavelengths required, the transformer primaries would need to be tapped and fine tuning, which is especially needed to overcome jamming on 600 ms., accomplished by means of a small variable condenser shunted across the primaries. It was estimated that with this method of amplification two stages of radio-frequency would be required to fulfil satisfactorily condition 2, but owing to the number of adjustments which would be necessary to cover from 300-1,000 metres it was not considered practicable to employ this method.

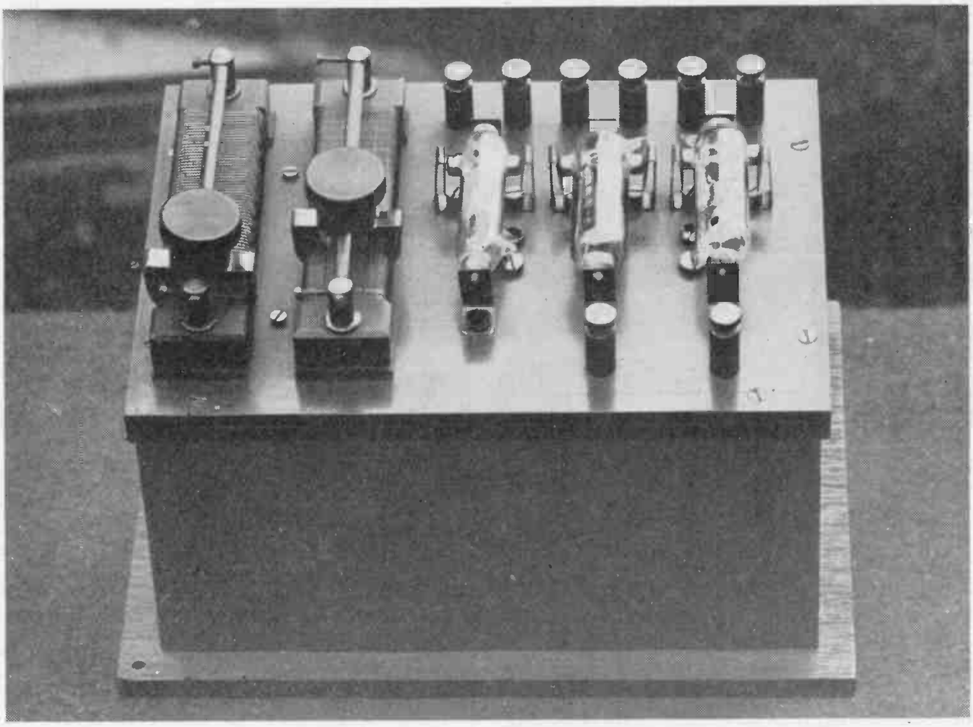


Fig. 1.—General view of amplifier.

Coming now to the chief requirements of this amplifier it will be seen that they are essentially a highly sensitive spark receiver with critical adjustments reduced to a minimum, the desideratum being a sensitive high frequency amplifier operating efficiently from 300 to 1,000 metres inclusive with the ease and simplicity of adjustment of a single valve receiver. The various methods of obtaining the radio-frequency amplification required, which were considered by the author in the preliminary stages of the design, were :—

A. Tuned copper-wound, high-frequency transformers.

Method (B), *i.e.* the tuned anode system was next considered, but here again, whilst the number of adjustments required is decreased owing to the fact that tappings would be discarded with only a small decrease in efficiency, it would still not comply with condition 2. Furthermore the author is of opinion that since with this method of amplification tuning is so extremely sharp—even when a vernier condenser is used paralleled with the anode inductance condenser— that more than one stage of tuned anode amplification is almost impossible in an amplifier operating under commercial quick-search conditions. Good audibility of approximately R.6 strength was required on standard $1\frac{1}{2}$ k.w. ship spark stations on a night range of from 500 to 600 miles, and it was magnification obtainable with a copper wound transformer against an aperiodic transformer, led the author to adopt a round figure of 50 per cent. less amplification in the case of an aperiodic transformer other things being equal, so that since two tuned transformers had been considered sufficient to satisfy condition 2, four aperiodic transformers were shown to be necessary.

This entailed the use of five valves in all, which number was considered to be too great from the point of view of economy in filament watts and anode feed current, yet two aperiodic stages only did not appear to guarantee

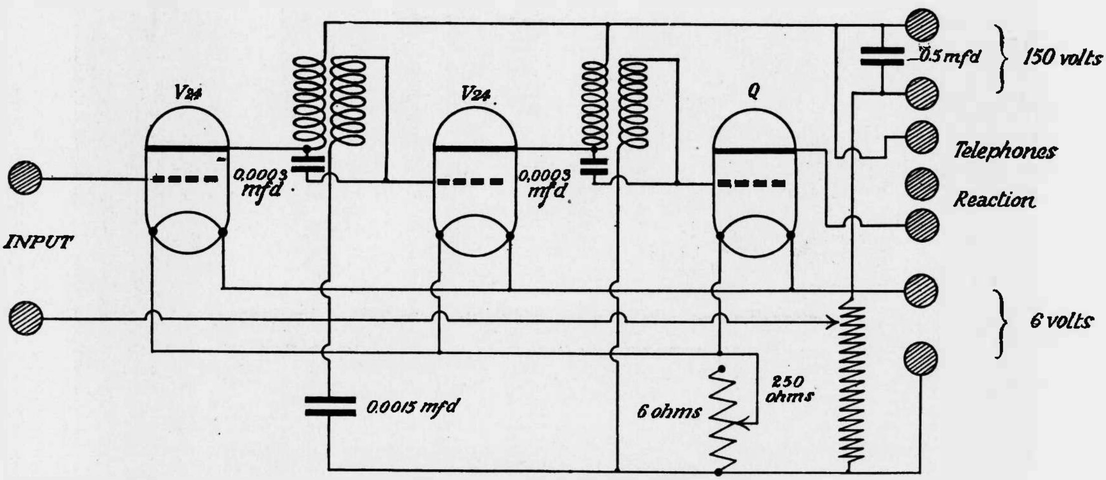


Fig. 2.—Wiring diagram of amplifier.

considered extremely doubtful if only one stage of high-frequency amplification would satisfy this condition.

The author therefore decided to employ method (c), that is, radio-frequency transformers wound with resistance wire giving high damping and consequently aperiodic with respect to the resonant frequencies.

With this type of transformer having an optimum magnification value at 600 ms., good sustained amplification will be given over the range of 300 to 1,000 metres, the amplification however being considerably greater at 1,000 ms. than at 300 ms., owing to the resonance curve of this type of transformer.

Having decided to employ aperiodic high-frequency amplification, the number of such stages had next to be determined.

Previous investigation into the relative the margin of safety on weak signal strengths that was desired.

The original aim had been to produce a receiver fulfilling the various requirements which have been specified without the employment of regeneration, but it was now decided to incorporate regenerative working and in so doing to ensure that two stages of aperiodic amplification would satisfy the somewhat exacting conditions which were required. The general scheme of design had now been fairly rigidly determined as a 3-valve radio-frequency amplifier; the first two valves coupled with aperiodic resistance-wound transformers, the third valve functioning as a rectifier of the amplified radio-frequency impulses.

At this stage it may be of interest to note that as regards actual cost, the figure for the two transformers wound with eureka wire is just under the cost of a receiver utilising copper wound transformers with their attendant switches and variable condensers.

Having decided on the general scheme of design, the number of controls was next considered, and it was deemed necessary that two filament rheostats should be employed one in common to the H.F. stages and one to control the operating characteristic of the rectifier valve.

It was further decided that a potentiometer was necessary in common to the H.F. stage in order to operate at the highest efficiency by means of grid control.

wound transformers a voltage drop between the + H.T. supply and the anodes of the valves would, for the windings required, be in the neighbourhood from 20 to 30 volts, thus the high-tension battery would need an E.M.F. of approximately 100 volts in order to maintain the anodes at 70 volts.

Furthermore an examination of the average characteristics of the R. type valve will show that to operate on the straight portion of the anode current grid volts curve (for E=70), with zero grid potential, the anode current will be in the region of 1 milliamp., which for 3 valves would give an anode feed of probably

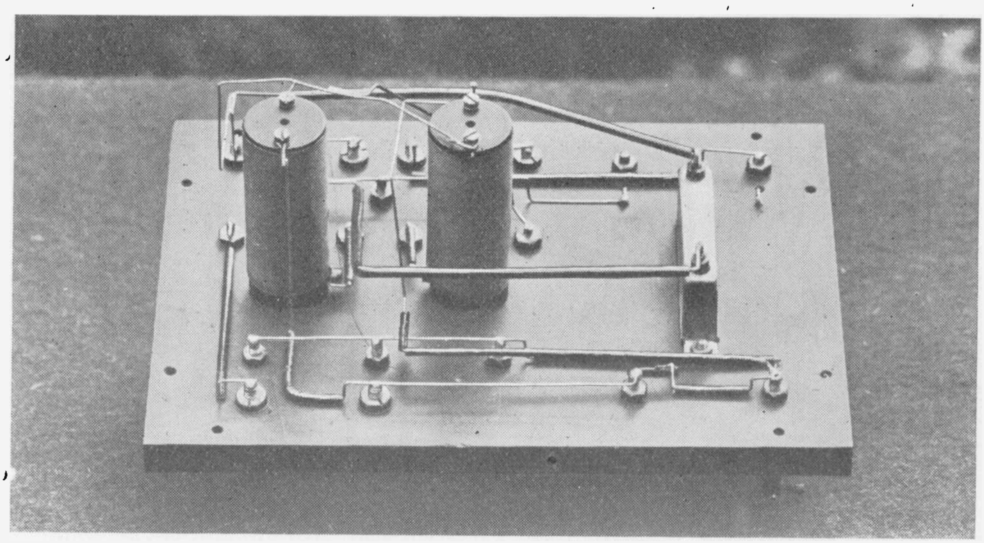


Fig. 3.—Underside of panel showing transformers and H.T. dyepass condenser.

nearly 4 milliamps., which was considered to be rather high.

At this point arose the determination of the type of valves to be employed and also the means to adopt for rectification.

The Marconi R. type valve was first considered, the average working conditions of which are as follows :—

Filament volts, Ef, 4.00 volt.

Filament current, If, 0.75 to 0.8 amp.

Plate potential, E, 60-80 volts.

To give a reasonable length of operation on one charge of the filament accumulator, it was decided that a 6.0-volt battery would be necessary to balance the voltage drop of an average 60-volt battery when discharging at approximately 3 amperes.

The plate potential was next considered and it should be noted that with resistance-

The standard Marconi receiving valve type V24 was next considered and for the H.F. stages was finally adopted for the following reasons :—

1. 5-volt filament being well within the economical running of a 6-volt battery.

