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Editorial.

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

IN this number will be found a letter from our contributor, Mr. W. A. Barclay, advocating the use of the Heaviside operator in preference to *j* in alternating current calculations. We publish this letter because it deals with a subject of some importance about which very hazy ideas are entertained by many who would be very pleased to have their doubts removed and a little light thrown on the real meaning of these symbols which are championed by various authorities. In our opinion the change suggested by Mr. Barclay is merely a change of label without any change of principle and we fail to find in his letter any argument showing a real advantage of one method over the other.

If any quantity, such as current or voltage, is assumed to vary according to a sine law, say for example $c=\hat{e}\ sin\ \omega t$, a changing angle ωt is immediately introduced and with it the conception of a rotating line, the projection of which on some fixed plane is proportional at every moment to the varying quantity, although there may be nothing angular or rotating about the alternating quantity itself. The rotating vector idea is not something extraneous which may or may not be dragged into alternating current calculations, for it is there immediately the word sinusoidal is used. It is more fundamental than the sine wave. The rate of change of the quantity is proportional to the rate of change of the sine of the angle, *i.e.*, to $d/dt\ (sin\ \omega t)$ or, putting D for d/dt, to $D\ sin\ \omega t$, which is equal to $\omega\ cos\ \omega t$. As Mr. Barclay points out,

$$D\ sin\ \omega t = \ \omega\ cos\ \omega t$$

and

$$D\ cos\ \omega t = -\omega\ sin\ \omega t.$$

By treating these as algebraic equations, and squaring and adding each side, it follows that $D^2=-\omega^2$. Another step, however, and the difficulties begin, for if

$$D^2=-\omega^2 \text{ then } D^2/\omega^2=-1 \text{ and } D/\omega=\sqrt{-1}$$

and therefore, instead of $D\ sin\ \omega t=\omega\ cos\ \omega t$ we may write $\sqrt{-1}\ sin\ \omega t=cos\ \omega t$, which is algebraically untrue, as can be shown by expressing the sine and cosine in the exponential form, viz. :—

$$sin\ a = \frac{e^{a\sqrt{-1}}-e^{-a\sqrt{-1}}}{2\sqrt{-1}}$$

and

$$cos\ a = \frac{e^{a\sqrt{-1}}+e^{-a\sqrt{-1}}}{2}.$$

It will be noticed that this inconsistency has not arisen from the introduction of vectors nor from the use of *j* but from the application of algebraic methods to the formula $D\ sin\ \omega t=\omega\ cos\ \omega t$, which is not really an algebraic equation. Let us explain what we mean by this statement. D is not a number or magnitude which can be multiplied by another number or magnitude, but is a symbol showing that a certain operation is to be performed on *sin* ωt, and this operation is of a peculiar nature, depending not on the value of *sin* ωt at the moment considered, but on what it was a moment ago and what it will be a moment later. An indication of the impossibility of regarding this as an algebraic equation is given by the fact that when one of the factors on the left-hand side, viz., *sin* ωt vanishes, the right-hand side has its maximum value. Nevertheless we agree with Mr. Barclay that the relation $D/\omega \sin \omega t = \cos \omega t$ is a very useful tool; one might simplify the writing of it, however, by putting j instead of D/ω, thus getting $j \sin \omega t = \cos \omega t$. Neither D/ω nor j are mere numbers but are symbols of operation; the former placed before a sine wave is an instruction to take its rate of change and divide by the angular velocity, and the relation just established tells us that the result is equal to the cosine, or in other words, if D/ω operates on the projection on the vertical of a rotating line, the result is equal to the projection of a rotating line of the same length 90° ahead. In other words D/ω applied to a vector rotates it 90° in the direction of rotation, but many people prefer to use the simpler symbol j for this purpose.

Throughout this article we use the word "vector" in the special sense in which it is usually employed in the graphical treatment of alternating currents.

When applied twice in succession D/ω or j rotates the vector through 180° and the projection on the vertical is equal and opposite to that of the original vector; thus $D/\omega(D/\omega \sin \omega t) = -\sin \omega t$.

This is equivalent to multiplying the vector, or the quantity represented by the vector, by -1, and this tempts one to assume that a single operation is equivalent to multiplication by $\sqrt{-1}$ and even to put $D/\omega = j = \sqrt{-1}$. This is only obtained, however, by the unjustifiable assumption that D/ω or j can be treated as an algebraic multiplier and that therefore $D/\omega \times D/\omega \times \sin \omega t = -\sin \omega t$, which is really meaningless. It is not surprising therefore that one arrives at the inconsistencies pointed out above.

As a matter of fact $j \sin wt$ is every bit as real as *sin* ωt, but since, in stating the horizontal and vertical components of a vector, it is necessary to label them in some way, so as to indicate that only those of the same kind can be added and subtracted, it is convenient to regard the label j as an imaginary quantity. When we write $z = r + jx$ we mean that the vector z has a horizontal component r and a vertical component x; without the j before it x would represent a horizontal line which could be added arithmetically to r, but with the j we know that x has been turned through 90° in the anticlockwise direction so that r and jx are at right angles. There is nothing imaginary about it, except that many people use the word imaginary as a label for the vertical components and similarly the word real as a label for the horizontal components, since it is generally known that one cannot add real and imaginary quantities. If we write $jz = jr - x$, we state that if we rotate the vector z through 90° we get a vector with a vertical component r and a horizontal component $-x$. It must be emphasised, however, that we did not really multiply z by j in an algebraic sense, when we wrote jz; what we did was to operate on z by turning it through 90°; similarly $j(jx)$ indicates the operation of turning the vertical line x through a further 90° and thus giving the horizontal line $-x$.

Hence this method is correctly known as the vector or symbolic method, but there appears no justification for introducing $\sqrt{-1}$ or any other imaginary quantity.

We will not deny that we have often made the mistake ourselves of saying let $j = \sqrt{-1}$ when we really intended j to be a vector operator, nor will we give a list of the well-known writers who have fallen into the same error, but we will endeavour to avoid such confusion in the future. We may summarise our conclusions by saying that

$$D/\omega \sin \omega t = \cos \omega t \quad \ldots \quad (1)$$

$$j \sin \omega t = \cos \omega t \quad \ldots \quad \ldots \quad (2)$$

$$\sin a = \frac{e^{ja} - e^{-ja}}{2j} \quad \ldots \quad \ldots \quad (3)$$

$$\cos a = \frac{e^{ja} + e^{-ja}}{2} \quad \ldots \quad \ldots \quad (4)$$

are all quite correct provided it be understood that j in (2) means something quite different to the j in (3) and (4). In (1) and (2) the D/ω and j are symbols of operation on vectors, which if operating twice in succession are equivalent to multiplication by -1, whereas in (3) and (4) j represents the algebraic imaginary $\sqrt{-1}$.

Losses in Inductance Coils. The Need for a Standard of Efficiency.

By S. Butterworth. [R143

ALTHOUGH the general non-technical user of inductance coils is now practically certain when he purchases a coil that he will get one which will tune in to the wavelength he requires, he has as yet no reliable means of forming any notion in regard to its efficiency. All he has to go by are the advertisers' pamphlets setting forth the views of the designer in his more optimistic moods or such expressions as "Maximum air space," and "Try this coil on your set and notice the wonderful improvement in purity and quality!"

The technical user can, of course, determine all the properties of the coil if he knows the inductance, self-capacity and the resistance at the wavelength of operation, but, even so how many know what is a reasonable resistance to expect for any given coil?

There is, therefore, a clear need for a numerical standard to safeguard the general purchaser and to enable him to form a fair estimate of what to expect in regard to increase in intensity on substituting a more efficient coil in a normal receiving set. If such a numerical standard can be established it is also very desirable that its value should be given on every commercial coil.

An outline will now be given of what the writer considers a feasible method of arriving at such a numerical standard. He recognises, of course, that there are alternative methods, and thus the method sketched is only to be looked upon as tentative and is offered as a basis for discussion.

The efficiency of the coil alone is conveniently expressed by its Power Factor or the ratio of resistance to reactance at the operating frequency. The Decrement gives the same thing, being the Power Factor multiplied by π, but the term "decrement" is a survival from the days when damped waves predominated. As applied to continuous waves, the term is meaningless. The reciprocal of the Power Factor gives the magnification of voltage across the coil with respect to the impressed voltage when in a resonant circuit of zero external resistance. The advantage of the Power Factor is that it is fairly constant for a well-designed coil over the whole of its working range. But, except in circuits, such as wavemeter circuits, the coil is usually in series with a very appreciable resistance, and comparative values of Power Factors have therefore a tendency to exaggerate the virtues of highly efficient coils. It is preferable, therefore, to suppose the coil in a circuit having a standard external resistance and to determine the voltage magnification when this circuit is tuned.

Since the capacities used in tuned circuits are usually of the same order, the standard circuit should have a standard capacity which is the mean of those normally used in a receiving set. This would imply that for each inductance there would be a normal wavelength at which the coil would be in tune with the standard capacity.

To make the numerical standard carry with it a general notion of the order of the efficiency of the coil, the measured voltage magnification should be expressed as a percentage of a standard magnification which would represent the proper magnification to expect with a reasonably efficient coil. This percentage could be given some such name as "Intensity Factor."

It is realised that we might manipulate the voltage magnification still further, as when the magnified voltage is impressed on the grid of a detector valve the resultant L.F. E.M.F. is proportional to the square of the voltage magnification and the final sound intensity to the fourth power, so that it is quite possible that some power of the voltage magnification would be more suitable.

The essentials for the proposed "Intensity Factor" are that it should convey some immediate notion of the order of sound intensities to expect with different coils and that it should contain a recognisable relation to some reasonable standard in this respect. The above mode of arriving at the Intensity

Coil.	No. 28 A.W.G.			32/38 A.W.G. Litz.		
	Res. ohms.	M.	I.F.	Res. ohms.	M.	I.F.
Loose basket weave ...	6.3	46.0	99	3.0	52.5	113
Single layer	6.6	45.5	98	3.5	51.4	110½
Radial basket weave ...	7.65	43.8	94	3.65	51.0	110
Narrow basket weave ...	10.4	39.8	85½	5.4	47.5	102
2-layer bank wound ...	10.6	39.5	85	4.3	49.7	107
Honeycomb	14.5	35.0	75½	5.5	47.4	102
3-layer bank wound ...	14.7	34.8	75	5.3	47.7	102½
4-layer bank wound ...	18.5	31.4	67½	8.7	42.1	90½

Factor fulfils these conditions, and as it does not preclude values greater than 100 per cent. does not need to set an impossible ideal before the manufacturers.

We will now examine how this system would work out in the case of coils intended for the broadcast range.

A suggested standard value for the Power Factor of the coil alone over the broadcast range is 0.005, a value which should be possible for a solid wire receiving coil of reasonable size.

The standard external resistance will be taken as 20 ohms as one has in mind a standard aerial circuit, and the standard capacity will be taken as 200$\mu\mu$F.

It is then readily shown that the standard voltage magnification is given by the formula

$$M_s = 200/(1 + 56.6/L^{\frac{1}{2}}.)$$

and the normal wavelength by the formula

$$\lambda_s = 26.7\ L_{\frac{1}{2}}.$$

L is the inductance in microhenries.

The following values hold for various inductances :—

	Microhenries.							
L	50	100	150	200	250	300	350	400
M_s	22.2	30.0	35.6	40.0	43.6	47.0	49.6	522
	Metres.							
λ_s	189	267	326	377	421	461	499	534

For intermediate values the curves shown (Fig. 1) are useful.

In the absence of an authoritative list of British coils the coils chosen for illustration will be those for which the tests are described in the Technological Paper No. 298 of the *Bureau of Standards*. All these coils have an inductance of 291 microhenries so that their normal wavelength is 455 metres, and the standard magnification is 46.5. The resistances at this wavelength and the deduced magnification (M) and intensity factor (100 M/M_s) for the coils are given in the table above.

These coils are said to be fairly representative of American coils in general. For details in regard to dimensions, etc., the reader is referred to the above paper. He should be warned, however, that No. 28 A.W.G. is roughly equivalent to No. 30 S.W.G. and 32/38 to 32/42.

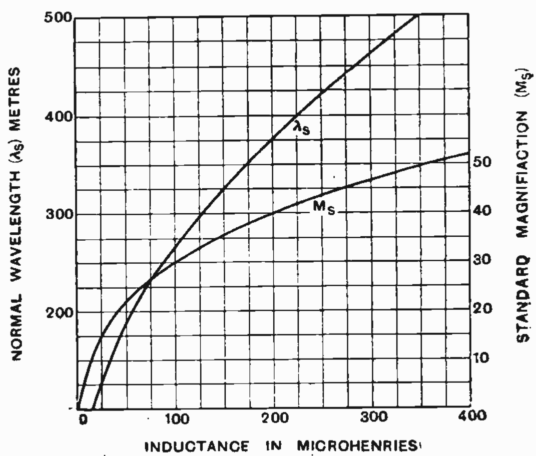


Fig. 1.

The Intensity Factors in the columns headed I.F. show that the assumption of a Power Factor 0.005 for a good solid wire coil at this wavelength is rather stringent but is not unreasonable.

The table may be left to speak for itself in regard to the utility of the Intensity Factor as a numerical standard of efficiency.

A New Valve Rectifier.

Inexpensive Accumulator Charging from A.C. Mains.

By L. A. Sayce, Ph.D., M.Sc., A.I.C. **[R355·55**

IF the happy time ever arrives when we shall be able to dispense with the lighting of valve filaments we shall have got rid of the chief inconvenience and expense of maintaining wireless sets. Until then, articles like this will continue to be written to point out how the trouble may be minimised.