2. Low anode current for H.F. amplification at zero grid potential—under 1 milliamp.

3. Low anode voltage required, *i.e.*, 30 volts.

4. Very low internal capacity.

Coming now to the method of obtaining rectification both anode and grid rectification were considered and since the writer has had considerable experience with Marconi receivers employing the former method, it was decided to rectify with a "Q" type valve, the grid being maintained at its best operating potential by means of a potentiometer. This necessitated one extra adjustment over that required by grid rectification by means of a grid condenser and leak, but as the combination of a separate filament rheostat and grid potentiometer on the rectifier constitutes a very efficient limiter for selective working on 600 ms., the extra adjustment was in this instance considered to be quite justifiable. The final circuit arrangement being shown in Fig 2.

The preliminary considerations having now been discussed and the main design scheme having been decided upon, it is proposed to give some detail of the actual construction.

Before proceeding further it may be advisable to point out that in a radio-frequency amplifier of this type a tendency toward self-oscillation may cause a certain amount of trouble, if one or two important factors are lost sight of.

Although this type of amplifier is certainly far less liable to burst into self-oscillation than either of the tuned types considered above, this tendency, nevertheless, may show itself if the transformers are placed too close together. The writer has found that if high-frequency transformers of the type used in this amplifier are placed *less* than approximately three inches between centres, a certain amount of self-oscillation may occur, necessitating an adjustment of the grid potentiometer in order that a positive potential may be applied to the high-frequency grids.

The use of the potentiometer in this manner will stop any tendency towards self-oscillation but at the same time it should be noted that it will reduce seriously the efficiency of the circuit owing to the damping effect of the positive grid current set up by the grids themselves being positive. If, however, the transformers are placed no closer than the minimum distance above, it will be found that the circuit is perfectly stable under all conditions, even when the plate voltage is as high as 150 volts

It may be found helpful also to remember one other factor which will lead to increased efficiency, and that is, that the input and output leads to the H.F. transformers should be short and well separated not only from themselves but from those of the other transformers. The actual arrangement of these leads is shown in Fig. 4. If careful attention is paid to this, and to the preceding point, it will be found that the only work the grid potentiometer will be called upon to do is to operate the H.F. amplifying valves at the most efficient points on their characteristics ;

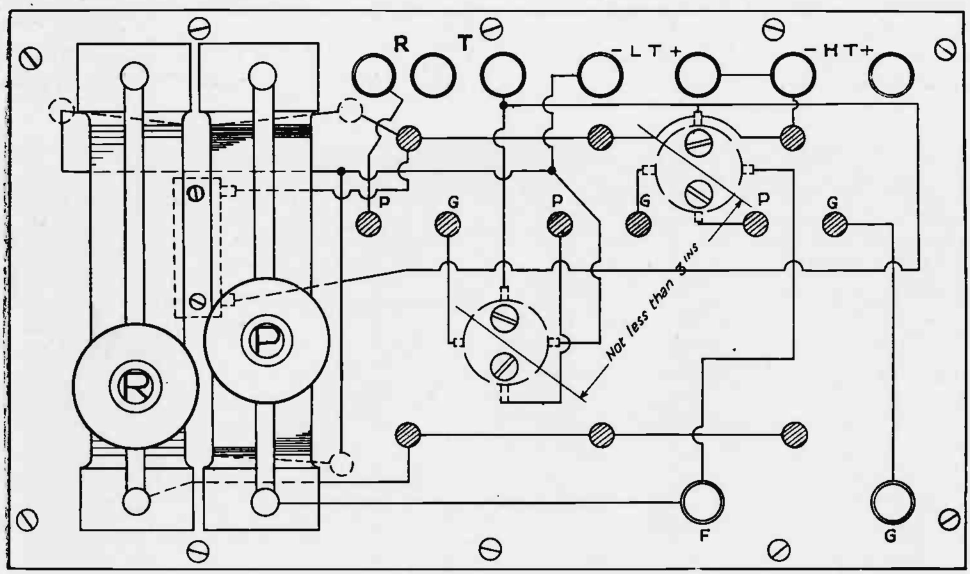


Fig. 4.—Diagram showing wiring lay-out.

this, in the writer's opinion, is the legitimate function of a H.F. grid potentiometer which in a carefully designed and assembled amplifier should not be called upon to damp out oscillating tendencies by means of positive grid potential.

In the design of highly damped aperiodic transformers, such as used in this amplifier, it is essential that the maximum degree of coupling should be employed between the primary and secondary windings. Even in such aperiodic transformers there is a certain resonance peak on the curve which can be plotted showing amplification against wave-length ; any weakening of this coupling between windings tends to make this peak far more pronounced, and if this is the case the great advantage of this method of high-frequency amplifications, namely, sustained amplification, is immediately lost. This coupling is also increased by means of small condensers of 0.0003 m.f.d. capacity which are connected between the windings themselves ; these condensers helping still more to flatten out the resonant peaks of the transformers. In order to obtain maximum coupling between windings it is necessary to wind the transformers with single-layer primaries and secondaries, both windings being in the same direction with a one to one ratio of turns.

The essential high damping of the transformer winding is obtained by the use of resistance wire, which, in the amplifier in question consists of No. 46 S.W.G. Eureka wire. In passing it may of interest to note that the writer's experience with this type of transformer is that, using this gauge of resistance wire wound on formers with a diameter of $1\frac{1}{8}$ inches, the optimum wave-length is approximately equal to the number of turns, that is to say, for 600 ms. work both primary and secondary are wound with 600 turns. Finally Fig. 5 shows the relationship between amplification and wave-length both with and without re-action, the curve being, of course, only relative, since the degree of amplification will vary according to the station which is being received. Whilst considering this effect of reaction it should be noted that some method of reversing the reaction coil leads should be incorporated in the design, since on coming down to 300 metres a phase reversal occurs in the neighbourhood of 400 metres, thus necessitating a reversal of the reaction coil itself on the lower wave-lengths.

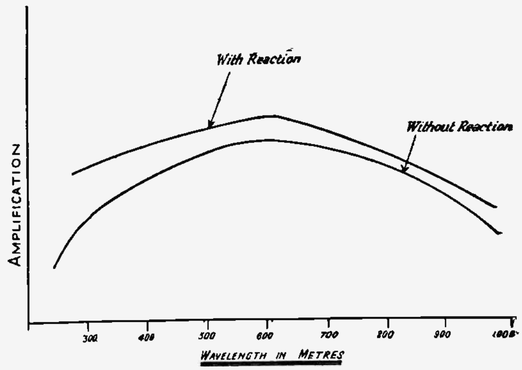


Fig. 5.—Amplification curves with and without reaction.

Telegraphy on a Power of 30 Watts.

SINCE going to press with "The Month's DX," we have received some details of what is surely a world's record for amateur transmission. Mr. E. J. Simmonds, 2OD, who is too well known to need an introduction to readers of EXPERIMENTAL WIRELESS, worked for some considerable time Mr. Dodman, of Summit, New Jersey, U.S.A., using an AT40x valve. The input was 35 M.a. at 900 v., and the transmission was conducted as easily as if the stations were not situated more than a few hundred miles apart. This in itself is sufficient evidence of the efficiency of the apparatus and the skill displayed in its design and adjustment.

Discussion on Loud Speakers for Wireless and other Purposes.*

THEORY OF LOUD-SPEAKER DESIGN: SOME FACTORS AFFECTING FAITHFUL AND EFFICIENT REPRODUCTION.

By L. C. POCOCK, B.Sc., A.M.I.E.E.

If it is assumed that properly amplified and undistorted speech voltage is available in the output circuit of a final amplifier, the problem is to procure the reproduction of speech efficiently and faithfully. The exact criteria for the reproduction of speech are better known than for music, but it is probably safe to say that a system capable of reproducing speech perfectly will give a highly satisfactory performance with music.

If V is an impressed voltage of any frequency or amplitude within the region to be amplified without distortion, and P the resulting alternating air pressure outside the system, the conditions are :—

$$P = A V$$

where A is an efficiency constant independent of the frequency and amplitude. It is also necessary that there shall be no asymmetric distortion, that is, any single frequency V must produce only the corresponding single frequency P. This condition is also expressed by the equation above.

Present-day electro-magnetic loud speakers are, without exception, a compromise between relatively good efficiency and good quality, such efficiency as can be secured being obtained only with the aid of mechanical resonance, which is contrary to the criterion for faithful reproduction given above. Further, although telephonic speech has generally been handled in the past as a steady-state problem, recent improvements in transmission have rendered the transient phenomena associated with consonant sounds and every change of amplitude of some importance. The reproduction of severe transients cannot be perfect in any resonant system or in any system containing mass and stiffness, even though the damping be such as to prevent any natural oscillation; the severity of transients actually encountered in speech is dependent on the damping of the vocal resonances, and information on this subject, together with like information on the auditory mechanism, might indicate the desirable degree of damping from the point of view of transient phenomena. It is clear that the use of resonance to increase the efficiency cannot be pushed too far.

Practical loud speakers consist of a rather sharply resonant system working into an acoustical load, namely, a horn. It is not quite accurate to describe the horn as a load, because the useful work is the energy transmitted through the horn. The horn is operating in a capacity analogous both to an electrical transformer and to an electrical transmission line. The likeness to a transformer is seen in the passage of energy from the high mechanical impedance of the diaphragm to the low impedance of the open end through the coupling device, which reduces energy reflection to a minimum and aims at obtaining the greatest possible transfer of energy. The likeness to a transmission line lies in the propagation of waves across the non-uniform section of the horn; the analogy is to a non-dissipative line containing distributed inductance and capacitance, the line constants changing steadily from end to end of the line in such a way that the impedance measured at one end of the line is high, and that measured at the other end is low. Such a system would form a maximum energy coupling between two different electrical impedances.

The acoustical impedance of a horn at its small end depends a good deal on the cross-section and also varies with the solid angle and the form of the horn, but, as in electrical analogies, the impedance is also a function of the impedance into which energy is delivered, *i.e.*, at the open end. Another view of the acoustical impedance at the small end is to regard it as the impedance of the large end modified by the horn through which it is measured. In general, the horn impedance also varies with frequency, and, though horns of approximately uniform impedance can be made, it is clear, from a consideration of the varying mechanical impedance of the diaphragm, that such a horn is not necessarily the best.

These are some of the factors which enter into the performance of a horn. The practical considerations are usually those of size; for indoor use the horn must not be too long, so that the problem is equivalent to attempting to obtain an electrical line of length equal to a wave-length of less and having a very much higher line impedance measured from one end than when measured from the other end. The acoustical impedance is virtually coupled to the diaphragm, so that some idea of its variations with frequency can be obtained by observing the motional impedance of the receiver. A large number of horns, of a size suitable for use in private houses, have been examined in this way, and resonances of varying degree have been found in all; larger horns might, however, be expected to show lesser effects.

The resonance of a receiver without horn may be

* Two papers of particular interest to the experimenter which, amongst others, were read before a joint meeting of the Institution of Electrical Engineers and The Physical Society of London, on Thursday, November 29, 1923.

such that the diaphragm vibrates with more than 50 per cent. of the amplitude at resonance over a frequency region about 100 periods wide. When the horn is put in place the diaphragm is made to do more work and the resonance is made less sharp. The new damping co-efficient cannot be simply expressed, because the resonance is no longer simple but is complicated by the coupled horn resonances.

The actual pressure variation in the air when the receiver is excited at different frequencies can be measured. Figs. 1 and 2 show the characteristics of two types of receiver. The curve in Fig. 1 is for a flexible diaphragm driven by a small armature supported on a spring. The effective moving mass is not appreciably greater than that of the ordinary telephone receiver. The curve is an average of the results of five receivers and shows definite peaks in the lower frequency region, due to the horn. It is seen that the distortion due to these resonances is small compared with the general effect, due to the mechanical resonance of the system. This is an important point: horn distortion can be brought within reasonable limits; the receiver mechanism is often responsible for defects of tone for which the horn is blamed.

In connection with Fig. 1 it may also be stated that the perfection of reproduction is a great deal better than the appearance of the characteristic would suggest; the contracted logarithmic scale disguises the really rather gradual fall of the curve at the higher frequencies; even at the extreme end of the curve the highest frequency shown is reproduced with sufficient intensity to add greatly to the quality of reproduction.

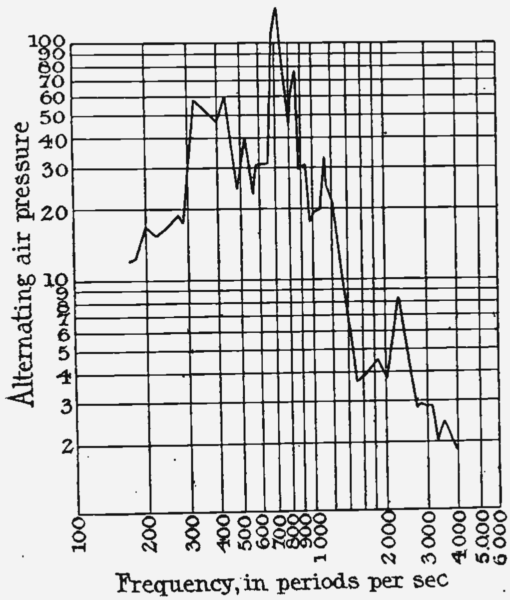


Fig. 1.—Alternating pressure output of loud-speaking receiver corrected for impedence of circuit and receiver.

Fig. 2 is the characteristic of a loud-speaker of the iron-diaphragm kind, similar in principle to the ordinary telephone receiver; in this case the curve is an average of several tests taken on the same receiver. The frequency of maximum response is seen to be a little lower than in Fig. 1, and the curve drops somewhat steeply between 1,000 and 2,000 periods per sec. (p.p.s.).

In both the above cases the receiver output is corrected for the impedance of the associated amplifier, that is, a fixed voltage is operating on the loud-speaker through a fixed resistance representative of the amplifier output impedance that would be suitable for use with the receiver considered. Since the impedance of most receivers at about 4,000 p.p.s. is two three, or more times as great as the impedance at 1,000 p.p.s., the reproduction of the higher frequencies is somewhat impaired due to this cause.

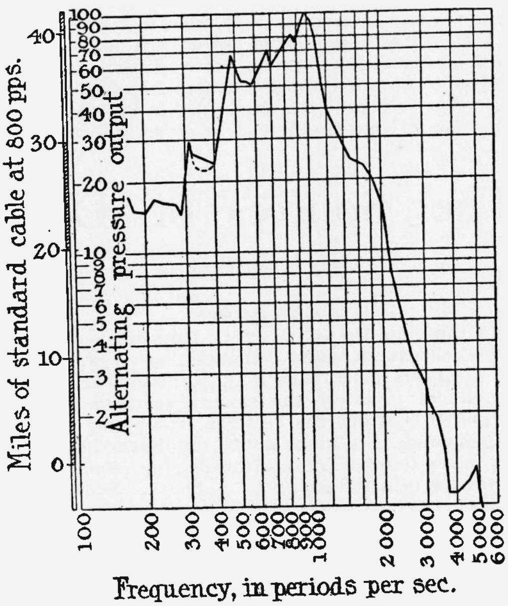


Fig. 2.—Alternating air-pressure variation with frequency for large receiver when used with constant E.M.F. in a circuit of which the output impedance is 1,000 ohms.

Receivers have been constructed in which large vibrating surfaces are used without a horn. It appears that the vibrating surface must be of such dimensions that there is difficulty in securing the necessary lightness of the moving parts, especially when the added mass due to the reaction of the air, is taken into consideration. In any case, the very important distortion due to the use of mechanical resonance to obtain good efficiency remains in evidence.

With regard to the mechanical construction of an electro magnetic receiver, the ordinary construction of a telephone receiver requires considerable modification if it is to handle more than a very small amount of power and, even when so modified, there is danger of distortion due to the asymmetrica forces called into play by the passage of symmetrical currents. A receiver of the type giving the characteristic shown in Fig. 1 is capable of handling about 10 watts without a symmetrical distortion, because the armature is driven by symmetrical forces. The amplitude of vibration may be of the order of 0.01 inch.

To sum up, with present-day constructions of receivers, faithfulness in reproduction cannot be obtained beyond a certain degree without making receivers very inefficient. Reproduction can, by careful design, be made very satisfactory, but to obtain the very last degrees of perfection, *e.g.* by filters, enormous increases in the power amplification would be necessary to operate the receiver, in fact, valves of far higher power capacity than are used in any radio receiving sets. As it is an easy matter to obtain the present amount of amplification, it is seen that the chief interest in raising the efficiency of loud-speakers is to permit the application of quality-correcting devices, provided of course that increased efficiency is obtained without sacrifice of quality.

With regard to the overall efficiency obtained in loud-speaking receivers, it is probable that 1 per cent. is a high estimate and that a few tenths of 1 per cent. would generally be nearer the mark. The principal loss is iron loss, and (though lamination will reduce this) hysteresis still accounts for a very considerable loss on account of the high frequencies concerned. It does not seem likely that any great improvement in real efficiency can be obtained unless a magnetic material with exceptionally low hysteresis loss and good permeability is discovered. Small improvements are possible by building receivers on a larger scale and using more powerful magnets, but the necessity of making some part of the moving system of iron and low mass makes the employment of high alternating flux density in this vital part unavoidable.

The Sources of Distortion in the Amplifier.

By Professor C. L. FORTESCUE, M.A., M.I.E.E.

(1) Scope.

In this note the output P.D. from the rectifying valve of crystal is taken as the starting-point. With an ideal amplifier this P.D. is magnified and a current of precisely the same wave-form as the output P.D. from the rectifier is supplied to the loud-speaker. In many actual amplifiers, however, the wave-form is not faithfully reproduced and distortion is introduced.

(2) The Causes of Inaccurate Reproduction.

These may be put under the following headings :—

(*a*) Curvature of the valve characteristics.

(*b*) The use of intermediate circuits having more or less clearly defined natural frequencies.

(*c*) The unavoidable reaction effects present in most designs of note magnifiers.

(*d*) Unsatisfactory reproduction in the last (or output) transformer.

(3) The Effects of Curvature of the Anode Current Characteristics.

(*a*) *Resistance amplifier.*—The ideal resistance amplifier is as shown in Fig. 1, and consists of a valve with a non-inductive and capacityless resistance R_a in series with the anode and a condenser of very large capacity across the battery terminals. The valve characteristics may be conveniently plotted as a characteristic surface in terms of V_b and V_g, allowance being made for the resistance R_a.

The surface shown in Fig. 3 is the ordinary characteristic surface, the lines corresponding to constant anode current, but allowance is made for a series resistance of 10,000 ohms. The fluctuations of the grid P.D. above and below the mean value may be plotted below the diagram of Fig. 3 as at G. Then, by projecting up to the line PQ, corresponding to the given value of the battery voltage, the values of the anode current can be plotted above and below the mean value at C. A reference to Fig. 3 shows that the anode current wave-form can only be an exact replica of that of the grid P.D. when the constant-current lines are equally spaced along the line PQ. Thus, if the surfaces are plotted out for any given value, the possible range of anode current and grid voltage over which faithful reproduction can be obtained will be easily seen and the appropriate values of V_{g_0} and V_b can be chosen. The values taken in plotting Fig. 3 are $V_b = 200$, $V_{g_0} = -4$. The amplitude of the fluctuations of V_g is 3.5 volts and of i_a, 1.75 mA.

(*b*) *Transformer amplifier.*—Except in the last stage, a transformer in the anode circuit should closely approximate to a resistance. When very heavily damped, due to its own losses and the load of the valve, and when near the resonant point, this is actually the case. The effective resistance to the alternating P.D.'s (which are the ones under consideration) is, however, very much greater than the resistance of the anode winding as measured by direct current. The resistance must be ascertained by A.C. bridge methods at the resonant frequency. Some transformers having a direct-current resistance of the order of 2,000 ohms are found at the resonance point to have effective resistances of 200,000 to 300,000 ohms when loaded on the secondary side with resistances corresponding to the grid resistance of the next valve. The representative characteristic surfaces must therefore be plotted for this high value of R_a and not for the d.c. resistance ; the latter is only used to obtain effective starting-point for any actual battery voltage.

For frequencies other than the resonant frequency of the transformer the conditions are more complicated, and merely plotting the characteristic surface with a correction for a series resistance is insufficient. The surface must be plotted without correction and both the grid and the anode fluctuations must be allowed for. The line PQ of Fig. 3 becomes a curve—an ellipse in the case of two pure sine waves—and so long as this curve remains within the zone where the constant-current contours are equally spaced the reproduction will be satisfactory.

(4) Effect of Curvature of the Grid Characteristics.

If the grid voltage fluctuations have any considerable positive values the grid currents will be quite appreciable, and the wave-form of the grid current will differ very widely from that of the grid P.D. Fig. 2 shows approximately the curve of the grid current corresponding to the conditions assumed for Fig. 3. The grid currents will generally react on the source of P.D. and lead to a change of wave-form somewhat in the same way that the wave-form of the E.M.F. of an alternator is dependent upon the wave-form of the current which it is supplying.

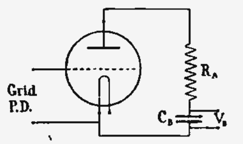


FIG. 1.—Resistance amplifier.

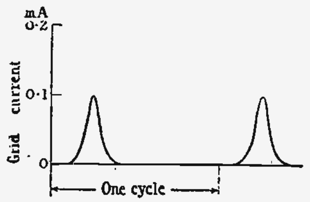


Fig. 2.—Wave-form of grid current with conditions of Fig. 3.