Charging accumulators from D.C. mains is a simple matter and is inexpensive, too, if the cells are connected in one of the mains of the domestic supply. When this supply is A.C., however, we have to fulfil two requirements before accumulators can be charged satisfactorily: we must provide a transformer to "step-down" the voltage of the mains to a convenient figure, and a rectifier to supply a uni-directional current.

The construction of a suitable transformer has already been described in this Journal, and rectifiers, both electrolytic and mechanical, have also been discussed frequently.

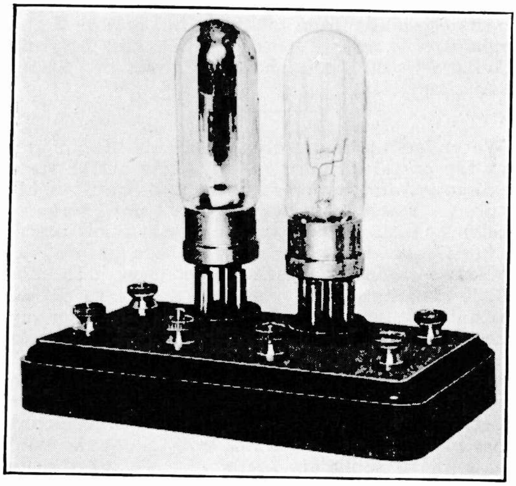


Fig. 1. *The rectifier panel.*

The present writer, after long use of both of these types, has, however, abandoned them, for accumulator charging, in favour of a little rectifier valve recently brought out by the Philips Lamp Co. (whose distributors in this country are Messrs. Mullard Radio Valve Co.). This valve, the low price of which is not its least advantage, gives a rectified output up to 1.3 amps and can be run without attention for an indefinite period.

The valve is provided with two large anodes and a spiral filament requiring an E.M.F. of about 2 volts to maintain it at the necessary dull-red heat. If a voltage much above 30 volts (R. M. S. A. C.) is applied between anodes and filament it "flashes over" and becomes conductive in both directions. A "resistance lamp" is therefore supplied for use with the valve, containing an iron filament which renders the valve perfectly stable because its resistance rises very rapidly with its temperature.

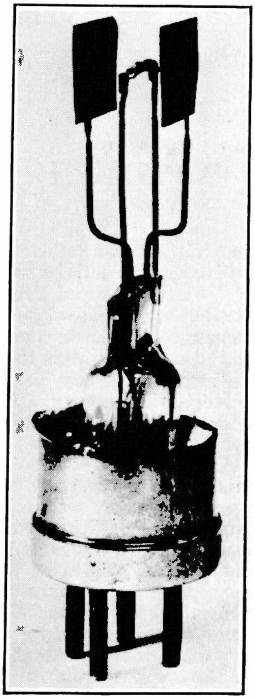


Fig. 2. *Internal construction of the rectifier.*

Fig. 1 shows a convenient method of mounting the valve and its stabilising lamp. Both of them are made to fit standard valve sockets and two of the latter are fixed to an ordinary 6 in. × 3 in. switch-block which is also provided with six terminals. Fig. 3(*a*) is a diagram of the circuit used and Fig. 3(*b*) is the wiring diagram. The valve, with its two anodes, could, of course, be used for full-wave rectification, but better results have been obtained by the circuit shown. It should be noted that the stabilising lamp has a centre tap to its filament. For the present purpose the two halves are connected in parallel and are represented as R_1

and R_2 in Fig. 3(*a*). S_1 is the main secondary winding of the transformer. The iron ballast resistance makes it unnecessary to have many tappings of S_1. The writer uses two only: 20 volts and 30 volts, the tapping in use depending upon the number of cells on charge. S_2 is another secondary winding giving a voltage of 2 volts for lighting the filament. Once the valve has commenced to work, this winding can be switched off and the filament will be kept hot by the discharge. The filament will last longer, however, if the filament current is left on continually, for the discharge then takes place along the whole filament instead of being concentrated at one place; and only a few extra watts are used.

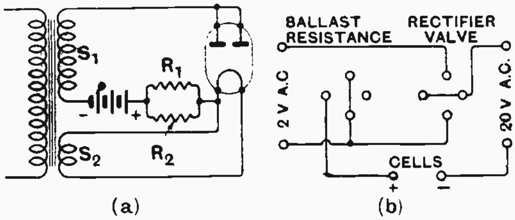


Fig. 3. *The circuit and wiring diagrams for half-wave rectification.*

Among the Experimental Transmitters.

[R009.2

THE Belgian station BW5 is transmitting by telephony on 180 to 200 metres every Tuesday, Wednesday and Friday, after 23.00 G.M.T. and on Sunday from 9.30 a.m. to 12.30 p.m., and wishes to get into communication with British amateurs who, unless they can converse in French, are asked to speak very slowly and repeat their call-signs frequently. Reports will be welcomed if sent *via* M. J. Mahieu, Le Manoir, Peruwelz, Belgium.

Apropos Mr. Mahieu's request, there seems to be a growing tendency on the part of transmitters, especially when working on telephony, to disregard the regulation that their call-signs should be announced three times at the beginning and end of each period of transmission. This neglect may possibly account for some of the ever-increasing complaints about the misuse of call-signs and it certainly prevents the transmitters receiving many valuable reports from listeners on the strength and quality of their signals which is, presumably, one of the main objects of experimental tests.

The article on Long-Distance Work by Mr. Hugh N. Ryan (5BV), which appeared in our issue for February, has aroused considerable interest and, incidentally, has revealed a number of amateurs who are also conducting experiments with a view to determining the relation between signal strength and weather conditions.

Mr. F. Weir-Mitchell, of the Government Radio Station, Maymyo, Burma, has, for some time past been experimenting in this direction and would like the help of a few transmitting amateurs in various countries. As the monsoon season is shortly expected in Burma, these investigations will be all the more interesting and Mr. Weir-Mitchell will particularly welcome weather reports from all parts of the world; these should preferably be sent weekly.

Mr. R. Pollock (G5KU), 4, Glenhurst Avenue, N.W.5, is studying the fading effects at sunset and nightfall and for this purpose is transmitting simultaneously on 45 and 23 metres at 18.15, 18.45, 19.15, 19.45 and 20.15 G.M.T. He will be glad to hear from any listeners who will co-operate in these tests.

Mr. A. M. Houston-Fergus (G2ZC and MAG), La Cotte, La Moye, Jersey, is also conducting a similar series of experiments on 45 metres and will welcome reports especially from amateurs in London, N.E.; England N.E. and E.; Scotland E., and England N.W. (north of Birmingham and west of Chester to Anglesey).

We understand from correspondents in Holland that the postal authorities are taking active steps to discover and suppress unlicensed transmitting stations. Dutch amateurs have not hitherto received much encouragement from their postal authorities, a few licences have been granted to wireless societies and technical colleges, but individual experimenters have been unable to obtain transmitting licences and have, therefore, in many cases, installed unauthorised sets, their call-signs being distinguished by the initial figure "o." Several of these unlicensed sets have been traced through QSL postcards sent by amateurs in other countries and some well-known transmitters have had their sets confiscated. The unlicensed amateurs in Holland, therefore, ask all foreign co-experimenters to avoid correspondence which may bring trouble upon them.

For new amateur call-signs allotted, changes of address, and general information on the subject of QRA's wanted or identified, we would refer readers to our weekly contemporary *The Wireless World* where this information is published as soon as it is received.

The Rugby Radio Station of the British Post Office. [R611

Paper read by Mr. E. H. SHAUGHNESSY, O.B.E., before the Wireless Section, I.E.E., on 14th April, 1926.

Abstract.

THE paper gives a very complete description of the Post Office high-power station at Hillmorton, near Rugby.

After a short introduction, dealing with the general requirements of the station, choice of site, etc., the paper falls into three general parts: (1) Power Plant, (2) High Frequency Generating Valve Plant, and (3) Masts and Aerials. The first and third subjects are dealt with comparatively briefly, the greater bulk of the paper being devoted to description of the technical wireless side of the station.

Fig. 1* shows the general layout of the site, masts, aerials, etc.

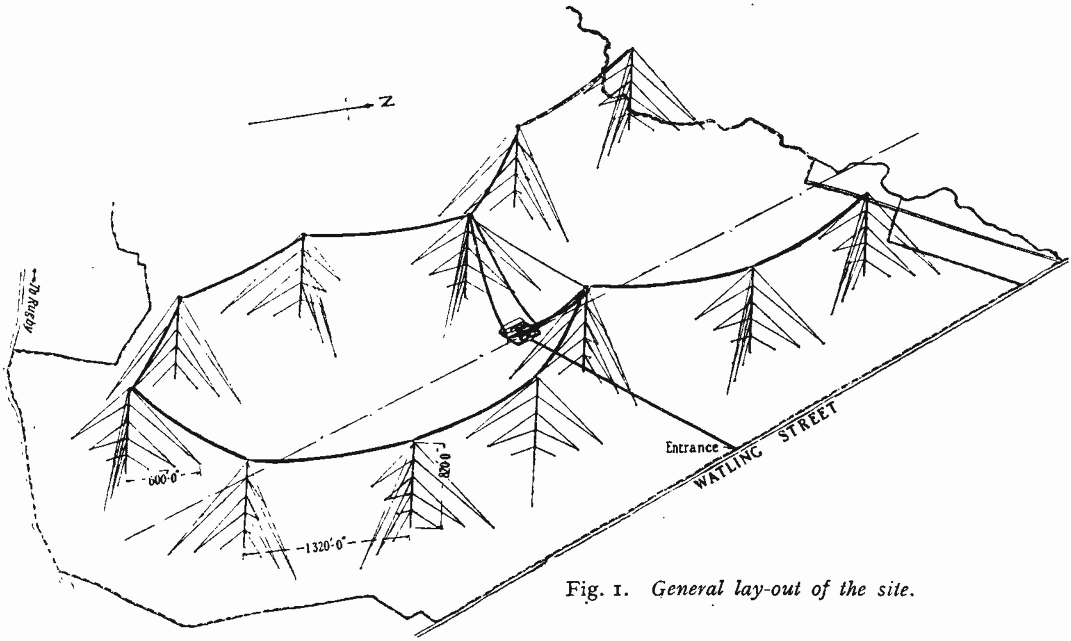


Fig. 1. *General lay-out of the site.*

Bulk supply of electrical power is taken from the system of the local supply company in the form of three-phase 50 cycle A.C., having an earthed neutral and 12,000 volts between phases. Duplicate cables are provided from the company's local station; the two-feeder cables terminate at the wireless station in a separate selector switch cubicle, which permits either or both cables to be connected to the E.H.T. alternating current switchboard. After considering the relative merits of machines as compared to mercury-arc, thermionic valve or other rectifiers, it was finally decided to install motor-generator sets for H.T. supply to the valves. Main motor generator sets provide high-tension direct-current supply to the valves, two frequency converter sets are used for heating valve filaments, and two motor generator and booster sets are provided for battery charging and low tension D.C. supply. All power used other than that required for the main motor generators is supplied by two auxiliary step-down (12,000 : 416 volt) transformers. Details are given of the various machines

* The author's original figure numbers are adhered to throughout this Abstract.

used, and of the wiring and protective devices employed. Diagrams (not reproduced here) are given of the layout of the power-house, and of the wiring of the motor-generator sets, control panels, etc.

The high frequency plant was designed to use valves to be capable of giving an output of 500kW to the aerial. The aerial was arranged so that it could be used as one large aerial or be divided at the station building into two unequal parts for simultaneous transmission on two aerials. The H.F. generating plant was accordingly arranged for such simultaneous transmission, but so far the smaller part has been reserved for experiments in transatlantic telephony.

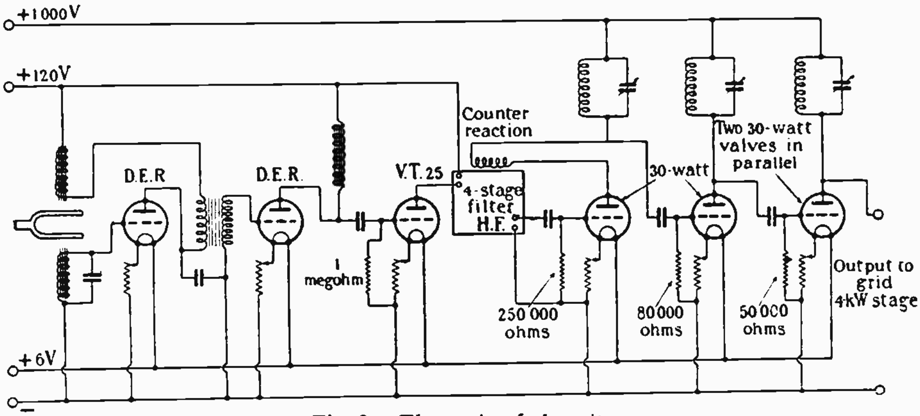
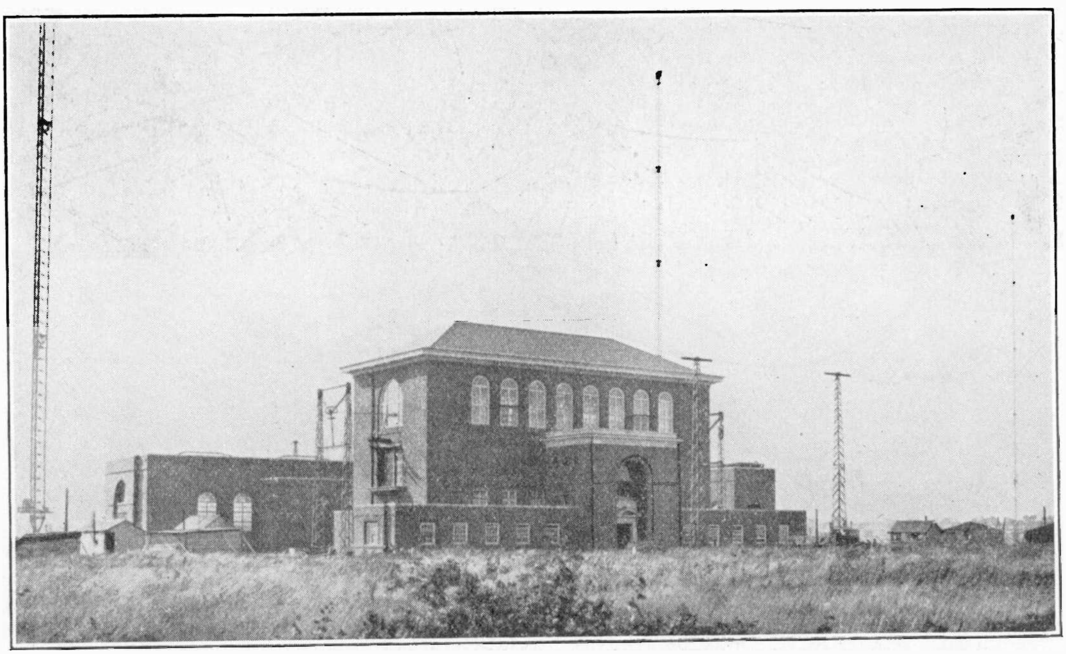


Fig. 8. *The tuning-fork unit.*



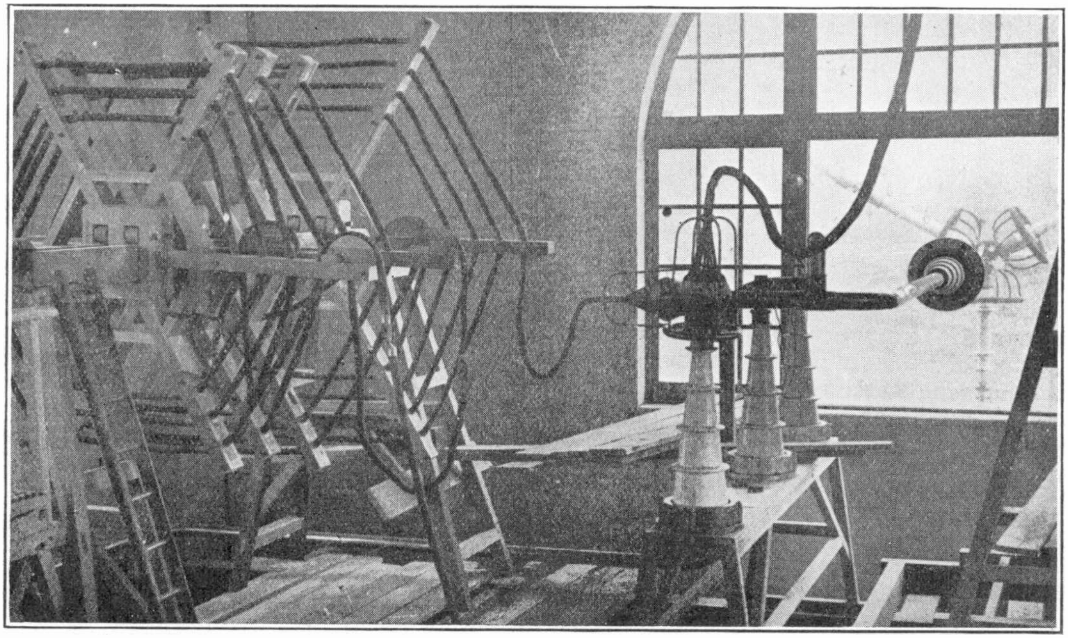
A general external view of the transmitting building. At the left-hand side of the building, on the upper window, can be seen the lead-in for the aerial now being used for the telegraphic transmission. The lead-in for the smaller aerial now being used for the experimental transatlantic telephony transmissions is at the corresponding window at the other end.

The aerial immediately available for the telegraph transmitter is, therefore, the larger part erected on eight masts. It has a capacity of 0.003μF, with a resistance of 0.7 ohm at 14kC and 1 ohm at 24kC. The combined resistance of the aerial and its tuning coil is slightly greater, being 1 ohm at 22kC.

To maintain constant frequency, a tuning-fork system was used as a master control, such an arrangement having already proved successful at the P.O. Station at Northolt. The valve-maintained fork has a frequency of about 1,800 cycles (adjustable within small limits), and the high frequency for controlling the main set is obtained by selecting the 9th harmonic by filtration. The frequency produced is remarkably constant, temperature variation being about 1 cycle in 10,000 per degree C. A small adjustable electric heater is provided to maintain a constant temperature in the box containing the fork. The general scheme of the fork and its immediate amplification is shown in Fig. 8, the complete unit shown being termed the "Tuning Fork Unit."

The output from this unit is amplified through three successive stages before it is delivered to the aerial circuits. The various stages are designed to deal with input powers of the order of 4kW, 50kW and 1,000kW respectively, giving output powers of 2kW, 30kW, and 540kW respectively. These are referred to as the 4kW stage, the 50kW stage and the "power units" respectively. The combination of the 4kW and the 50kW stage form an "excitation unit." These and the tuning fork units are provided in duplicate, and either tuning fork unit can be used with either excitation unit, while either excitation unit can be used to drive the final stage of amplification which consists of a number of "power units." All the stages and units are contained in high tension enclosures. All meters can be read conveniently, and such adjustments as are necessary while the power is on can be made from outside the H.T. enclosures.

The final stage (*i.e.*, the "power units") is not provided in complete duplicate. The power-station practice of having a number of units capable of being worked in parallel has been adopted, as it offers greater advantage in general flexibility.



Photograph, taken from inside the building, showing the lead-in and also the inductance spiders.

The excitation units and the power units utilise the same H.T. D.C. supply. A simple arrangement permits this supply to be switched on to the 4kW stage, the 50kW stage and the power units in use by the pressing of a single button on the control table at the same time assuring that all accessible units are "dead."

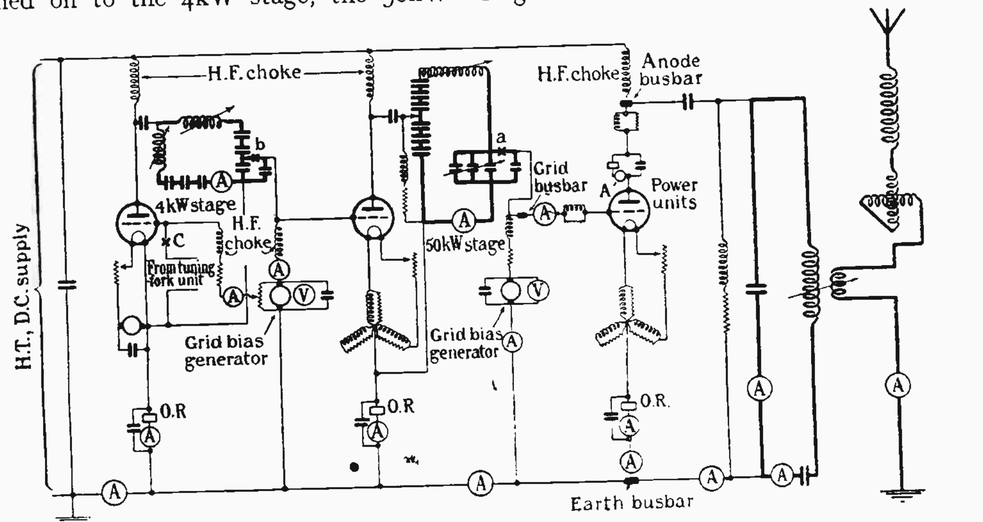


Fig. 10.

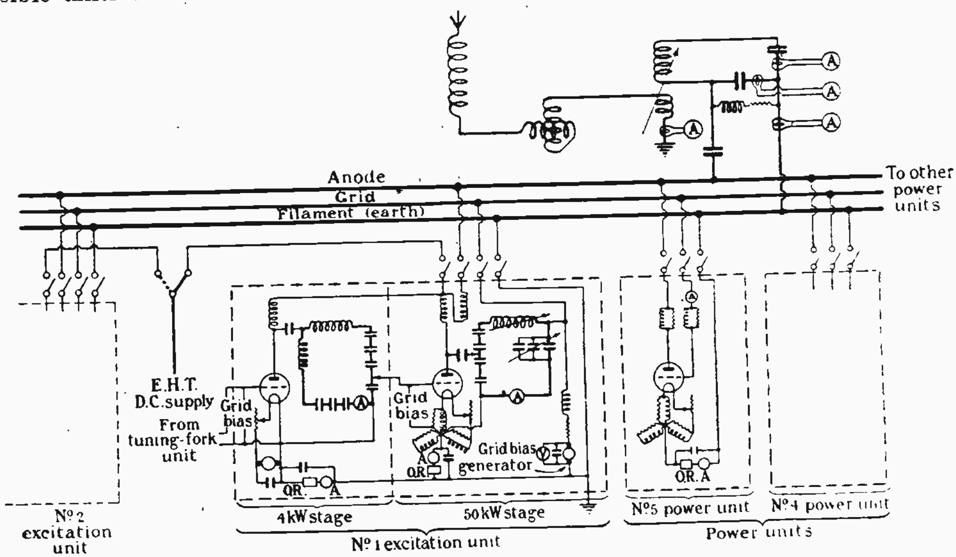
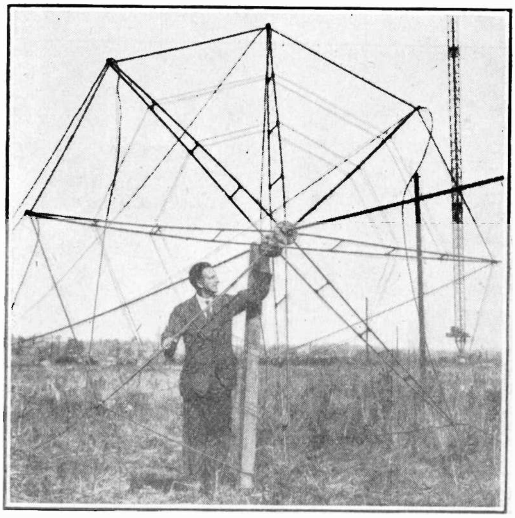


Fig. 11.

Fig. 10 is a skeleton diagram of the circuit arrangements from the output of the tuning-fork unit to the aerial. The tuned high-frequency circuits at the various stages are indicated by the thick lines. A particular characteristic of the circuits is the use of a single tuned circuit between one stage of amplification and the next, and the use of capacity coupling. An advantage of capacity coupling is that a condenser provides a low impedance path for the harmonics necessarily generated by a valve transmitter when operated as an efficient power amplifier, and thus acts as a desirable harmonic filter.

Fig. 11 is a schematic diagram showing the method of feeding the H.T. D.C. supply through a selected excitation unit to the power units. Three busbars run the length of the installation for the anode, grid and filament respectively. To bring a particular unit into operation in parallel with others it is only necessary to connect it to the busbars by one 3-way switch, and to light the filaments by means of the switch for the unit.



One of the aerial spreaders in the course of erection, the relative proportions giving a clear idea of their size.

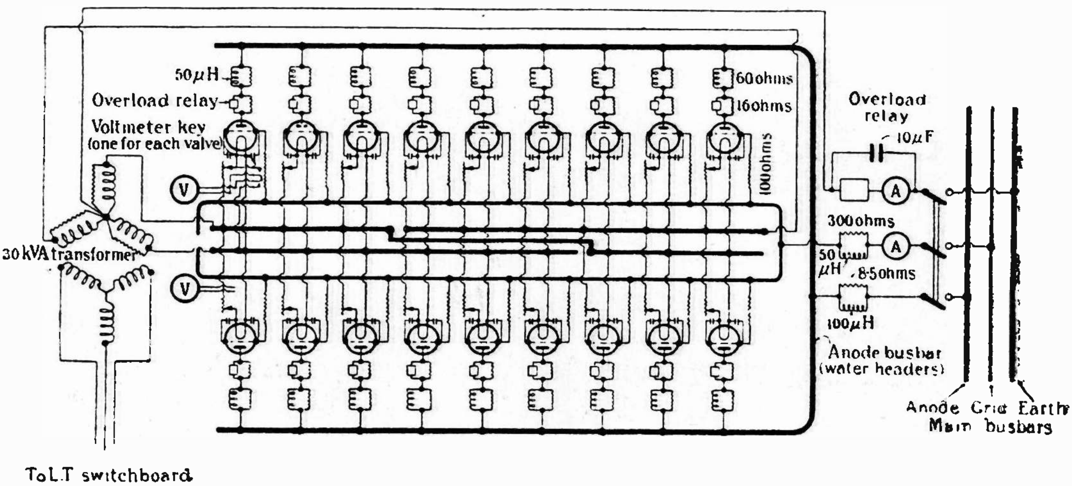


Fig. 13.

The filament supply for the 4kW stage is at 15-20 volts D.C., supplied by one of the generators in the auxiliary machine room. The supply for the 50kW stage and the power units is from 416 volts, three-phase, 100 cycles, transformed down to the 20 volts required by transformers in the units themselves. A regulator maintains constancy, and the load is balanced between the three phases to reduce the effect of any periodic change of emission current due to the use of A.C. for filament heating.