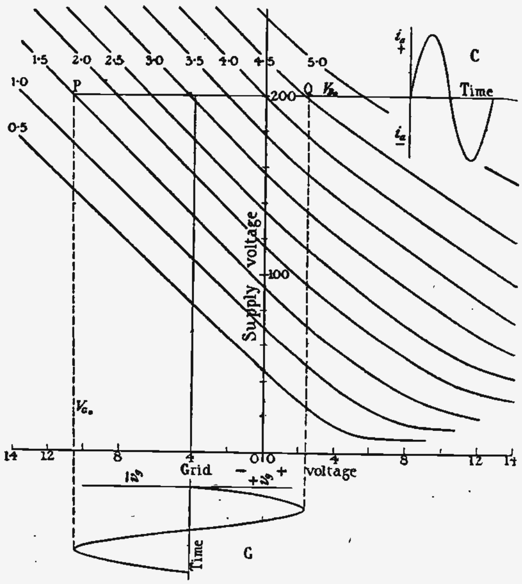


FIG 3.

be greatest at the resonant frequency. Thus any sustained harmonic having this frequency will be unduly pronounced and the speech will appear "tinny" or "drummy" depending upon the pitch of the accentuated harmonic. The larger the number of stages of amplification that are used the more marked is the effect.

In the case of those high-frequency components which are not sustained, the effects are less pronounced. This effect is thus most noticeable with musical sounds and with the vowel sounds. Secondly, for frequencies other than the resonant frequency the transformer is no longer equivalent to a resistance, and complications arise from the relative phase of the grid and the anode potential fluctuations on account of which it becomes very difficult to determine the wave-form of the anode current when the amplitudes are fairly large.

The only way of avoiding this difficulty is to render the effect of the grid current negligible. Valves have not yet been produced in which the grid current is negligible when the grid is positive and the anode voltage is low, and consequently positive values of the grid voltage must be avoided. This gives another limitation to the range of the anode current characteristic curves that can be used, and indicates that the anode battery voltages should be high, and that the mean grid voltages should be considerably negative.

(5) Effect of the Natural Period of the Intermediate Circuits.

This trouble arises in the case of a transformer amplifier. In the first place any marked resonance means that the effective impedance in the anode circuit is dependent upon the frequency. The impedance—and therefore the amplication—will

(6) Reaction Effects.

These effects are well known, particularly in high-frequency amplifiers used as self-heterodynes. They are equally important, however, in note magnifiers, as is shown by the tendency of a high-power magnifier to "howl" when adjusted for maximum amplification. This reaction effect is greatest in transformer amplifiers, and is attributable to the capacity between the electrodes of the valves. The coupling between consecutive grid and anode circuits tends to produce stability and decreases the effective amplification. But where more than one stage is employed there is also a coupling between a grid circuit of one valve and the anode circuit of the valve next but one to it. This coupling acts through the two valve capacities in series, but if the voltage step-up per valve is more than two the coupling effect tending towards instability is greater than that from the immediately adjacent anode circuit opposing instability. With three valves the effect of the last anode circuit on the first grid should be in the direction of stabilising, but on the second grid circuit it may well produce instability.

The effect of this reaction is that with sustained waves the frequency which renders the system most nearly unstable attains to a higher amplitude, relatively, than other waves of other frequency.

It seems probable that there are in general several frequencies which are thus accentuated, but owing to the similarity of the consecutive stages in most amplifiers these frequencies are close together and are usually near the natural resonance point. The resulting effect is thus an accentuation of the defects arising from marked resonance.

The pure resistance amplifier is not entirely immune from the effects of reaction unless the condenser across the anode battery is of very large capacity indeed. Under certain circumstances, also, if the capacity across the anode resistance is appreciable a resistance amplifier will "howl" owing to an oscillation being set up in the same way as in the "Kallirotron."

(7) Distortion in the Last Stage.

The last stage is not infrequently a source of serious trouble for two reasons :—

(i) The amplitudes are large.

(ii) The "load" on the output transformer—*viz.*, the winding of the loud-speaker—is inductive and this inductance is not constant.

With regard to (i), the output required for a sustained musical note is of the order of 10 mA (R.M.S.) at 5 volts (R.M.S.). To give an equivalent volume of sound with ordinary speech a peak value of perhaps double these figures will be necessary, and after allowing for the losses in the transformer it seems that the output from the anode circuit of the last valve will be equivalent to an alternating current of peak value 30 mA at an alternating P.D. of peak value 15 volts. A transformer is almost invariably used, and the actual values would more probably be 10 mA at 45 volts. This involves a valve giving an emission current of perhaps 50 mA, with a fluctuation of anode current over the range 15 to 35 mA ; and a voltage at the anode of perhaps 120, fluctuating between the limits of 75 and 165. General numerical considerations such as these show the necessity for valves of considerable output in the last stage.

High battery voltages are also necessary—in the above case the steady fall of P.D. in the anode circuit would be of the order of 50 to 100 volts, and a battery giving something in the neighbourhood of 200 volts would be unavoidable.

With regard to (ii), owing to the inductive nature of the load the last stage cannot be regarded as being even approximately a resistance, and the same effects are noticed as with a transformer operating out of resonance.

(8) Conclusion.

With properly designed valves and circuits it does not appear that any serious distortion can be charged against the amplifier. Valves giving considerable power output must, however, be used in the last stage.

Some resonance effect seems unavoidable in the transformers, and may be accentuated by reaction. The presence of this effect may, however, be an advantage owing to the fact that it can be used to some extent to compensate for defects in other parts of the equipment.

Aerial Design for 200-metre Transmission.*

ON Friday, December 17, a meeting of the Radio Transmitters' Society was held at the London School of Economics, the President of the Society, Capt. P. P. Eckersley, being in the chair. An informal discussion on aerial efficiency on short wave-lengths was opened by Mr. L. G. Morrow, who gave a short talk on "Aerial Design for 200-Metre Transmission."

Mr. Morrow's Paper

I think that you will all agree that the efficiency of our stations depends, first and foremost, on the efficiency, or otherwise, of the aerial, or more correctly speaking, the aerial-earth system, and if we are to pursue this search after efficiency to a satisfactory conclusion, it means that as much as possible of the power which we put into the aerial must be available as *usefully* radiated energy.

To obtain the greatest proportion of useful radiated power it is necessary to minimise to the greatest possible extent the various losses which occur in the aerial system, and it is mainly on the reduction of these losses that I expect the discussion which follows will centre round.

I will, therefore, try to point out briefly how these various losses occur, and by what means we can minimise them in our aerial design.

Any aerial system when supplied with H.F. currents absorbs power, some of which is radiated in the form of an electro-magnetic field, and represents useful power, whilst the rest is absorbed in various ways, and constitutes a total loss, since it contributes nothing towards the radiated power.

Now all the power absorbed by the aerial can be regarded as if it was expended in a *Resistance* of such a value that it would absorb the same power expended in the system for the same current flowing in that circuit. This resistance is a fictitious quantity, and is known as the "effective" resistance.

This effective resistance may be divided into two parts.

(1) Radiation Resistance, and

* A paper read before the Radio Transmitters' Society on December 17, 1923.

(2) Loss Resistance.

Taking the former, we may again define this as being a fictitious resistance, the value of which will absorb the same power as is radiated for the same, current as flows in the aerial, and is, therefore, the measure of ability of the aerial to radiate power. An aerial with a high radiation resistance will be a better radiator than one with a low radiation resistance, hence we should design our aerial so that the radiation resistance is the greatest *percentage* of the total resistance.

If we examine the formula which gives us the radiation resistance (*i.e.*)

$$R_r = 60\pi^2 \frac{h^2}{\lambda^2}$$

we see that R_r is dependent on two qualities, namely height and wave-length; in other words, R_r is directionally proportional to the square of the height, and inversely proportional to the square of the wave-length. Now, as far as we are concerned, our wave-length is within quite small limits fixed by the powers that be; therefore in order to obtain a high percentage radiation resistance we have only the height left as a variable quantity.

Unfortunately in most cases the heights of our aerials are directly proportional to the depths of our pockets—it is in my case—and even if it was not a question of expense, we cannot go on increasing the height indefinitely, since to do so will, in all probability, bring our fundamental higher than we wish.

The only remaining alternative is, therefore, to reduce the loss resistance as much as possible, at the same time keeping the radiation resistance as high as possible by careful consideration of the relation between fundamental wave-length and operating wave-length, and by getting as much height as we can.

The loss resistance of an aerial is due to a number of separate losses, which we can enumerate as follows:

(1) Dielectric losses in the neighbourhood of the aerial.
(2) Ohmic resistance of the aerial itself.
(3) Ohmic resistance in the ground or counterpoise.
(4) Eddy current losses in nearby conductors.
(5) Leakage losses.

Before we proceed further, it will probably simplify matters to show these losses graphically, including R. Of the five losses we have just mentioned, the first and fourth are, in many cases, outside our control, but we can certainly reduce the remainder as far as possible by careful design.

Taking these losses in order, the dielectric losses are due to hysteresis phenomena taking place in such materials as the masts, stays, trees in the vicinity of the aerial, etc., and these losses increase directly as the wave-length. On 200 ms these absorption losses should not amount to very much, but we can reduce these as much as possible by keeping the ends of the aerial as far as practicable from the mast, especially the free end, breaking the stays with insulators and careful design of the lead-in tube. (In passing, I might perhaps mention the fact that in my own station I was troubled by harmonics when the stays were broken, but by breaking each stay into three I was able to cure this.)

Ohmic Resistance.

Very little need be said about this, save that the aerial wire should be of large cross section and good conductivity. The large cross section may be obtained by using stranded wire, in which each strand is insulated to prevent the skin effect increasing the resistance. Joints should be eliminated as far as possible, and where occurring should be well sweated.

Ohmic Resistance in the Ground or Counterpoise.

I think you will all agree that attention to the earth resistance is of paramount importance, and unless you are the fortunate possessor of a constantly perfect earth, I think the counterpoise is the only way to reduce our earth losses. When energy is delivered to an aerial, a large portion of this energy is dissipated into the neighbouring ground and is not recovered, but if we arrange some kind of reflector between the aerial and the earth, and make this reflector in comparison with the earth proper an almost perfect conductor, then we shall be able, to a certain extent, to minimise these losses.

The function of such a reflector or counterpoise is, therefore, to intercept the downward radiation from the roof of the aerial, and to carry the return current on the wires forming this counterpoise rather than the earth.

According to Maxwell, an *earthed* counterpoise with wires 1 ft. apart and 2 ft. 6 ins. above ground, will carry about 80 per cent. of the current, leaving 20 per cent. in the ground, and if the counterpoise is insulated there is less than 1/1,000 per cent. earth current.

Now usually domestic troubles will ensue if we arrange a counterpoise at only 2 ft. 6 ins. above ground; therefore, we are practically limited to a minimum height of about 7 ft. I am afraid time does not permit a full consideration of the design of counterpoises, but you will find in the *Proc. Inst. Elec. Engineers*, May, 1922, what I think is the finest modern treatise on this subject, by Mr. T. L. Eckersley.

We should, however, design our counterpoise in such a way that, if possible, it extends on both sides and at each end to a distance equal to half the height of the aerial above it, paying as much attention to insulation as in the aerial itself. The wires forming the counterpoise should obviously have as little ohmic and H.F. resistance as possible, and should be spaced about 1 ft. apart, being suspended on triatics attached to metal posts.

The ensuing discussion was characterised by its unconstrained nature, the free exchange of ideas, and the genuine interest which was displayed on the whole question of aerial losses and their elimination. The discussion was contributed to by Messrs. F. L. Hogg, H. S. Walker, H. Andrewes, G. Marcuse, E. J. Simmonds, and others—not to mention the revered President.

Mr. Hogg explained an original scheme which he devised for arriving at an approximate value for the total resistance of a transmitting aerial. A blank experiment is first made by dissipating just enough power on the plate of a transmitting valve when not oscillating to make it visibly red-hot in a given light, the exact power input to the valve being noted. The same valve is next made to oscillate and put a certain current into the aerial. The input and efficiency are adjusted until the anode is just as red as it was before. The total power input to the valve is again measured, and the difference between this and the first reading gives the power expended in the aerial system, whence, from a knowledge of the aerial current the aerial resistance can be calculated from the relation watts$=C^2R$.

The other speakers gave their experiences with various types of aerials, counterpoises, insulation and types of aerial wire.

Capt. Eckersley gave some interesting points of information, and once more exhorted us to try the "ratio-tap" for short-wave valve transmitters. He gave interesting instances of the losses which may occur when wood comes into the field of the aerial system. In one case a counterpoise was suspended by insulators from wooden posts, and it was found that undue losses were taking place; these losses were surprisingly reduced by substituting iron posts for the wooden ones. In another case an aerial lead-in was taken through an insulating bush in the wall of the wooden hut in which the transmitter was situated. The measured aerial resistance was found to be one ohm in excess of the calculated value; for some time this ohm could not be accounted for and could not be eliminated. When, however, the lead-in was taken through a large ebonite panel inserted in the side of the hut this ohm disappeared at once.

Capt. Eckersley also described the earth system used at the Bournemouth Broadcasting Station which gives good results when it is not practicable to instal the usual counterpoise. A system of radial wires are taken from the lead-in point, terminating in a large copper circle buried about 6 ft. below the surface of the ground. He also added his endorsement to the necessity of making all counterpoise wires exactly equal in length.

Answering a question put by Mr. Andrewes, Capt. Eckersley said that the introduction of a series condenser does not affect the radiation resistance of an aerial.

The whole meeting was a great success, both from a social and a technical point of view. So far there has been every indication that the Radio Transmitters' Society has a great future before it.

The Trend of Invention.

We summarise below the more important wireless inventions which have been disclosed during the month, special reference being made to those of immediate interest to the experimenter.

Still the problem of minimising interference appears to be engaging the attention of inventors. The number of patents taken out for systems for prevention of interference is legion, and still the problem seems far from being solved in a simple and effective manner. Several new arrangements are disclosed in the patent specifications printed during the last month. In British Patent No. 183,838 (British Thompson-Houston Co., of American origin) the aerial circuit is coupled to a circuit containing an artificial transmission line having an effective length equal to a number of wave-lengths of the signal to be received, which may consist of a solenoid, for example, or a series of inductances shunted by condensers. A number of coils are coupled to points one wave-length apart on this artificial line, and each of these coils is electrically connected to the grid circuit of a triode. These triodes have a common anode circuit. It is clear that when the grid coupling coils are coupled to points of the artificial line one wave-length (of the signal to be received) apart the E.M.F.'s in these coils due to the signal will be in phase, and thus all the triodes will assist one another in producing an effect in the anode circuit. If, however, the coils are not spaced exactly a wave-length apart the signal will produce a smaller effect in the anode circuit; hence if the arrangement is adjusted to receive a definite wave-length, other wave-lengths all have less effect, and thus the arrangement assists the usual resonance tuning, which is still employed, in the elimination of jamming. An example of this arrangement is illustrated in Fig. 1. The resistance shown at the right hand end of the artificial line is for the purpose of preventing reflection and should be made equal to the surge impedance of the line. An ordinary amplifier or detector is represented diagrammatically at B.

A different line of attack on the interference problem is shown in British Patent No. 187,986 (British Thompson-Houston Co. of American origin), which depends for its operation on the phase of the signal.

Broadly, this invention appears to reside in making the signal to be received supply the anode potential to a triode as well as the usual variation of grid potential. Thus, unless both the anode and grid potentials are substantially in phase no current will flow in the anode circuit of the valve.

The simplest arrangement is shown in Fig. 2. The aerial circuit is coupled both to the anode circuit and grid circuit of a triode. In the grid circuit is included a phase shifting device A, so that the phase relation between the two potentials may be adjusted. It is necessary, in order to eliminate interference, that the anode tuned circuit be sharply tuned to the signal, since it acts as a flywheel circuit, and fixes the phase of the system.

The beats formed as the result of interaction of a C.W. signal with a locally generated wave may be treated in the same way, the flywheel circuit then being tuned sharply to the beat-frequency.

Another modification is shown in Fig. 3 for using this principle to increase the directional properties of aerials. Two directional aerials at preferably right angles are used, and the E.M.F. in one aerial is applied to the anode circuit of a triode and in the other to the grid circuit by way of a phase shifter, represented by E. In the diagram A and B represent detectors, and C a local oscillator. In this case the arrangement is working at the beat frequency.

In order further to reduce atmospheric disturbances current limiting devices may be used in any except the flywheel circuit.

Another arrangement for the prevention of interference is shown in British Patent No. 185,397 (of French origin). The arrangement described by this patent specification essentially consists of a multi-valve aperiodic amplifier, retro-actively coupled and having a tuned circuit so adjusted as to make the amplifier maintain oscillations at a frequency which is a multiple or a sub-multiple of the frequency of the signal to be received. This amplifier is followed by an audio-frequency amplifier having its transformer circuits sharply tuned to the beat frequency formed by the interaction of the signal and the locally generated oscillation. It is stated that the detection of the signal takes place before it is applied to the aperiodic amplifier.

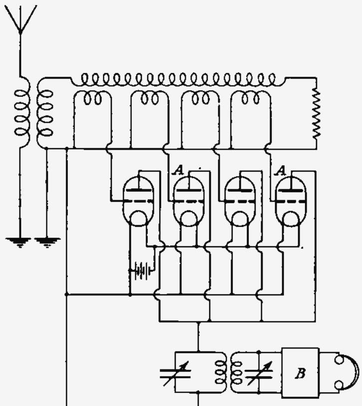


Fig. 1.

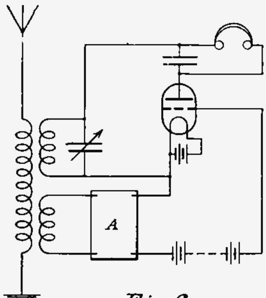


Fig. 2.

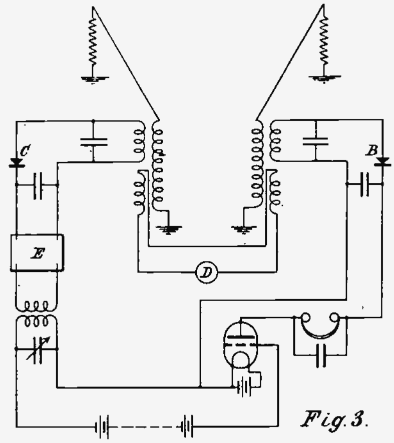


Fig. 3.

Grid Control for Transmitting.

An interesting system of keying a transmitter, particularly suitable for a single-valve transmitter is shown in British Patent No. 205,878 (Preston and others, British). Broadly, according to the invention the grid coil is divided into one or more portions of which one portion is shunted by a variable condenser, and one portion may be short-circuited by a switch. A straightforward arrangement is shown in Fig. 4. The normal grid tuned circuit is formed by the inductance D and condenser E. The tuned circuit FGH is provided, the coil H of which may be short circuited by the switch P, which is electro-magnetically controlled by the key Q. The circuit FGH is tuned approximately to the same frequency as the other oscillatory circuits. In these circumstances the set will oscillate when the switch P, short-circuiting the coil H, is closed, and will stop oscillating when the switch is open. Another arrangement is shown

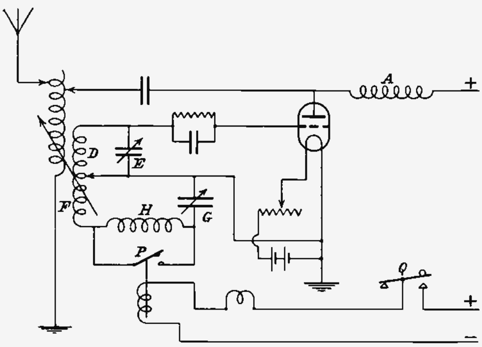


Fig. 4.

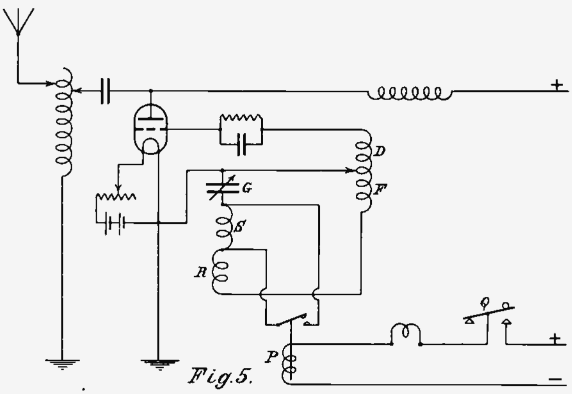


Fig. 5.

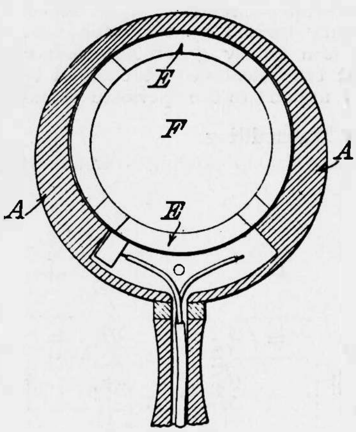


Fig. 6.

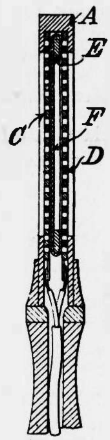


Fig. 7.