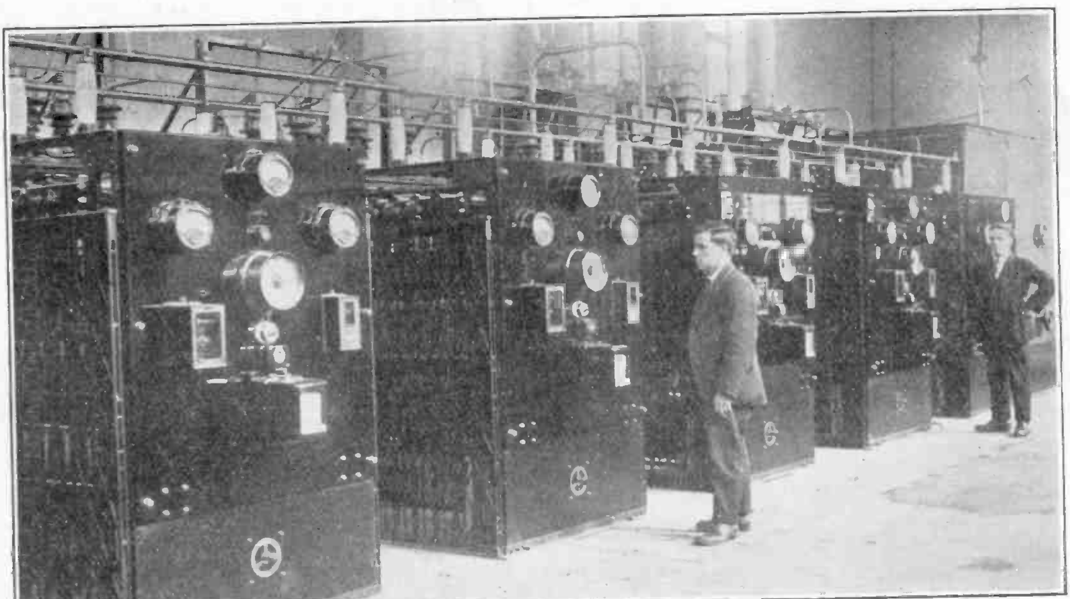
The 4kW stage utilises 600-watt glass valves. The 50kW stage utilises three water-cooled valves, similar to those of the power units. The inductances are wound of stranded wire on a framework of American whitewood, 243/36 S.W.G. being used for the 4kW stage and 729/36 for the 50kW. The condensers are mica in oil. With each excitation unit is a remote-controlled auxiliary machine unit of one motor driving four generators for: (1) Anode supply for amplification of tuning fork unit; (2) filament supply of 4kW stage and for tuning fork unit (by means of potentiometer); (3) grid bias for 4kW and for 50kW stages; (4) grid bias for power units.

Five-power units are provided, each capable of an output of 180kW from eighteen 10kW water-cooled valves made in England by the Western Electric Co. Three units are thus required for a 500kW aerial power transmission, leaving two units spare. Two transmissions of over 300kW could also be undertaken by using two units for each, leaving one unit spare. Each power unit consists of 18 valves in a rectangular enclo- power units and excitation units. The three-way switch for connecting a power unit to the busbars cannot be operated until gates on the sides of the units have been locked.

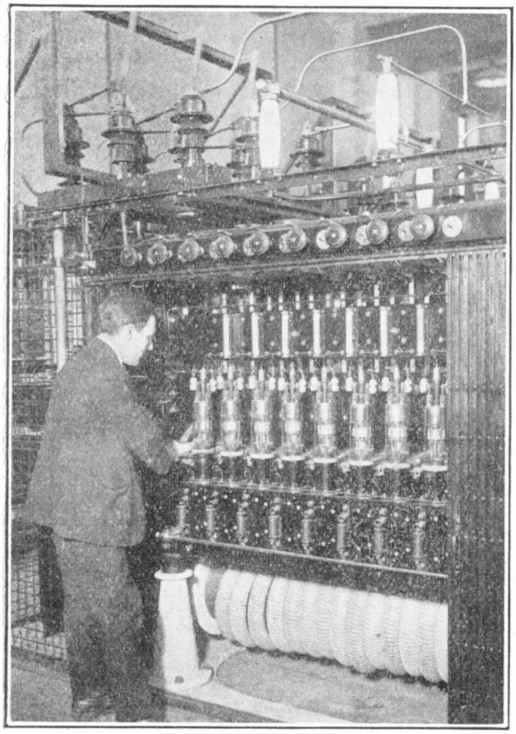
An internal view of the transmitting room. The control table is seen in the centre of the picture. The second engineer is standing beside the "excitation units," i.e., the 4kW and 50kW stages, as described in this abstract. To the extreme left are some of the power units. On the right is the L.T. switchboard.

sure, arranged with nine valves on each side and a front slate panel containing meters. The three busbars run above the various

Fig. 13 shows the wiring arrangement of a power unit. Reference is made to the difficulty of using a large number of valves



A general view of the power units, where the busbars are clearly seen.



One of the power units with its Bostwick safety gate open on one side. The handles of the filament rheostat for each of the nine valves forming one side of the unit are seen above the gates, while eight of the valves are visible in the photograph, with an overload relay below each. The coil behind the insulator is a rubber water pipe.

groups, the inter-electrode capacity of adjoining valves or groups of valves forming the condenser of the oscillating circuit in association with the inductance of the leads. This difficulty is enhanced with water-cooled valves. The stabilising arrangements used in these units consist of: (1) Two small condensers of 400 $\mu\mu$F each, mounted on each valve between the grid and each end of the filament; (2) a series non-inductive resistance of 100 ohms between each individual grid and the grid busbar; (3) the anode feed from the individual valves to the top water header (which acts as anode busbar) consists of a coil of 50 μH in parallel with a non-inductive resistance of 60 ohms to the same header and a similar resistance to the bottom water header, the two headers being metallically connected at the end of the panel.

Inter-oscillation between the power units is prevented by the devices shown in Fig. 13 in the main feeds from the busbars to the unit. The combined anode is fed through a "stopper" consisting of 100 μH in parallel with a resistance of 8.5 ohms. The combined grid is fed through a circuit of 50 μH in parallel with a resistance of 300 ohms formed by six straight-filament lamps in series.

Details and illustrations are given of the safety devices and control circuits. A control table suitably placed in the transmitting

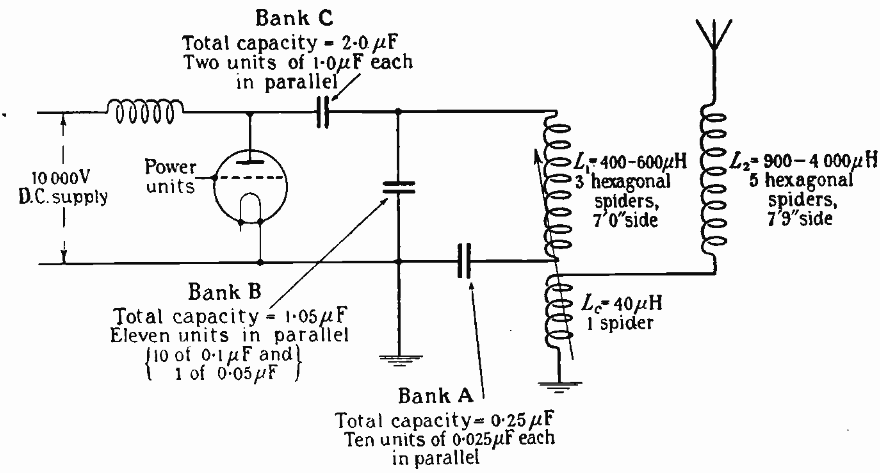
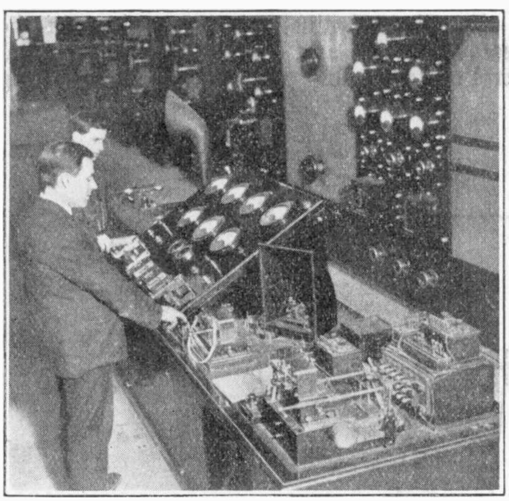


Fig. 17.

in parallel due to the tendency of the valves to "self-oscillate," either individually or in room contains all the essential controls and the most important meters of the wireless transmitter. The control equipment comprises :—

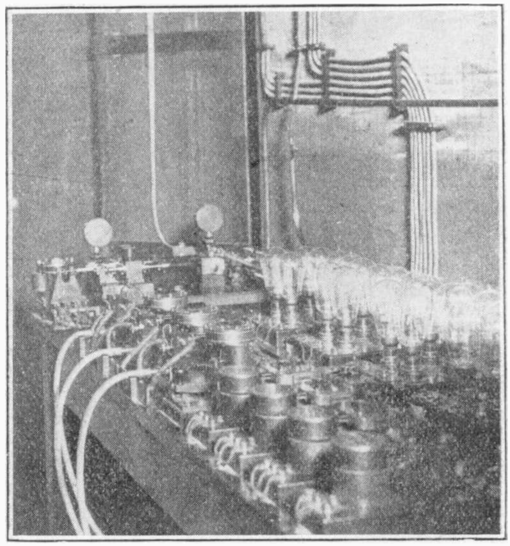
(1) Press buttons to start and stop auxiliary machines.
(2) Press buttons to start and stop air compressor for keys.
(3) Press buttons for H.T. D.C. switch.
(4) Switch to start distilled water pump.
(5) Switch to start cooling-water pump.
(6) Switch for main filament supply.
(7) Filament supply voltmeter.
(8) High tension D.C. voltmeter.
(9) High tension D.C. feed ammeter.
(10) Ammeter reading H.F. feed current to main oscillating circuit.
(11) Ammeter reading H.F. current in capacitative arm of primary oscillating circuit.
(12) Ammeter reading H.F. current in inductive arm.
(13) Aerial ammeter.

Apparatus terminating the landline from the C.T.O., London, is also on one side of the control table, with controls to the power-house on the other side. The duty engineer has therefore full control of the entire station from his position at the control table.



The control table, the central sloping portion containing the switches and meters mentioned in this abstract. To the right of the table is seen the land-line apparatus and to the left is the apparatus for signalling power requirements to the power house. A loud-speaker and wireless recorder also permit checking of the actual signals sent out from the aerial.

The coupled aerial circuit is then considered. The use of a coupled circuit is emphasised for the reduction of harmonics, and various types of circuit are briefly



View of a Creed key and pilot keys. These are housed behind the 4kW section of the excitation unit.

reviewed theoretically. The circuits of Fig. 17 are stated to have been found satisfactory. Low decrements in both primary and aerial circuits being essential, it was necessary to provide the most efficient inductances, and condensers having very low loss. The economic and other considerations governing the choice of the electrical dimensions shown are briefly discussed. The condensers are mica, immersed in oil made by Messrs. Dubilier to P.O. specification. They have a power factor of 0.00025 at the working frequency. The coils are wound of a cable of 6,561 strands of 36 S.W.G., each strand being insulated by enamel and one covering of cotton or silk. The coils are wound on frames of American whitewood, the cable being wound in slots on movable wooden spiders which are supported on rollers on the wooden framework. Relative movement of the spiders gives a variometer tuning. The aerial coil has 5 spiders each of 8 turns in the form of a hexagon with 7 ft. 9 ins. external sides; inductance continuously variable from 900 to 4,000μH. The primary circuit coil has 3 spiders each of 4 turns in the form of a hexagon of 7 ft. external side; inductance 400 to 600μH. The coupling coil has 2 turns 6 ft. 5 ins. external side; inductance 40μH. It is mounted on the same framework as the primary coil. The measured resistance of the entire primary circuit was 0.088 ohm at 16,000 cycles giving a decrement of 0.0053. That of the aerial inductance and coupling coil was 0.11 ohm.

Keying is effected by the simultaneous operation of a simple make and break key at each of the three points marked *X* in Fig. 10. Creed pneumatic keys are used for the points "*a*" and "*b*," and a magnetic relay key for point "*c*." The latter two keys when open leave a condenser between the grid and filament. The condenser is of sufficient value to make the grid-filament

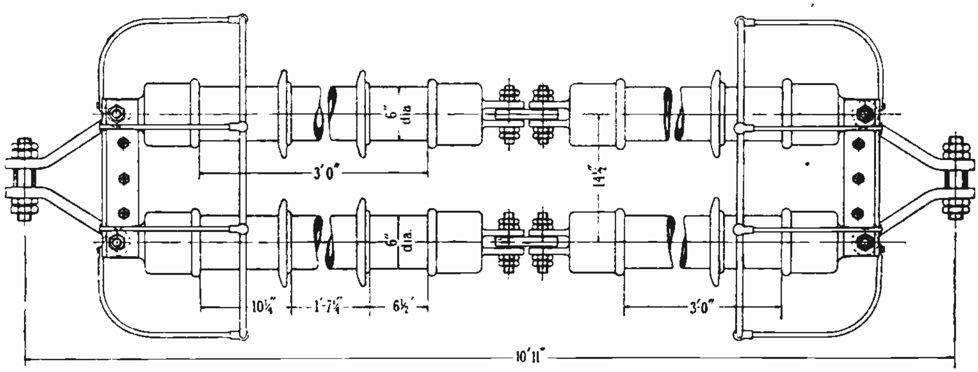
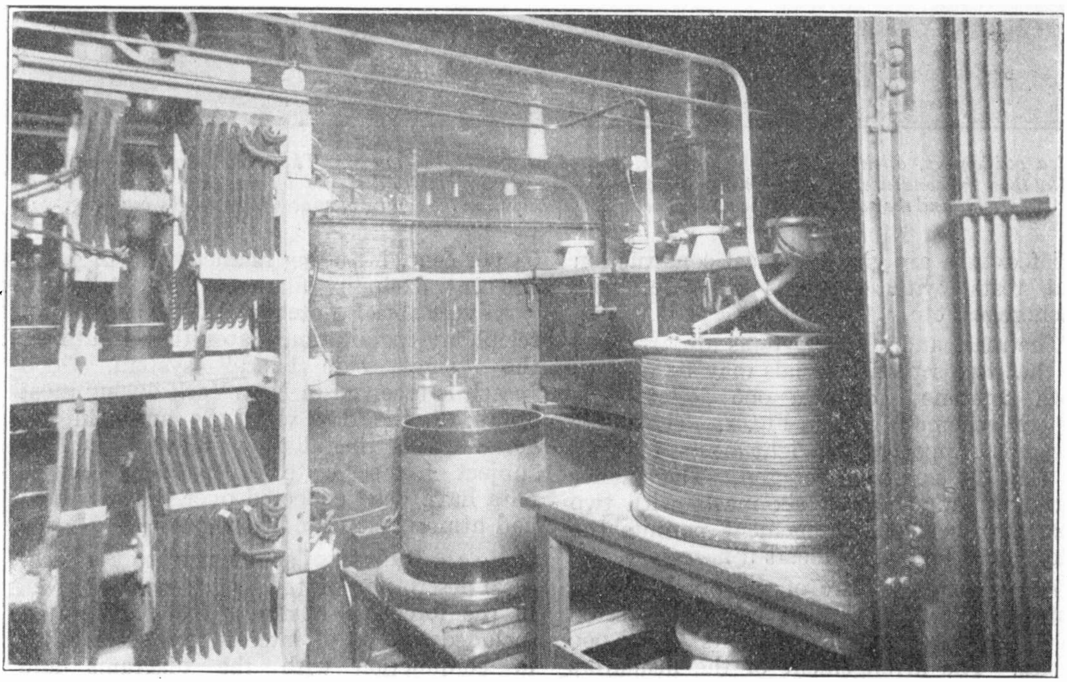


Fig. 25.



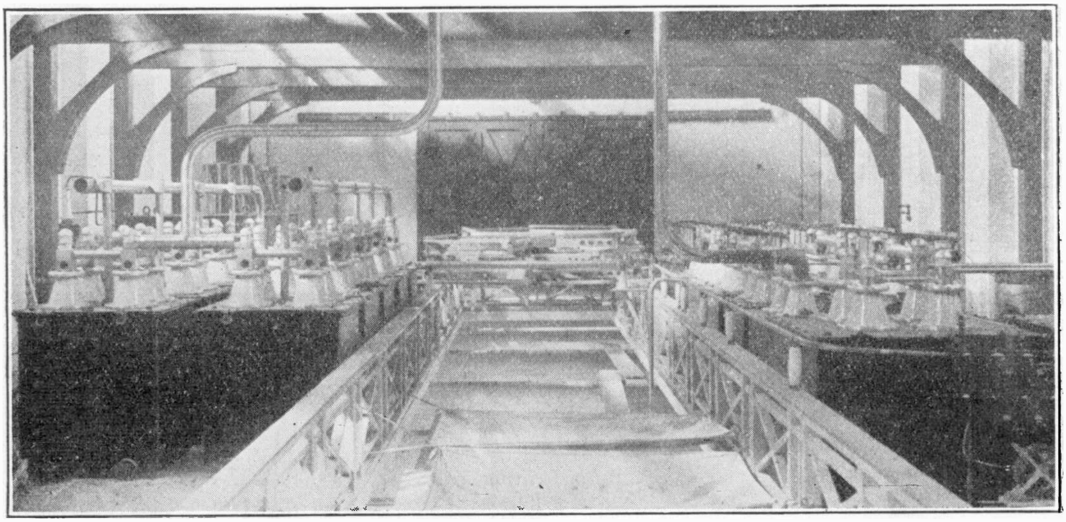
Some of the inductances in the amplification stages.

impedance capacitative, counteracting any tendency to self-oscillation in the stage concerned.

The following section on masts is brief (this subject having been dealt with in a recent paper before the Institution of Civil Engineers by Col. A. S. Angwin and Mr. T. Walmsley). The masts are 820 feet in height, and are of the stayed and pivoted type, insulated at the base. The pivot is 17 ft. above ground level; below this are columns of porcelain insulators and a granite cube, the whole supported by a steel column.

The earth system on the telegraph side consists of copper wire buried a few inches below ground and following the general plan of the aerial. An insulated counterpoise at 16 feet height has been erected under the smaller aerial.

Measurements of effective height of the aerial show that its value with the masts insulated is 1.22 times its value with the masts earthed. The former value is 607 ft., or 78.5 per cent. of the mean geometric height of the aerial. A table of various measured values reveals a transmitter efficiency of



Mica condensers, oil-immersed, which are being used at the Rugby station. The mica pattern is much less bulky than the condensers of aluminium plates immersed in oil formerly designed by the Post Office for use at Leafield, and the adoption of the mica condenser has helped in the saving of space in the Rugby building.

Brief details are given of mast construction and tests, with diagrams of base, stay anchorages, etc.

The mast and aerial systems are arranged so that two separate aerials may be used or both combined to form one aerial. The general scheme is seen in Fig. 1. The larger aerial is supported on eight masts, forming in plan an elongated octagon. The smaller aerial is supported on six masts with two open arms. The arrangement permits the addition of four more masts if necessary.

Aerial insulators are of the porcelain rod tension type, weighing 6½ cwt., and tested to a pressure of 120,000 volts at 50,000 cycles. The arrangement of the insulators is shown in Fig. 25.

64 per cent. including filament and of 71-72 per cent. excluding filament.

A very brief note on the experimental telephony installation states that it utilises the "single side band" system. Good speech is received in New York during most hours of the day with 185 amps in the aerial. This installation may form the subject of a separate paper when reliable data have been collected over the period of bad atmospheric conditions.

Note.—By way of supplement to the technical description of the Rugby station, given in the foregoing abstract, the photographs included will be of interest to readers taken in conjunction with the diagrams and descriptions in the abstract.

DISCUSSION.

The meeting was very largely attended, and a lengthy discussion followed the reading of the paper.

The discussion was formally opened by the Chairman reading a communication from **Dr. W. H. Eccles** (Vice-Chairman of the Wireless Commission), who was unable to be present. Dr. Eccles referred to the excellent co-operation which had existed between the Commission and the Post Office engineers working under the author, and to the large detail of design work done by the engineers. The splendid operation of the station was a testimony to the value of the design work.

A telegram was also read from **Mr. L. B. Turner,** a member of the Commission, regretting his absence through indisposition, and complimenting the author.

Sir G. Wrightson (head of the firm erecting the masts), after referring briefly to early developments of wireless, spoke of the smoothness which characterised the work of erecting the masts. Despite the heights involved, no serious accident occurred.

Mr. C. F. Elwell, comparing Bordeaux on arc, and St. Assise on high frequency alternator, said that the P.O. had anticipated valve practice in the design of the Rugby station. In the paper there was much to praise and little to criticise. He referred to the possibility in future design of fewer taller and more widely spaced masts with greater aerial pulls. He also discussed the work of maintaining small valves, and hoped for the possibility of one large valve with renewable parts to replace, say, all the valves of one of the power units.

Capt. P. P. Eckersley congratulated the author on the absence of interference in the broadcasting band, and spoke of the high state of H.F. technique in the Rugby station. With reference to tuning-fork control of frequency, the B.B.C. had actually used a 890 cycle fork as a drive for a relay station working at nearly one million cycles. He raised the possibility of omitting mast insulation and compensating the efficiency by increased amplification.

Mr. G. Shearing first referred to the large undertaking of valve transmission on the scale described. The Admiralty and H.M. Signal School had always advocated valves for high power generation, and it was gratifying to see the results now described. Having regard to the advances of short wave communication, might not Rugby be the climax of long-wave high-power practice? He also raised several points in connection with the power plant and other details. He believed rectifiers might have proved more advantageous than H.T. D.C. machines. Why was the filament supply converted to only 100 cycles? Would not a higher frequency have been an advantage?

Mr. R. N. Vyvyan congratulated the author and his staff on the design of the Rugby station, but expressed his confidence in the short-wave beam system as the solution of transmission.

Mr. Gibson discussed several points in connection with the use of distilled water for the cooling of the anodes. Higher electrical insulation with smaller loss was the first result, while undistilled water had also detrimental effects on the metal of the anode. He agreed with Mr. Elwell as regards the need for a larger valve, but considered a sealed-off pattern was more desirable than one with replaceable parts, possibly necessitating continual pumping, on account of difficulties with traces of gas.

Mr. Shaughnessy briefly replied to several of the points raised in the discussion. The height and arrangement of the masts was chiefly a matter of economics. As regards the valves, those used were the largest available, and the arrangement of the power units described permitted flexibility as regards the testing of any new types of valve that might be developed. As regards short waves he did not consider that there had yet proved sufficiently stable and reliable for systematic work. The use of machines for H.T. had the advantage of putting no keying fluctuation back on to the company's mains, while the motor-alternator for filament lighting was used chiefly to take advantage of regulation by Tirrill regulators in the interests of constancy as compared with the fluctuations of voltage if a transformer had been directly used. As regards beam communication he hoped that this system might in the future do even more than was claimed for it.

On the motion of the **Chairman** (Major B. Binyon) a very cordial vote of thanks was accorded to the author.

Laboratory Notes.

Two Useful Devices Described.

By E. Bainbridge Bell. **[R387 and R381.5**

IN the course of research on wireless receiving circuits involving the use of frame aerials, where stray and unbalanced capacity effects are objectionable, the following two devices have been found useful :—

(1) An Electrostatic Screen.

In an air-core transformer with " pancake " coils, it is necessary to insert an earthed screen between the windings in order to make use only of electro-magnetic coupling. In order to avoid eddy current paths these screens have been made of thin metal sheet with many transverse slits. We have found the following a quick and easy way of making such screens :—

A cylindrical wood former, say 4 inches in diameter, is covered with thin paper and closely wound with one layer of 26 D.C.C. wire. A strip is bared along a generator of the cylinder and a strip of copper is then soldered to the wire where it has been bared. The whole is covered with a solution of celluloid in acetone and dried. The solenoid is cut along a generator of the cylinder, unwrapped and flattened out. The result is a flat screen with the eddy current paths limited to the diameter of a single wire.

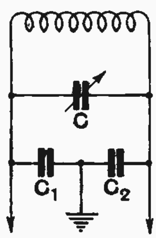


Fig. 1.

(2) A Condenser Potentiometer.

When using a frame aerial it is often necessary to equalise the capacity of each side of the frame to earth, and as the capacity of the two balancing condensers C_1, C_2 (in series) (see Fig. 1) is in parallel with the frame and tuning condenser C, it is generally necessary to readjust the tuning condenser after adjusting the balancing condenser, a good balance involving several readjustments.

If, however, the two condensers C_1 C_2 are coupled together in such a way that

$$1/C_1 + 1/C_2$$

is constant for any adjustment, retuning the condenser C is avoided.

Where a large ($1{,}000\mu\mu$F) adjustment is necessary, two " Polar " condensers are used. These have a law approximately

$$C = k/a - d$$

when d is the scale reading and k, a are constants.

Two of these are connected by a coupling sleeve in such a way that as the spindle of one is turned through a given angle, the spindle of the other is turned through the same angle in the opposite direction.

If d_1 d_2 are the angles through which the spindles are turned,

$$d_1 + d_2 = \text{constant}.$$

Now $C_1 = k/a - d_1 \quad C_2 = k/a - d_2$

$$\therefore \quad \frac{1}{C_1} + \frac{1}{C_2} = \frac{a - d_1}{k} + \frac{a - d_2}{k}$$

$$= \frac{2a - (d_1 + d_2)}{k} = \text{constant}.$$

If only a small variation is necessary a " neutrodyne " condenser made by Messrs. Bowyer-Lowe can be modified as follows :—

The condenser consists of a fixed and a moving plate, the capacity being adjusted by moving one plate at right angles to itself by a screw motion. An extra fixed plate was fitted so that the moving plate was between the two fixed plates.

The law of each condenser was then :—

$C = k/d$ (where d is the distance between one fixed plate and the moving plate).

If $C_1 = k/d_1$ and $C_2 = k/d_2$: $1/C_1 + 1/C_2$
$= d_1 + d_2/k$.

Now $d_1 + d_2$ is constant.

Therefore $1/C_1 + 1/C_2$ is constant.

Mathematics for Wireless Amateurs.

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

Introduction.

THIS series of articles is intended for those wireless amateurs who wish to understand their subject but find that they are seriously handicapped by a lack of mathematical knowledge. It will be assumed that they gave up mathematics when they left school, and have probably forgotten nearly all they ever knew about it.

No doubt there are many amateurs in this position who are quite willing to be so and who even pride themselves on being "practical men" and not mere "paper merchants." In so far as this is a genuine distrust of theorists and not a case of sour grapes, it will be sufficient to refer them to the history of the subject. There they will find that the so-called practical man is generally not nearly so practical a person as the wool-gathering theorist and mathematician. The story of the loaded telephone cable is a particularly good instance of this.