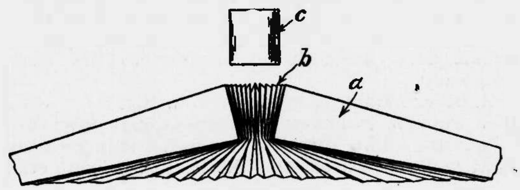


Fig. 8.

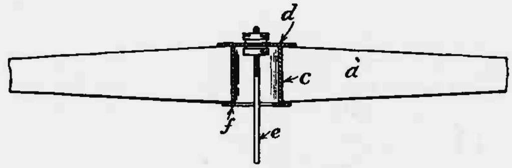


Fig. 9.

in Fig. 5 wherein there is no electro-magnetic coupling between the grid circuit and the anode circuit. In this arrangement the coils S and R are mutually coupled and wound in opposite directions. The main principle of this invention seems to be the use of an absorption circuit associated with the grid circuit of a triode. It is stated that this method of control may be used for grid modulation for wireless telephony. Presumably for this purpose it would be necessary to insert a variable resistance device such as a carbon microphone in place of the switch P, or possibly across the whole of the inductance of the extra circuit.

Telephone Instruments.

The advent of broadcasting has brought a problem new to the radio engineer, and that is to produce both good transmission and reception of

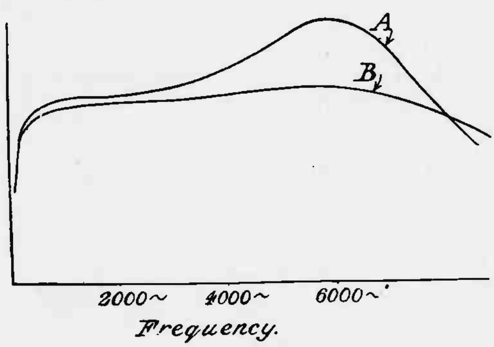


Fig. 10.

speech and more particularly music. It is undoubtedly preferable that the reception end should employ a loud speaking telephone instead of head receivers. For many years the electro-magnetic receiver and resistance transmitter have been almost the only instruments used for telephony. With the modern demand for perfect reproduction of music and speech, as opposed to "commercially good enough" production, inventors have turned to a very old instrument known once as the "speaking condenser." The speaking condenser has many advantages when pure reproduction is the main desideratum. British Patent No. 206,601 (McLaughlin, British) describes a condenser which may be used either as a microphone or as a telephone receiver, when associated with suitable circuits.

A sheet of tissue paper is coated on one side with a film of metal and is placed against a perforated plate of metal which is coated with insulating varnish. Figs. 6 and 7 illustrate the construction of this instrument. The frame-ring of A of insulating material carries two metal plates C and D, one

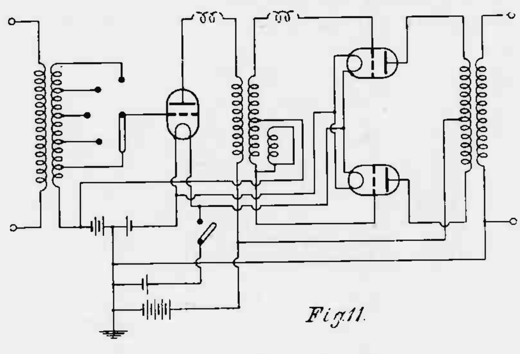


Fig. 11.

of which is coated with insulating varnish on its inside. The metal-coated tissue paper F is supported at its edge by a ring E.

The type of loud-speaking apparatus which has a large diaphragm and no horn has received some attention. British Patent No. 205,578 (The Gramophone Co. and others, British) describes an improvement on the now fairly well-known large pleated diaphragm, described in British Patent No. 11015 of 1909. The present patent is for a method of adequately straining the diaphragm by means of a core. To form the diaphragm a length of paper is pleated closely, and then the ends joined to form a tube having axial pleats. Then one end of this tube is pushed down and the other end expanded until the result is a nearly flat pleated diaphragm. At the centre the pleats remain, but near the margin they are stretched out. According to the new patent, before flattening out the diaphragm a cylindrical core is inserted and thus the required stress is imparted to the diaphragm. The core may be made of several convolutions of paper stuck together. Figs. 8 and 9 show the arrangement and are self-explanatory. The provisional specification states that for a diaphragm with approximately 100 radiating pleats each of width 7-16th in., the width of the strip from which the diaphragm is made being 6¾ ins., the diameter of the cylindrical core may be about 7-16th in.

Audio-Frequency Transformers.

It is well known to most people that audio-frequency transformers give rise to some distortion of speech currents, and many efforts have been made to minimise this distortion. British Patent No. 202,262 (Western Electric Co., of American origin) shows a method of doing this. A transformer is so designed that the effective inductance resonates with the tube capacity at a frequency near the upper limit of audibility, thus accentuating the higher frequencies which are apt to be bye-passed by the stray shunt capacities. In this way an amplifier can be made having a response characteristic as shown at A in Fig. 10. In order to suppress the rather pronounced hump it is well known to connect a large resistance across the secondary and so load the transformer. According to this patent, however, a third winding is provided of a few turns and a correspondingly low resistance is used, thus obviating the troublesome and generally expensive high resistance. Alternatively this low resistance may be shunted across a few turns of the secondary winding itself. The effect upon the response characteristic is shown at B in Fig. 10. Alternatively the tertiary winding or portion of the secondary may be made of the required resistance and short circuited. A diaphragm of a "push-pull" amplifier incorporating this invention is shown in Fig. 11.

General Apparatus.

A variable condenser having a rather novel principle is described in British Patent No. 206,769 (of American origin). The condenser is of the mixed di-electric type, and depends for its variation on "laying down" one plate upon another insulated plate. Figs. 12 and 13 show one form of condenser. When the spindle is rotated in a clockwise direction the capacity is a minimum as shown in Fig. 12, when the spindle is rotated in an anti-clockwise direction the spiral plate is "laid down" upon the mica or like insulator covering the inner surface of the cylindrical plate, thus increasing the capacity. The same effect can be secured by a springy inside plate normally curling away from the outside plate and pressed towards the latter by a revolving shoe. The drawback of a condenser of this type is its usually large minimum capacity and losses. However, a condenser of a given maximum capacity can be easily and cheaply made in a smaller compass than can the usual vane type of condenser.

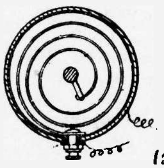


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Fig. 12.

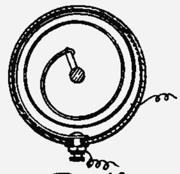


Fig. 13.

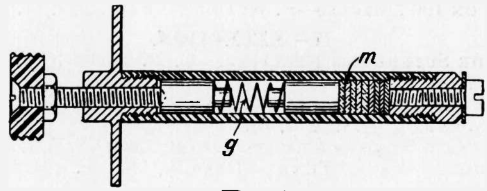


Fig. 14.

A patent for variable high resistances, such as grid-leaks, has just been published, namely No. 206,098 (Watkins, British). The construction described in the specification has a strong resemblance to the "Watmel" variable grid leak. The construction according to this specification is shown in Fig. 14. The discs or pellets M may be of fibrous material, for example cardboard or pâpier maché covered or impregnated with carbon or like material of low conductivity. Presumably our old friend, Indian ink, would be useful, perhaps combined with blotting paper. The compression spring G seems to be the essential feature. It seems as if a resistance of this type, while very useful for certain purposes, is not so valuable as might at first be thought. It would be expected to be somewhat unstable, and its resistance at a particular setting variable. However, in use in an experimental laboratory it is very valuable to have an infinitely variable high resistance, even if this is somewhat unstable.

Recent Wireless Publications.

Figures after the title of each publication indicate Volume and Number of Publication containing the article. Where only one number is given, this indicates the serial number of the publication. The abbreviations used in this bibliography will be found in th early issues of "Experimental Wireless."

I.—TRANSMISSION.

SOME POINTS ON TUBE TRANSMITTERS, PART I. H. F. Mason (*Q.S.T.*, 7, 4).

SOME POINTS ON TUBE TRANSMITTERS, PART II. —H. F. Mason (*Q.S.T.*, 7, 5).

A METHOD OF CONTINUOUS WAVE TRANSMISSION ON 100 METRES.—F. W. Dunmore (*W. Age*, 11, 2).

II.—RECEPTION.

THE SUPERDYNE RECEIVER.—C. D. Tuska (*Q.S.T.*, 7, 4).

TUNED RADIO FREQUENCY AMPLIFICATION.—A. L. Budlong (*Q.S.T.*, 7, 5).

A NEW NON-OSCILLATING DETECTOR (*Q.S.T.* 7, 5).

SHORT WAVE TUNER DESIGN.—K. E. Hassel (*Q.S.T.*, 7, 5).

A NEW AND ULTRA-SENSITIVE DETECTOR, THE SODION.—John V. L. Hogan (*Radio News*, 5, 6).

SOME NOTES ON RECEIVING ANTENNA RESISTANCE. —Samuel C. Miller (*W. Age*, 11, 2).

TUNED RADIO FREQUENCY AMPLIFICATION.—L. W. Bishop (*W. Age*, 11, 2).

MINERALS THAT ARE USED AS CRYSTAL DETECTORS. —Dr. E. Bade (*W. Age*, 11, 2).

A SUPERSONIC HETERODYNE RECEIVER.—W. S. Barrell (*W. World*, 223).

THE OPERATION OF THE ARMSTRONG SUPER.— D. F. Stedman (*W. World*, 223).

THE SUPERSONIC HETERODYNE RECEIVER.—W. S. Barrell (*W. World*) 224.

THE FUNDAMENTALS OF LOUD SPEAKER CONSTRUCTION.—A. Nyman (*W. World*, 226).

THE OPERATION OF THE ARMSTRONG SUPER (*W. World*, 226).

LOUD SPEAKERS.—E. Alexander (*Mod. W.*, 2, 3).

DISCUSSION ON LOUD SPEAKERS.—The Institution of Electrical Engineers with Physical Society (*Electn.*, 2377).

THE FADING OF RADIO SIGNALS.—Prof. G. W. O. Howe (*Electn.*, 2378).

III.—MEASUREMENT AND CALIBRATION.

MEASUREMENTS OF RADIO SIGNALS (*Q.S.T.*, 7, 4).

EIN EINFACHES KOMPENSATIONSVERFAHREN ZUR UNTERSUCHUNG VON KONDENSATOREN BEI NIEDEREN UND MITTLEREN FREQUENZEN.— Wilhelm Geyger (*Jahrb. d. drahtl. Tel.*, 22, 4).

THE WIEN BRIDGE.—A. Rosen, A.C.G.L., B.Sc., (*Phy. Soc. Lond. Proc.*, 35, 5).

V.—GENERAL.