Again, of those who realise the necessity of mathematics, there are probably many who are scared of the subject and convinced of their inability to tackle it. They may think that theirs is what Oliver Wendell Holmes neatly described as the $2+3=5$ sort of mind, as distinct from the $a+b=c$ kind. But this partition, though real enough, is not an insurmountable wall, dividing mankind into two classes. Given desire enough, almost anyone can find the way over, for mathematics is really no more than the hitherto pedestrian faculty known as common sense trained in the use of its wings, and everyone has a certain amount of common sense.

Finally, there may be those who think themselves too old to commence the study of mathematics. Actually this idea need not deter them at all. Plato recommended that no one should commence the study of philosophy, which included mathematics, before the age of twenty-one, and there is much to be said in favour of this view. Generally one starts too early, rather than too late, and risks acquiring a permanent distaste for the subject by so doing.

Now a word about the scope of the series. As the title implies, it is proposed to deal with the subject from the special point of view of wireless amateurs. This means that particular attention will be given to those ideas and methods which are most likely to be of use to wireless amateurs. It does not mean that only these ideas and methods will be considered, because that would be impossible. Mathematics can be divided up into various branches, but no one of these is independent of the ideas embodied in the others. Much of what follows will appear to have no direct bearing on wireless telegraphy, but the reader must be content to accept the fact that in these matters one cannot always see the end from the beginning. Take, for instance, the proposition that the area of the square drawn on the longest side of a right-angled triangle is equal to the sum of the areas of the squares drawn on the other two sides. At first sight this would not seem to have much to do with alternating current circuits, but it eventually proves to have a very close connection indeed.

The series will be divided into five parts, according to the following rough classification :—

Part I.—Elementary Algebra.

Part II.—Plane Geometry.

Part III.—Trigonometry, including Elementary Hyperbolic Trigonometry.

Part IV.—Elementary Differential and Integral Calculus.

Part V.—Vectors, and their application to Alternating Current Problems.

Each subject will be started right from the beginning. Moreover, the elementary part of each subject will be considered very fully and very deliberately. In mathematics, as in most other things, it is the first step that counts. Once the fundamental ideas are well and truly assimilated, the rest is easy.

Even for those who feel themselves to be already well grounded, this return to the beginning will not necessarily be a waste of time, for memory, though a good servant, is also a presumptuous one and sometimes tries to usurp the place of understanding.

PART I.

ELEMENTARY ALGEBRA.

1. Symbols.

One of the most characteristic things about algebra is its appearance, and to a beginner it is certainly not prepossessing. In place of concrete and understandable numbers, to which we have learned to attach definite meanings, we are confronted with such things as

$$a + b = c.$$

The immediate and natural reaction is like that of the little girl who knew her tables up to twelve times and was asked what was three times thirteen—" Don't be silly. It doesn't exist." The writer's earliest recollection of algebra was precisely like that, which shows that the matter was not clearly explained to him, or at least not clearly enough. The whole point is that the letters of ordinary algebra are not really being used as letters at all. They are just symbols which stand for numbers, and it so happens that the letters of the alphabet are very convenient symbols to use because they have an agreed shape and known names. In addition, certain other symbols are used which are either a short way of making statements (for instance, the symbol "=" is only a short way of writing " is the same as " or " is equal to ") or else instructions to do certain things with the numbers represented by the letters.

2. Algebra as a generalisation of Arithmetic.

Bearing in mind the real character of the letter symbols used in algebra, we can understand this statement taken from Chrystal's text-book. " Ordinary algebra is simply the general theory of those operations with quantity of which the operations of ordinary arithmetic are a particular case. The fundamental laws of this algebra are therefore to be sought for in ordinary arithmetic." This, then, let us proceed to do.

3. The Fundamental Laws of Algebra.

(A) *Addition.*

What do we really mean by the addition of two numbers in ordinary arithmetic? It is a fascinating subject, and one is tempted to digress. Briefly—a number is a group of ones that we know by name. Adding two numbers means finding the name of the group which contains as many ones as the two groups put together. Thus we know (by memory now, but originally by trial with fingers or beans) that the group two combined with the group three has the same number of ones as the group that we have agreed to call five. (There is no special magic about the name five. If we had called it John, then John would be the group containing as many ones as we have fingers on one hand.)

The above example is an ideal case, concerned with pure numbers. In fact, some will call it metaphysical, but that will not make it any less important to understand it, nor any harder to understand. In practice, however, we shall not be concerned with pure numbers but with numbers of things—volts, amperes, pounds, shillings and pence, cabbages or kings—and here we come to one of the most important rules in the whole of mathematics.

Things can only be added together in the arithmetical sense if they are things of the same kind.

For instance, three apples can be added to two apples, and the resulting group can be called five apples. But can three apples be added to two oranges? Yes, in the sense that they can all be put into the same dish, but the number five cannot be attached to the group—unless indeed you call them five fruits, but then you are obeying the general rule, for you have obliterated the distinction between the two kinds of things, and have really added three fruits to two fruits; in other words, the things have been regarded as of the same kind. But obviously this can only be done if the distinction between the two kinds is unimportant for the purpose in mind, and in wireless problems this never happens.

The above is the essence of what is known by the rather impressive title of " The Theory of Dimensions." It will be considered more fully later on, but for the present it will be enough to realise that if the working out of a given problem in wireless leads to the conclusion

$$L+R=10 \text{ ohms},$$

where L means some number of micro-henries and R means some number of ohms, then the result is wrong without any further consideration, because it adds together two numbers of things of different kinds and calls the result a single number of one of the kinds.

Now we can go on to the finding out of the generalised rules of arithmetical addition, and the easiest way will be to fix on some one particular kind of thing that we can make a picture of either mentally or actually. Then, on the understanding that all our numbers, or symbols standing for numbers, mean numbers of this particular thing, we shall be obeying the fundamental rule about addition, and the conclusions arrived at will apply generally to any form of arithmetical addition. A convenient thing to choose will be a travel or a journey of, say, one inch in some definite direction, this direction being from left to right parallel to the bottom edge of the page. This may seem a curious thing to choose, but it will be found later that it is very suitable for finding out the rules about subtraction also, which are not so easy to understand as those of addition.

Any number, say, three, of these things will mean three journeys of one inch added together, and since the adding of two journeys means starting the second from the finishing point of the first, this will be the same as a journey of three inches in the given direction. In general any number a will mean a journey of a inches in the given direction (Fig. 1). Suppose now that the journey a is carried out in two stages, first a journey b and then a journey c, as shown in the upper part of Fig. 2. Then a can be described as the result of adding the journey c to the journey b, *i.e.*,

$$a=b+c.$$

Further, it is clear that it does not matter which of the two journeys b or c is made first (lower part of Fig. 2), so that

$$a=b+c=c+b.$$

In the same way it will be just as easy to show that

$$b+c+d=b+d+c$$
$$=c+b+d$$
$$=d+c+b, \text{ etc., etc.,}$$

d being another journey of d inches added to the other two. The same idea could be extended to any number of journeys without alteration and we thus arrive at the second general rule about addition.

A succession of additions will lead to the same result whatever the order in which they are carried out.

(A.1.) *The Use of Brackets.*

Returning to the statement

$$a=b+c,$$

this expresses the idea that the two journeys b and c can be considered as a single journey. Similarly, any number of journeys b, c, d, e, etc., can if desired be associated together and considered to be a single journey

Fig. 1. *Representing the number* a *by a journey of* a *inches in a horizontal direction to the* right.

$b+c+d+e+$etc. Or, again, two of these journeys can be considered as a single journey, if that is convenient for some particular purpose, leaving the others as separate journeys. When it is desired to consider any particular group of journeys (or numbers) as a single thing, that group can be enclosed between two brackets thus $(c+d)$, and that

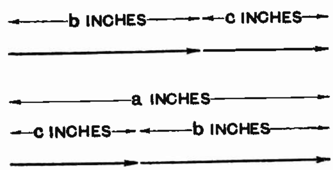


Fig. 2. *Showing that a journey* a *can be made up of journey* b *and then journey* c, *or journey* c *first and then journey* b.

means that we will take this as a whole, without regard to the fact that it is actually made up of two parts. Thus the compound group of numbers a, b, c, d can be written in the form

$$a+b+c+d$$

or in the form

$$a+b+(c+d),$$

the c and d numbers being, so to speak, wrapped up into a single brown paper parcel. This is called the Law of Association for addition, though it is certainly very difficult to see why it should be called a law at all, any more than the wrapping up of things in a brown paper parcel should be called the Law of Brown Paper. However, the idea of associating certain sets of numbers together by means of brackets is a useful one in practice.*

(A.2.) *The Addition of Double Groups.*

Before leaving this subject of addition it may be as well to return for a moment to our three apples and two oranges, because they can be used to illustrate a very important extension of the idea of addition, one which will prove useful in connection with alternating current circuits.

It has been shown that the group three apples plus two oranges cannot be expressed in any simpler form, since the two parts of the group cannot be combined in the sense of arithmetical addition. Two such double groups can be so combined, however. For instance, three apples plus two oranges combined with four apples plus six oranges can obviously be expressed as one double group, seven apples plus eight oranges, *i.e.*, the two sets of apples can be added and the two sets of oranges can be added. To generalise this idea, suppose the letters a, b, c, etc., to represent numbers of apples, and the Greek letters α, β, γ, etc., to represent numbers of oranges, and suppose that the working out of a problem concerned with these double groups of apples and oranges leads to the statement

$$a+\alpha+b+c+\beta+\gamma=d+\delta$$

Then the number d on the right-hand side must be the result of adding together all the apples on the left-hand side, and similarly the number δ must represent all the oranges on the left-hand side. The statement is therefore equivalent to two separate statements

$$a+b+c=d$$
$$\alpha+\beta+\gamma=\delta$$

If this simple idea is thoroughly assimilated, the reader will find that he has got a firm footing in Vector Analysis.

(B) *Subtraction. The Meaning and Use of the Negative Sign.*

The idea of subtraction in the ordinary arithmetical sense is one with life which makes us almost painfully familiar. Returning to the ideal case, we know (by memory) that if two ones are subtracted or removed from a group of five ones, then what remains is the group that we have agreed to call three; and if the ones are, say, pounds, then our understanding of the process is intensified in some cases by its emotional associations. For a child, actually carrying out the process with fingers or beans, the matter ends quite definitely when all the five ones have been subtracted, and if he is asked to take away any more after that he will say, quite rightly, "It can't be done." Later on, however, he will be forced to acquire the idea of a negative number when he finds that seven pounds have been subtracted from his five pounds, leaving him with a debt of two pounds. Mathematically speaking he would now be said to possess minus two (—2) pounds, and assuming him to be an honest man, he will realise that if later on he earns two more pounds, these must be set against his debt of two pounds, leaving him the possessor of exactly nothing. Expressing this mathematically,

$$-2+2=0$$

and since this is true whatever the magnitude of the debt and of the equal amount that has to be earned to set against it,

$$-a+a=0$$

where a means any number.

This statement is the most general way of saying what is meant by the negative number $-a$. It is that number which, when added to or combined with the positive number a makes the total result nothing. The actual or practical meaning of the negative number $-a$ will therefore depend on, will in fact be in the sense indicated above, the reverse of, the meaning that we attach to the positive number a.

The form of expression should be noticed carefully. The word "subtraction" does not come into it. We are actually going to deal with subtraction, but it will be found that when this operation is given the wider sense that it has in algebra it will be much clearer and more convenient to think of it as the combination or addition of positive and negative numbers.

What is the meaning of the negative number $-a$ in terms of the things or units that were used in finding out the rules about

* The associative law for addition is usually expressed: $a+(b+c)=(a+b)+c$.

addition? The positive number a was shown to represent a journey of a inches to the right, and the negative number $-a$ is such that

$$-a+a=0.$$

In other words, adding the number a to the negative number $-a$ cancels the effect of the negative number, *i.e.*, brings us back to the starting point. This becomes quite intelligible if the negative number $-a$ means a journey of a inches to the left. In fact this is the only way to make in intelligibly consistent with the given meaning of $+a$. (See Fig. 3.) One of the most important rules of the negative sign now becomes clear. Applying the negative sign to the number a reverses the direction of the journey of a inches which this number represents. Applying the negative sign to the number $-a$ will therefore reverse it again, which brings it back to its original direction, *i.e.*,

$$--a=+a.$$

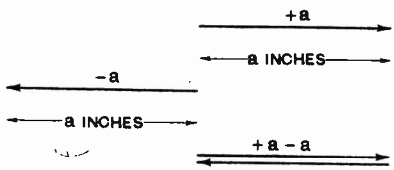


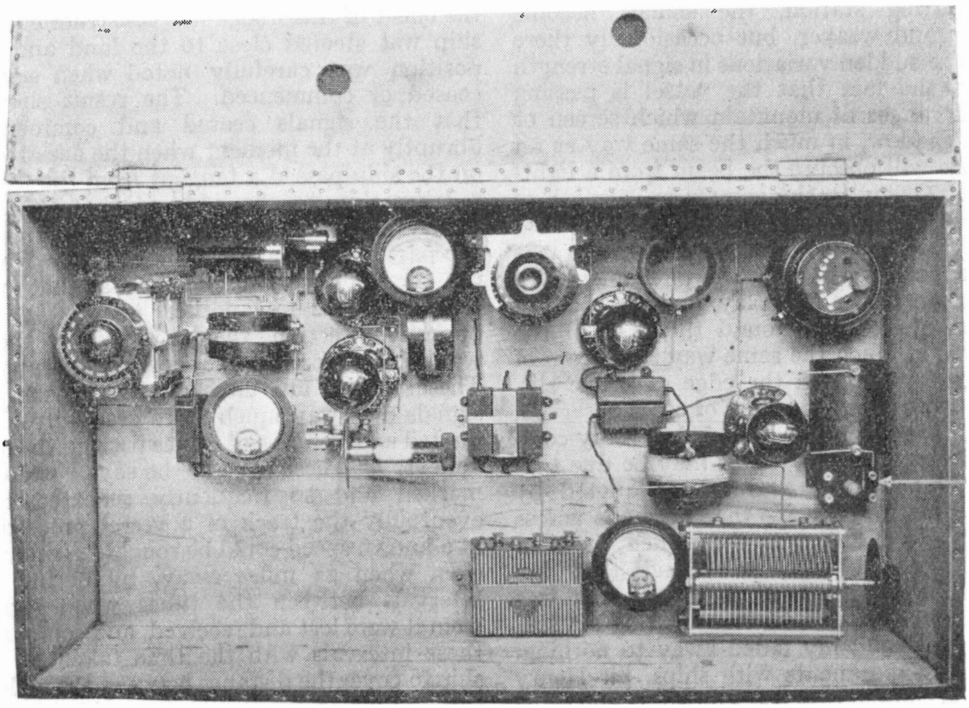
Fig. 3. *Showing how the number* $-a$ *is represented by a journey of* a *inches in a horizontal direction to the* left.