VACUUM TUBE CHARACTERISTICS.—John H. Miller (*Q.S.T.*, 7, 4).

EFFECT OF GRID FILAMENT CONDUCTIVITY ON AMPLIFICATION.—F. M. Colebrook, B.Sc. (*Electn.*, 2375).

ELECTRONIC EMISSION (*Electn.*, 2378).

ZUR THEORIE DER AUSBREITUNG ELECTROMAGNETISCHER WELLEN AUF DER ERDKUGEL.—Otto Laporte (*Ann. d. Physik* 70, 8).

DIE HISTORISCHE ENTWICKLUNG DER ELEKRTONENRÖHRE IN DER DRAHTLOSEN TELEGRAPHIE.—Otto von Bronk (*Telefunken-Zeitung*, 32/33).

EINFLUSS DER ELEKTRONENEMISSION AUF DIE TEMPERATURVERTEILUNG GLÜHENDER WOLFRAMDRÄHTE IN ELEKTRONENRHÖREN.—Hans v. Helms (*Telefunken-Zeitung*, 32/33).

ELECTRON EMISSION FROM THORIATED TUNGSTEN FILAMENTS.—Irving Langmuir (*Phys. Rev.*, 22, 4).

DIELECTRIC LOSSES AT RADIO FREQUENCIES IN LIQUID DIELECTRICS.—A. B. Bryan (*Phys. Rev.*, 22, 4).

MEASUREMENT OF MAGNETIC FIELDS OF MEDIUM STRENGTH BY MEANS OF A MAGNETRON.— Albert W. Hull (*Phys. Rev.* 22, 3).

POLARISATION CAPACITY AND RESISTANCE AT RADIO FREQUENCIES.—C. B. Jolliffe (*Phys. Rev.*, 22, 3).

REMOVAL OF THORIUM FROM THE SURFACE OF A THORIATED TUNGSTEN FILAMENT BY POSITIVE ION BOMBARDMENT.—K. H. Kingdon and Irving Langmuir (*Phys. Rev.*, 22, 2).

TORQUES AND FORCES BETWEEN SHORT CYLINDRICAL COILS CARRYING ALTERNATING CURRENTS OF RADIO FREQUENCY.—W. A. Parlin (*Phys. Rev.*, 22, 2).

THE TANTALUM HIGH-VOLTAGE RECTIFIER.— Harold L. Olesen (*Q.S.T.*, 7, 5).

RADIO VISION.—H. Gernsback (*Radio News*, 5, 6).

UNTERSUCHUNGEN ÜBER HOCHFREQUENZTELEPHONIE AUF STARKSTROMLEITUNGEN. E. Habann (*Jahrb. d. drahtl. Tel.*, 22, 4).

UBER DIE RICHTUNG ATMOSPHÄRISCHER STÖRUNGEN.—F. Schindelhauer (*Jahrb. d. drahtl. Tel.* 22, 4).

UBER EINE NEUE EMPFANGSANLAGE DER HAUPTFUNKSTELLE NORDDEICH.—G. Leithäuser (*Jahrb. d. drahtl. Tel.*, 22, 4).

DIE SCHWINGUNGSERZEUGUNG DURCH RÜCKKOPPLUNG VERMITTELS DER ANODEN-GITTERKAZITÄT BEI DER HOCHVAKUUMEINGITTERRÖHRE.—(*Zeitschr. f. tech. Phys.* 1923, 3).

METEOROLOGIE UND WELLENTELEGRAPHIE (*Zeitschr. für tech. Phys.* 1923, 3).

MAGNETISCHES MATERIAL FÜR HOCHFREQUENZFELDER.—Richard Gans (*Physikal. Zeitschr.*, 24, 11).

SEKUNDÄRE ELECTRONENEMISSION IN GLÜHKATHODENRÖHREN.—A. Goetz (*Physikal. Zeitschr.* 24, 2).

ZUR EXPERIMENTELLEN UNTERSUCHUNG VON TELEPHONEN (*Ann. d. Physik*, 70, 4).

METEOROLOGIE UND WELLENTELEGRAPHIE.— Friederich Herath (*Zeitschr. f. techn. Phys.*, 1923, 3.)

CHARACTERISTICS OF AIRPLANE ANTENNAS.—E Bellini (*W. Age*, 11, 2).

DISTORTION IN RADIO TELEPHONY (Concluded).— H. A. Thomas (*W. World*, 223).

VULCANISED FIBRE.—James Strachan (*W. World* 224).

LES ACCUMULATEURS : LEUR FONCTIONNNEMENT, LEUR ENTRETIEN, LEUR RECHARGE.—E. Pepin ster (*R. Elec.*, 4, 18).

Correspondence.

The Periodic Fading of Signals.

To the Editor of EXPERIMENTAL WIRELESS.

SIR,—I was very interested in Mr. Cash's observations on the regular fading of signals which is so frequently noticed. I have myself noticed this regular fading at times, although I have not made any careful observations on them. It is puzzling why there should be this regularity if one is to account for fading entirely by atmospheric conditions, which, as we know, do not follow any regular changes at equal intervals of only a few seconds or minutes. It is difficult to imagine weather travelling across the Atlantic in the form of a long procession of evenly-spaced lumps, and I think we must look for some other explanation. It has occurred to me that the periodic rising and falling of the strength of signals received from a distant station may be very reasonably explained by assuming that interference takes place between direct waves and waves reflected from the heaviside layer.

Suppose a receiving station B is listening to a distant transmitting station A on about 200 metres wave-length. The radiation from A goes out more or less uniformly in all directions, part travelling straight to B's aerial, and part arriving at B after reflection from the heaviside layer. B therefore receives signals from A *via* two distinct paths, and the amplitude of the oscillations induced on B's aerial will depend on whether the two sets of waves help or oppose each other at that point. If the path difference between the direct and reflected courses is equal to a whole number of wave-lengths, the two sets of waves will assist each other and produce a strong signal, whereas if the paths differ by an odd number of half wave-lengths the two sets of waves will tend to cancel and produce silence. As we go along the line adjoining A and B we come alternately to points where the direct and reflection paths of waves coming from A differ by equal and odd numbers of half wave-lengths. In fact, there are extending out from the transmitting station A alternate zones of maximum and minimum signal strength, the distance between successive zones depending on the wave-length, the effective height of the heaviside layer considered as a reflector, and the mean distances of the zones under consideration from the transmitting station.

So much has already been suggested, and was mentioned by Capt. Round at a recent meeting of the Radio Transmitters Society. The phenomenon of diffraction bands in the case of ordinary light has been familiar for a long time, and it is only reasonable to expect similar effects on a larger scale with radio waves.

My own little corollary is that we should take the earth's rotation into account. If the height of the heaviside layer were constant and the wave-length of a given transmitting station A were constant, then B would be permanently lucky or unlucky in his reception of A according to whether he was situated on a "dark" or "bright" zone. But the accepted theory is that the ionised layer has a much smaller effective height during the day than during the night. As night comes on it goes up, and when day approaches down it comes again. In fact the effective reflecting surface is probably on the move the whole time except just at the turning point a little after midnight. As the heaviside layer rises or falls, as the case may be, the whole set of interference bands or zones sweep along and pass one after the other through the receiving station B. As the velocity and spacing of the bands will be nearly uniform over short periods the operator at B will hear a regular swelling and fading of signals.

In trying to calculate the fading period for a given distance on this theory one is up against the difficulty of not knowing the height of the heaviside layer at various times duringt e day, or the rate at which it rises at night. Also, we are not justified in considering it a definite reflecting surface, as it is a layer of attenuated ionised gas probably many miles thick; more probably the waves are deflected by successive refractions, the effect being more akin to inverted mirage rather than to reflection proper.

E. H. ROBINSON.

Vo the Editor of EHPERIMENTAL WIRELESS.

DEAR SIR,—After reading Mr. Hogg's letter in the current issue of EXPERIMENTAL WIRELESS, I should like to point out that Mr. Hogg's calculation of the effective height of his aerial is entirely erroneous. In his letter he assumes that the effective height of an aerial is its mean geometric height. This is by no means the case. In calculating the effective height of an aerial the following things must be taken into consideration:—

(1) The mean height of the aerial. (This is not the mean height of the flat top of the aerial minus the height of the counterpoise, as Mr. Hogg seems to think; if so, why not lay the counterpoise along the ground ?)

(2) The effect on the aerial of surrounding trees, houses, etc. I feel compelled to point out this error in order to prevent your other readers from falling into the same trap as Mr. Hogg.—Yours faithfully,

M. C. ELLISON. (2JP)

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In reply to Mr. Ellison's letter regarding my aerial, I am fully aware of the facts which he has mentioned. I was only trying to point out that my report on the resistance was nowhere near 10 ohms. I believe that this is not far out in an amateur aerial to take the effective height as about two-thirds of the height above the counterpoise. I am afraid the misapprehension arose through my omitting the word "greater." I intended to say the effective height was not greater than 28 ft. so as to leave the exact effective height out of the question. Personally I consider myself lucky if my true effective height is 19 ft.! I shall not attempt to be absolutely accurate, as such calculations are nowhere near correct, and merely serve as a very good guide.—Yours faithfully, FREDERICK L. HOGG.

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—In your last issue of EXPERIMENTAL WIRELESS you publish an article by Mr. H. N. Ryan on the "General Efficiency of Reception on Short Waves." There are two points in this article on which I find myself in complete disagreement, and I should be very interested to hear what the author has to say on the matter.

(1) On p. 142, column 1, Mr. Ryan says the following :—"The universal fault with all short-wave plug-in coils on the market is that the wire used is far too thin. All coils for short-wave work should be wound at least 18 or 20 gauge wire. . ." I should like to ask him (A) how pure resistance enters into the matter at all, seeing that at such frequencies as those with which he is dealing the resistance of the coil is negligible compared with the inductance of the coil, *i.e.*, pLR? (B) If the pure resistance were a matter of concern, why has he entirely neglected the increase of resistance with frequency? If he were to use wire of gauge 19 at a wave-length of 200 metres the H.F. resistance of that wire would be 9·4 that of its D.C. or L.F. resistance; whereas if he used considerably finer wire this ratio would be very much less, and the D.C. resistance would not be increased in anything like the same proportion.

(2) On p. 141 at the foot, or rather near the end of column 1, the author states :—"Theoretically, the signals heard in the 'phones are loudest and purest when the local oscillations . . . are of exactly the same amplitude as those produced by the received signals." I beg to differ on this point. One of the great points about heterodyne reception is that the resulting rectified current is proportional to the signal E.M.F. and *not* to the SQUARE of the signal E.M.F., as would be the case if the heterodyne method were not used. But in order to arrive at this direct proportionality the local oscillations must be very large compared with the signal. In the case of ordinary reception the signal E.M.F. oscillates about a small curved portion of the rectifier curve. In the case of heterodyne reception, the beat wave is no larger than the signal E.M.F., but it is super-imposed upon the local oscillation, hence in the positive ½-cycles it works on the straight part of the characteristic, whereas in the negative it is carried beyond the point of zero current. Thus, in the former case the rectification depends on the curvature at P, and hence on the SQUARE of the signal E.M.F., and in the latter case on the SLOPE at Q, and by going one stage further it can quite easily be shown that the rectified current will then be approximately proportional to the signal E.M.F. But the whole point of this little discussion is, that in order to attain this desirable state of affairs the amplitude of the local oscillations must be sufficient to bring S_b on to the straight part of the rectifier curve when positive, and beyond the zero current position when negative. This state of affairs is *not* fulfilled when S_2 only $= S_1$. The only time when this state of affairs is desirable (*i.e.*, $S_2 = S_1$) is when advantage is being taken of the limiting action explained in the article by Capt. St. Clair-Finlay.

A few lines later on in his article Mr. Ryan goes on to say :—"Therefore, always try to keep the receiver only just oscillating for C.W. reception . . ." This is perfectly correct, and would at first sight seem to bear out his argument for small amplitude of local oscillations; but is the author aware that the point where the valve produces *maximum* amplitude of oscillations is that point at which the coupling between the grid and the anode is *least*, so long as the point where oscillation commences is not passed? I do not write this in any sense of undue criticism, but I believe the author to be *wrong* in the two cases I quote, and I have just given you a rough outline of *why* I think he is wrong. I should be glad if you would give Mr. Ryan the chance of replying to my criticisms, but I fear he will find he has made an error in the above, which may, unfortunately, be passed on to others.—Yours faithfully,

DESMOND DE BURGH.
(Flight-Lieut., R.A.F.)

To the Editor of EXPERIMENTAL WIRELESS.

DEAR SIR,—May I point out the article in question was based entirely upon practical experience, and sets forth the results obtained in practice. Therefore, I should have advocated the same principles, even had I felt them to be the wrong in theory. This, however, was not the case, and I cannot agree with all Mr. de Burgh's criticisms.

Firstly, he says that at high frequencies the necessity for using thick wire does not arise, since resistance is negligible, compared with inductance. Quite apart from theory, it is an experimental fact, established beyond question, that thick wire gives greatly improved results on short waves.

It is evident that, when receiving weak signals, every possible loss should be minimised. Now, the inductance of a coil at this frequency admittedly greatly exceeds its resistance, but no loss of energy is occasioned by pure inductance, whereas the chief source of loss in an inductance is due to its resistance.

I am afraid I fail to see his next point. He states that the ration of H.F. to D.C. resistance is less in a thin wire than in a thick one, of which elementary fact I was aware, but he is apparently trying to deduce from this that the H.F. resistance of a thin wire is less than that of a thick one, which can be shown to be incorrect by a simple measurement.

But whether Mr. de Burgh agrees with this or not, I made no mention whatever, in the article, of resistance, pure or H.F.

Now for the other point, which presents much more interest. Firstly, I do not agree that, in practice at any rate, the valve is producing maximum amplitude of oscillation when the coupling is just at oscillation point. When the plate and grid circuits of a valve are coupled and are not in resonance (*i.e.*, when the one with the higher natural frequency is functioning aperiodically, in our case the plate circuit) the point of maximum amplitude of oscillation appears to be with the coupling somewhat tighter than the critical value, approaching this critical value as the circuits are brought nearer to resonance. In an ordinary receiver of non-American design the plate coil is usually aperiodic, and therefore falls within this class.

I should not care dogmatically to state the foregoing effect, but it appears thus to me.

As to the question of strong or weak local oscillations, apart from how they are produced, I agree entirely with the case for strong oscillations as far as it goes, but though the effect in question is one of the most valuable points of heterodyne reception *for signals above a certain strength* there is a certain strength (admittedly a pretty weak, though far from unreadable, one) below which the effect cannot be utilised. The reason, I think, is that when the signals are very weak the strength of heterodyne required to bring the working point for +ve half-cycles) on to the straight part of the curve is so great compared with the signal amplitude (*i.e.* $S_2 > S_1$) that the latter is completely wiped out, since the circuit will not oscillate at two frequencies very close together, when the amplitude of one is very much greater than the other. So one must either work on the bend (where $r \propto e^2$), or lose the signal.

Since, apart from this effect, the beat note reaches its maximum when $S_1 = S_2$ (the maximum being $S_3 = (S_2 + S_1) - (S_2 - S_1) = 2S_1$ there is no useful object in increasing S_3 beyond S_1, when the incoming signals are too weak to take advantage of the further boosting without losing themselves in the process.

To the fatal effects of too strong a heterodyne, in practice, on very weak signals, I can testify, as can many others.

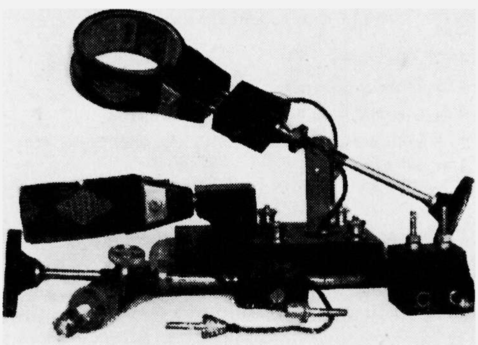
The explanation I put forward as a suggestion only. There obviously must be some point of critical strength such as I suggest. The indication of the suggestion turns upon whether this point falls within or without the range of readability. I personally think it falls well within it, though, of course, fairly near the lower limit. The article dealt professedly only with weak signals, and I stated that a receiver built on the lines suggested would not work at its best on strong signals, nor would it be required to do so.

I may say that a receiver of my own, on these lines, receives American amateurs and broadcast easily on a single valve, so I do not think, therefore, that anyone making one like it will have cause to complain of having been lead astray by my advice, as Mr. de Burgh seems to fear !—Yours faithfully,

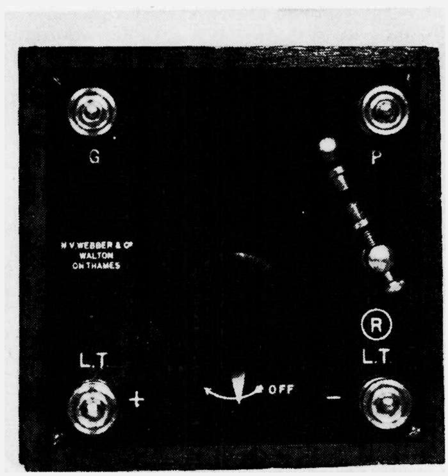
HUGH N. RYAN (5BV).

Business Brevities.

A NEW "POLAR" COIL HOLDER.—The Radio Communication Co., Ltd., have sent us for test a new type of coil-holder which embodies several really new and useful improvements. The movable coil support is perhaps best described as representing an anti-aircraft gun. On test it is found to give the most flexible adjustment of any type we have so far examined, since there are four possible directions of motion. It is obvious that any degree of coupling is obtainable, including direct and reverse retro-active effects, and also, of course, an easy adjustment of capacitative and magnetic coupling is easily obtainable. The holder is supplied both for panel mounting and as a complete unit with terminals.

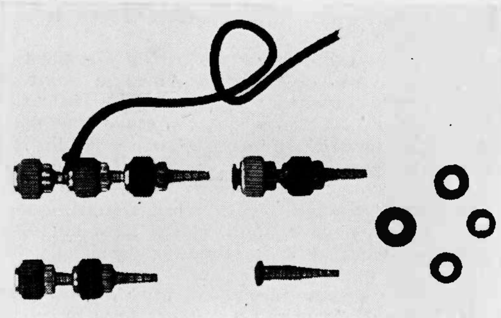


The New Polar Coil Holder.



The Webber Experimental Panel.

THE WEBBER VALVE PANEL.—It might seem at first sight somewhat unnecessary to mention so common a component as a valve panel, but that sent for test by N. V. Webber & Co. should appeal particularly to the serious experimenter, as it contains several refinements. The four terminals are of the large size double-type, enabling several wires to be fixed to each. The filament lead containing the rheostat is marked on the top of the panel, and a Polar fuse is included in the filament circuit. The above features in conjunction with an Igranic rheostat make the panel of particular value for experimental work.



Illustrating some uses of "Clix."

"CLIX."—"Clix," described as the "electrical link" with 159 uses, is one of the most useful "gadgets" which have been brought to our notice. Essentially, "Clix" are wander plugs, so made that the tapered end of one will fit into the socket end of another. The insulating tops may be removed and replaced by two bushes so as to enable them to be used as sockets on a panel top. "Clix" appear to be both mechanically and electrically efficient, and there is no doubt that they will be of very great value for experimental work requiring rapid and complex variations of connections. "Clix" have been produced by Autoveyors, Ltd.

* * *

Messrs. S. Rentell & Co., Ltd., have sent us the 1924 edition of their well-known "Practical Electrician's Pocket Book." This useful little book contains some 500 pages crammed with practical information and data, and should be of value to many readers. The price is 3s. net.

* * *

Messrs. Autoveyors, Ltd., have sent us their latest pamphlet relating to their capacity bridge. The booklet contains 15 pages of useful bridge circuits which should be of interest to the experimenter.

Experimental Notes and News.

It is understood that the Post Office has placed contracts in this country for the equipment of several new stations to operate between the various islands in the West Indies, including St. Kitts, Antigua, Barbados, Dominica, St. Lucia, St. Vincent, and Grenada. It will be interesting to see what wave-lengths are adopted, for the seven stations are comparatively within a very small area.

* * *

Although some excellent DX work is now being conducted by many experimenters, so far no one seems to have succeeded in communicating with the MacMillan American Arctic Expedition. It is understood, however, that several American amateur stations have been in touch with the ship, and there seems no reason why our own stations should not be able to maintain communication.

* * *

The Metropolitan-Vickers Electrical Company are making their first attempt on New Year's Eve to pick up the American Broadcasting Station "KDKA," and re-transmit it on 400 metres from Manchester. They will use 1½ kilowatts and the call sign will be 2AC.

It will be interesting to note what effect the broadening of the band of wave-lengths used by the British Broadcasting Stations will have upon jamming. The problem presents many difficulties, as the new wave-lengths seem, in some cases, to be affected by ship work, D.F. stations and harmonics. At the time of going to press the wave-lengths now adopted are as follows :—

495 Aberdeen.	385 Bournemouth.
475 Birmingham.	370 Newcastle.
435 Cardiff.	350 London.
420 Glasgow.	303 Sheffield (Relay).
400 Manchester.	

* * *

The Radio Association has decided to organise a National Radio Week next year. The main objects will be to demonstrate the growth of a new British industry, and to arouse interest in the possibility of broadcasting among all sections of the community.