Putting this shortly in words, *minus minus is plus*, and in signs

$$--=+.$$

Here we have a familiar acquaintance in academic dress, the familiar acquaintance being the phrase, "Two negatives make an affirmative."

(*To be continued.*)



The photograph shows an American crystal controlled transmitting set. The master oscillator (driven by the crystal) operates at 209.4 metres, and the fifth harmonic (41.88 *metres*) *of this is amplified in succeeding valves until the desired output is obtained.*

Fading. [R113.1

A Lecture delivered by Prof. E. W. MARCHANT, D.Sc., before the Radio Society of Great Britain, on 24th March, 1926.

THE phenomenon of "Fading" of strength of wireless signals is familiar to most of those who use wireless sets, particularly to those who have tried to listen over long distances. These variations are due to very varied causes. A good many of the so-called fading effects are really due to variations in the receiving set itself. The batteries supplying the filaments of the valve, for example, begin to lose their charge, or the high tension battery may run down, or there may be a bad contact at some point of the set. I intend to speak this evening about the actual reduction in strength of the received signal due to causes outside the control of the receiving apparatus. The fading of signal strength at sea, as a ship is travelling over the ocean, has been observed frequently; as the boat sails away from the transmitting station, the signals become weaker and weaker, but occasionally there are quite sudden variations in signal strength due to the fact that the vessel is passing behind ranges of mountain which screen or cast a shadow, in much the same way as an obstacle will obscure the beam from a lighthouse. Owing to the greater wavelength of wireless messages, the shadow that is cast by any obstacle is much less sharp than it is with a beam of light. The phenomenon of diffraction comes into play, and the beam of wireless waves gets round the edge of the obstacle in much the same way as a beam of light will get round the edge of a fine slit. There have been a number of cases observed, in which the signals have faded away comparatively suddenly. This may be due to a mountainous island. One case quoted by Dr. Eccles, in a voyage that he made across the Pacific Ocean, was that when the ship passed behind such an island that lay directly in the path of the beam that was coming from a wireless transmitting station, the signal suddenly faded away to nothing. In some experiments with ships, Sir Henry Jackson showed that soft sandstone and shale cliffs produce relatively little effect, the amount of absorption when the signals passed over land of this kind being such that about 80 per cent. of the distance is covered as compared with the signals passed over the sea. With limestone containing a large proportion of iron ores, the signal strength was very much reduced, the distance covered when the signal passed over land of this kind being less than 40 per cent., and in some cases as low as 20 per cent. of the distance that the same signal would pass over the sea. He mentions one case of considerable interest. The ship which was making the test was sailed close to an island of a wedge shape with a very steep cliff, the pinnacle of rock being extremely precipitous and jutting out from the mainland and rising abruptly out of the sea, so that the ship could pass close to it in perfect safety at a distance of about 100 yards. To ascertain the effect of this wedge-like construction, the ship was steered close to the land and the position was carefully noted when signals ceased or commenced. The result showed that the signals ceased and commenced abruptly at the moment when the aerial wire on the ship passed a tangent from the transmitting ship to the edge of the cliff, the action being exceedingly abrupt; at one transit, the part of the long dash in the letter F was the first indication of signals that was received, and in another transit in the opposite direction, the long dash of the F was the last received, the short being dropped. These results are unusual; as a rule the signals die away much more gradually. He quoted another case of waves passing through valleys. "These effects," he says, "were so marked and so frequently repeated that eventually the track of a vessel proceeding at a known speed could be roughly estimated, even when 25 miles away, by noting the intervals between the times when signals from it were lost and received, and comparing these intervals with the time taken by the ship to cover the distance between the valleys, through which the waves can evidently find their way with less obstruction than by any other route." He summarised the screening effect of rocks as being greatest with limestone containing iron ores, next with hard limestone and least with soft rocks.

Screening due to rocks has been observed in the neighbourhood of Grenoble, and is due to the nature of the country. In this district there are very deep valleys of limestone and other rocks, and the broadcast messages are sometimes difficult to pick up on aerials at the bottoms of these valleys. A similar kind of effect is observed with the Cardiff broadcasting station. This station is near the sea and behind it is a steep cliff. It is the experience, I think, of most people in Liverpool that Cardiff is one of the most difficult broadcasting stations to pick up, although actually it is not so far away as London and Bournemouth. Variations in signal strength (due to this kind of absorption) are, of course, not observed with fixed transmitting and receiving stations, but the phenomena are of interest, in so far as they explain the variation in strength that are observed with broadcast stations in different districts. The difference in the reception of two such stations may often be explained by obstructions that occur between the transmitting and receiving stations. For some reason Toulouse is very well received in this district, whereas Newcastle, as a rule, is not, and this, I think, is very largely due to the nature of the intervening land in the two cases.

It has been suggested that the fading of signal strength is due to weather conditions; although a great many measurements have been made at different times of the variations in the strength of wireless signals, there is no convincing evidence of any close relation between the state of the weather and signal strength. The only definite evidence of any such relation that I have observed, has been with signals coming over considerable distances at night, in which it appeared on several occasions, that the signal was considerably increased in strength after heavy rain. It seems as if the falling rain has "cleared the air" for the radio signals, in much the same way as a shower of rain will clear the air of dust or fog which obscures light waves, but there is hardly sufficient evidence to justify a generalisation on this point. When one deals with signals from longer distances, such as between this country and America, fading, as it is ordinarily understood, is much more marked. On some evenings, especially in winter, it is possible to hear American broadcasting stations quite clearly with an ordinary two-valve or three-valve receiver. This is not due to any remarkable qualities of the receiver, but is due to the fact that on these evenings the wireless atmosphere between this country and America is clear, and the waves come over at quite considerable strength. Some days they will be quite strong; the next day, when conditions appear to be very similar, the signal may be relatively weak, and this is more marked on broadcast wavelengths than it is on the longer wavelengths that are used for commercial transmission. If one is listening to such broadcast reception, the strength of the message may vary within wide limits, at one instant it will be quite strong, at another instant it will fade away to nothing, and sometimes this "fading" goes on continuously. The effect is something like what one observes occasionally with sound. A bell is tolling in a church tower, in the distance; at one instant, one hears the sound quite clearly, the next instant it fades away and then it comes on quite strongly again. In the case of a bell this effect is generally due to variations in homogeneity of the atmosphere, and the cause of wireless fading, although it is over much greater distances, is probably lack of homogeneity of the transmitting medium. The amazing thing about these wireless signals is that they *do* travel over such great distances as between this country and America. If one looks at the map of the world, it is evident that there is a great mountain of water between these two places, round which any beam, which travels in straight lines, could not be expected to pass. It is now generally agreed that they are reflected across these long distances by an upper layer of the atmosphere which acts as a sort of mirror to these rays. This upper layer consists of air at a fairly low pressure. When the pressure of air in a vacuum tube is diminished, its conductivity increases, and there is a certain pressure of air which makes the conductivity a maximum. As one goes up into the atmosphere, therefore, and as the pressure of air gradually falls, the conductivity of the air will gradually increase until, at a certain height (it is in the neighbourhood of 80 kilometres) the conductivity of the air reaches a maximum, and has a value approaching that of sea water. Such a layer of air will act as a reflector for electro-magnetic waves of long wavelength, and in dealing with the transmission of signals across the Atlantic, one can regard this upper layer as a mirror against which the waves will strike and be reflected downwards. The simple theory of the mirror can be worked out in just the same way as that of two parallel glass mirrors, but if one assumes a height of the layer of only 80 kilometres, it is not difficult to see that there may be a great many reflections from the surface of the layer and the surface of the sea, before a wave can traverse 3,000 miles across the Atlantic. Although this theory offers an explanation of the transmission it is not a complete explanation.

Dr. Eccles, some years ago now, in studying the passage of electro-magnetic waves through an ionised atmosphere, showed that if the wave travelled through a space in which the ionisation, or conductivity, varied, that the velocity of the waves in the more strongly ionised atmosphere was greater than it was when the atmosphere was weakly ionised. In considering fading, therefore, which is intimately bound up with the action of the Heaviside layer, we shall have to think about ionisation. The ionisation of the ordinary atmosphere is brought about through the agency of sunlight. When sunlight containing ultra violet light passes through air, it renders it conducting—in other words, it ionises it. When the light wave strikes the molecules some of them split into positive and negative ions and these ions will float about in free space, travelling sometimes over considerable orbits, in much the same way as a cloud of dust or fog in the atmosphere. If a positive ion strikes a negative ion it will combine with it to form an uncharged molecule, and if the ultra-violet light ceases, the ionisation will rapidly disappear and the positive and negative ions combine with each other and form a neutral atmosphere once more. The negative ions are more mobile as a rule than the positive ions. Although, perhaps, it is a little difficult to appreciate the exact mechanism of the transference of an electro-magnetic wave through an ionised space, one may gain some conception of it by imagining that when the electro-magnetic wave passes through the ionised atmosphere, the ions allow the electric force to operate more quickly and so permit the wave to travel with greater velocity. If one considers the nature of the ionisation of the atmosphere, this ionisation will be stronger in the upper regions than it is lower down, the ionisation, I have already explained, depends on the amount of ultra-violet light that there is in the atmosphere and the further one comes towards the surface of the earth, the less strongly ionised the atmosphere will be. It follows, therefore, that a ray starting out from a transmitter that is going into the upper regions of the atmosphere, will be bent round gradually, owing to the fact that the rays that are travelling along the upper regions of the atmosphere will go faster than those that are going along the surface, and if the ionisation of the atmosphere varies, the wave front may be bent so as to travel along an arc of the earth's surface instead of in a straight line. In long distance transmission it has been shown that the attenuation or dying away of the waves depends far more on the upper layers of the atmosphere than it does on the ground.

The strength of the reflected ray, except at night, will be relatively weak over short distances on account of the absorption of the rays by the ionised layer of air in the upper parts of the atmosphere. It is evident from the nature of the transmission that has been outlined above that there is likely to be great variation in the conditions of signalling and, therefore, that the strength of the signal that is received is likely to vary within wide limits. The upper atmosphere may possible be less liable to rapid variations in form than the lower atmosphere, as the upper atmosphere is farther from the irregularities on the earth's surface. At the same time, it is difficult to believe that the conditions in the upper atmosphere are quite constant. One has only to look at the sky on a windy day to realise how rapidly the conditions, even at a height of several miles, are varying. It is, therefore, extremely unlikely, that even at very high altitudes, the ionic conditions in the upper regions of the atmosphere will be so constant that the refractions and reflections which are necessary if signals of appreciable strength are to be received, will remain absolutely constant, and with these facts in one's mind, it is not at all difficult to explain the variations when American broadcast, for example, is being received. The remarkable thing about these receptions is that they are as constant as they have actually proved to be. Sometimes during the winter, American reception may remain almost as constant for an hour or two as reception from a broadcast station, say in Manchester, but on the other hand, it may vary within wide limits in a few minutes. One can imagine the swirling masses or clouds of ionised air which are responsible for these variations in signal strength. The most astonishing fact that has come out during the last two or three years has been the wonderful ranges that have been obtained with short waves. A number of tests made by Austin, the head of the Washington Radio Research Department, some years ago, led to the establishment of what is called the Austin-Cohen formula, by which the strength of the electric wave that was received at any distance from a transmitting station could be estimated. The strength of the electric wave is measured in terms of the electric field that is produced at the receiving station by the wave, in microvolts per metre on the receiving aerial. In the Austin-Cohen formula, a factor was introduced which takes account of absorption. This factor was of the form $\epsilon^{-\frac{\alpha d}{\sqrt{\lambda}}}$. The value of α has been determined by a great many experimenters. The figure for α that is usually taken is 0.002, d and λ being measured in kilometres, but it varies in different parts of the world. Now it will be seen in this formula that the greater the distance, the more the wave will be absorbed, that is, the larger becomes the value of the absorption factor. This, of course, is as one would expect, because the longer the path through the absorbing medium, the greater the amount of absorption will be, but the absorption is not simply proportional to the distance, it is proportional to the exponential ϵ raised to a power which depends on the distance, d, so that the absorption at a distance $2d$ will be more than twice as great as it would be at half the distance, the relative amount of absorption for the two distances depending on the value of the absorption factor. It is also evident that the absorption will be greater with shorter wavelengths, for example, if one has, say, to transmit over a distance of 1,000 kms. and $\lambda=4$ kms., the absorption factor will be proportional to $\epsilon^{-500\alpha} = \epsilon^{-1}$, if $\alpha = 0.002$, and it is evident from this formula that if you take a distance of 2,000 kms. and a wavelength of 16 kms. that you will get exactly the same amount of absorption. The formula, in other words, indicates that the longer the wave, the more suitable it is for long distance transmission. From this formula it would appear that to try and use short waves for long distances was hopeless: for example, if one were to reduce λ to, say, 10 metres, that is 0.01 of a kilometre, instead of using $\lambda = 4$ kms., the absorption factor would be increased to $\epsilon^{-10,000\alpha} = \epsilon^{-20}$ and the strength of the received wave $= 5/10^8$ of its unabsorbed value over a distance of 1,000 kms. instead of 1/2.7, which would be the value for the longer wavelength. To the surprise of everyone, it was found that when using wavelengths of 100 metres or less, it was possible to hear speech right across the Atlantic. I believe the first person who ever heard speech across the Atlantic was a man in Aberdeen, who heard a telephone message which was being broadcasted from some station in New York.

A good many people doubted the accuracy of his observation, but since then, during the winter months of 1924-25, a great many radio observers listened to broadcasts that came direct from America, and as you all know, the B.B.C. have actually transmitted from their broadcasting stations some of the music that has come right over the Atlantic on these short wavelengths. That was, of course, a very surprising result and indicated that the Austin-Cohen formula had very rigid limitations, in fact that it was only applicable with long wavelengths of the order of kilometres and upwards; but what is perhaps the most surprising result of all is the discovery which was primarily due to amateurs, who had been relegated to wavelengths from 100 metres downwards, that with wavelengths of only 10 to 30 metres, extraordinarily long ranges can be obtained.

It has been shown that it is possible to transmit messages all over the world on relatively small powers with short waves. These signals are, however, liable to very wide fluctuations in strength; "fading," in other words, is very marked. There has been very little information published as to the variations in signal strength between this country and America, with the short waves that are to be used in the beam system of transmission, but there seems no doubt that the range of variation is much wider than it is with longer waves. In American transmissions, it is not unusual to get variations in strength of the order of 20 : 1 on different days, and for shorter waves the range of variation is probably several hundred to one. One of the most interesting cases of fading is due to interference between the waves which are reflected from the Heaviside layer and those that travel direct over the surface of the ground.

In some experiments made last January (1925) by Appleton, the cause of fading was investigated in a very interesting way. The experiments were made at Cambridge, which is about 50 miles from London. It had been noticed on many occasions that the broadcast signals received from 2LO varied a good deal after sunset. These variations were not very large, about 5 per cent. or thereabout, but they were nearly always present. Now it may easily be seen that if these variations are due to a reflected ray from the Heaviside layer arriving at the receiving station at a sharp angle with the earth's surface, that the variations observed on a vertical wire will depend on the angle at which the waves come down.

There will be a combination of two waves, one coming direct, which can be called $E \sin \omega t$, and the other one coming in at an angle ϕ which will be given by $e \sin (\omega t - \theta) \cos \phi$.

The sum of these will give a resultant measured current in the aerial which will be the mean value of $[E \sin \omega t + e \sin (\omega t - \theta) \cos \phi]^2$. This gives $E^2 + 2Ee \cos \phi \cos \theta + e^2 \cos^2 \phi$.

Since e is very small compared with E the variations may be represented by $2Ee \cos \phi \cos \theta$.

If $\theta = 0$ or $n\pi$, the variations will be a maximum, but the actual variation will vary according to the difference in length of the two paths. The ray will be reflected from the earth on which it strikes and the variation in signal due to the reflected ray will be double that due to the incident ray. The variation in strength of the wave will, therefore, be $\pm 4Ee \cos \phi \cos \theta$.

Now, if the signals are observed, not by an aerial, but by a loop in the plane of the incoming wave, the magnetic field due to the direct ray may be represented by $H \sin \omega t$ and that due to the reflected ray by $h (\sin \omega t - \phi)$. The resultant effect on the loop will, therefore, be proportional to $H^2 + 2hH \cos \theta$ or allowing for reflection from the earth's surface, the actual variation will be $4hH \cos \theta$. If the two circuits connected to the loop and the aerial are so adjusted as to give the same strength of signal on a receiver containing a galvanometer, the variation in galvanometer deflection with the aerial and loop respectively may be used to determine the angle at which the reflected ray strikes the earth. The ratio between the variation with the loop and with the aerial was carefully observed; it varied within wide limits, but the greatest number of observations gave as the value of the ratio, Loop : Aerial=2.6. This gives a value of the angle between 60° and 70°.

Knowing the distance between the two stations a calculation can easily be made of the height at which reflection takes place and this comes to about 80 km., a height which agrees fairly closely with the value estimated by atmospheric conditions. Professor Appleton has gone a step further, and from the extent of the variations has made an approximate estimate of the reflection coefficient or the ratio of the strength of the reflected ray to the incident ray, and finds that it varies between 2 per cent. and 0.07 per cent. With a layer of this kind of varying nature, it is to be expected that there will be quite large variations in the reflecting power of the layer. The bending or refraction by the layer is brought about by the ionisation of the atmosphere, the more strongly the layer is ionised, the more the rays are refracted, the actual path of the ray through the lower ranges of the layer being curved; where the air is only slightly ionised the coefficient of refraction is relatively small; the higher up one goes the more strongly is the air ionised and the greater the coefficient of refraction becomes, until a point is reached where the ray travels parallel to the surface and is then gradually bent down once more.

These results were confirmed by some experiments that were made between Bournemouth and Oxford. The wavelength of the station at Bournemouth was varied continuously between limits of 385 and 392 metres. If one assumes there is a reflecting layer at a height of 80 kilometres, it may be shown that there will be four minima at a particular point due to interference. This was the extent of the variation that was actually observed. In another test the wavelength was changed from 385 to 395 metres, the average number of maxima and minima observed was 7, which again corresponds with the same height of layer.

It is interesting to note that subsidiary maxima and minima were noted on the galvanometer while these changes were going on, which appears to indicate that there may be multiple reflections, that is, that the ray between the transmitter and the receiver may be reflected, first from the Heaviside layer, then upwards from the ground, and then down again by the Heaviside layer. The number of fringes that would be produced by changing the frequency over a given range would be approximately twice as great as it would be with one reflection.

Quite recently, Mr. Hollingworth, who is working in connection with the Radio Research Board, has been able to trace out interference bands (due to the St. Assise station working on wavelengths of about 14,000 metres) in going from the South of England to the North. If one considers the signal received at any point A on the earth's surface, from a transmitting station T, it is easy to see that there will be a series of points A_1, A_2, A_3, at which the difference in path by way of the Heaviside layer to that going direct along the earth's surface will be a half wavelength, or an odd multiple of half wavelengths. It is easy to work out the distance between these points if one knows the height at which the reflecting layer is, or *vice versa*.

Mr. Hollingworth made a number of tests with a portable receiver with which he was able to measure the strength of signal received at different points. He made a motor tour from London to Aberdeen, making measurements at various points on the way, these measurements being taken in the summer when daylight conditions are steadier than they are in winter, and it was possible to obtain a record of maxima and minima. These results were published before the Wireless Section of the Institution of Electrical Engineers about six weeks ago. He found that at a distance of 400 kilometres there was a definite maximum in the signals from St. Assise, and at a distance of about 700 kilometres, that is, in the neighbourhood of Manchester, there was a definite minimum, and at Aberdeen the signals were about twice as strong as they were at Manchester. It is easy from these results to estimate the height at which the Heaviside layer should be, and it is estimated from these results to be about 70 kilometres.

Another observation which is of considerable interest is the variation after sunset. As a rule, signals will increase in strength immediately after sunset and then vary throughout the night within fairly wide limits. In some of the observation stations of the Radio Research Board, it was found that the signals immediately after sunset diminished appreciably in strength, then rose again until the night strength was very nearly equal to the day strength. One can easily explain these results by imagining that, as daylight passes, the height of the Heaviside layer is gradually raised. The state of ionisation of the atmosphere will clearly vary from day to night, the air being ionised at lower levels in the day time than it is at night, and observed results are quite consistent with this theory. In some experiments made in Liverpool many years ago, we found that the sunset effect was not by any means constant. On some days there was a very considerable increase in signal strength after sunset, on others, there was little or no variation, and it was noticed that the sunset effect was different in different places. All these effects are explained if the sunset effect is due to interference, and the variations observed *may* be due to the alteration in the height of the reflecting layer.

It is sometimes observed that very small variations in the length of the wave given out from a transmitting station produce large changes in the strength of signal at a given place (a phenomenon which has been used by Appleton in the experiments already described), for example, if any point corresponds with a dark patch for one wavelength it would not correspond with a dark patch for a slightly different wavelength, and when there is interference, there may be large variations in signal strength for relatively small variations in wavelength. This phenomen was noted many years ago with the transatlantic signals, it was found that towards sunset signals became very weak on one wavelength but much stronger on a slightly different wavelength, and after sunrise, the two wavelengths produced opposite results, that is, the wavelength that had given a weak signal now gave a strong signal and *vice versa*.

In a paper by the author before the Radio Society of New York, published in 1915, this question was dealt with at some length and theory of interference bands due to multiple reflections worked out.

Another effect that is produced by reflection from the Heaviside layer is that the polarisation of the wave may be altered. Those of you who are familiar with polarisation of light know that when plane polarised light is reflected from a magnetised surface the plane of polarisation may be rotated, and the same thing seems to occur with the light that is reflected from the Heaviside layer, with the result that the resultant beam that is observed on the earth's surface is elliptically polarised. Some most interesting results on this subject, that have been published recently, are included in a paper that was read by Captain Round and his colleagues before the Institution of Electrical Engineers last October. These investigators set out in the steamship *Dorset* and sailed to New Zealand and Australia *via* the Panama Canal, observing the variation in signal strength all the way. When they reached Australia, they made a number of observations outside Melbourne at a place called Kooweerup. When one is nearly on the other side of the world, the signals from a transmitting station may go round in either direction, and the direction in which one receives them depends on how much of the path along which they travel is in the dark or in the light. Signals travel most easily in the dark and, therefore, when the dark part of the earth's surface is between the transmitting station and the receiving station, the signals would go along it. Twelve hours later, when the part of the earth's surface which was dark has become light, the signals will come the other way round. For instance, in Australia these observers found that when the dark shadow over the earth lays between Melbourne and England, and included Africa and India, that signals from the Eiffel Tower appeared to come from the north-west; twelve hours later, when the dark shadow over the earth was on the opposite side of the hemisphere, they came from the south-east. At the time when the amount of darkness along both paths was the same, there was sometimes interference and large variation in signal strength due to the two signals coming opposite ways round the world not arriving in exactly the same phase. It is evident that if there are very slight variations in frequency of the emitted signals, there is liable to be a large fluctuation in the signal strength due to these interferences. As was recently mentioned in the description of the Rugby Station, the frequency at which the signals are sent out is maintained by a tuning fork and, therefore, variation in frequency of the emitted waves is likely to be negligible. This should prove most advantageous when listening to signals on the other side of the world.

The most remarkable changes in strength of signal occur at periods round about sunset and sunrise at the transmitting and receiving stations. In some of the figures given by Captain Round observed at Kooweerup, the signal increased from a very small amount, less than 10 microvolts per metre, up to as much as 140 microvolts per metre, at the time when there was sunrise at Melbourne and just after sunset at Carnarvon. In some of these observations, the signal strength decreased from 150 microvolts per metre down to 40 microvolts per metre in a period of less than twenty minutes, which will, of course, give a very big fading effect. From the point of view of broadcast reception, fading is a thing to be avoided, but, as I have said, it is quite beyond the power either of the transmitting station or the receiving station to get rid of it. I hope, therefore, that those of you who have been listening to American broadcasts, and to the broadcasts that have been relayed from various parts of Europe, will feel a little more sympathetic to the B.B.C. than perhaps you have been apt to do when the transmissions are very bad. It is a practical impossibility to obtain absolutely uniform transmission over very long distances, and nothing which either the transmitter or the receiver will do, can get rid of these variations.

DISCUSSION.

Admiral Sir Henry Jackson, F.R.S.: I have much pleasure in moving a vote of thanks to Professor Marchant for his very interesting lecture. He has described a very difficult subject in a manner clear and easy to understand, and he has dealt with it in a very short time. I think, as he says, these effects are recognised by practically all authorities as being chiefly due to deflection by the upper layer of the atmosphere. He mentioned my name as one who had delivered a lecture on some fading effects due to intervening land. It was a long time ago, and I had forgotten the paper, but I believe it has stood the test of time. I see that in America some experiments have recently been made which showed that the effect of intervening land on broadcasting results was very marked indeed. Professor Marchant has not touched on the short wave fading, so noticeable when receiving these from long distances. This may be attributed to the same cause, but the mechanism by which it is effected at great heights is a little difficult to understand. I have been doing work during the last few months observing three stations with similar wavelengths, power and operators. The results were certainly interesting as showing the effect of distance on fading effects of short waves. No doubt the fading does get worse as the distances increase; though I get it both in daylight and dark, at 70 miles, 1,200 miles and up to 6,000 miles. In the programme I have been listening to, the three stations follow one another very regularly according to a fixed programme, and very often I have noticed that when one station 5,000 miles away is clear the other two stations fade, but in other cases it is not so. Half an hour before I came here I was listening to two stations of exactly the same wavelength and power. One, a fixed station, 1,200 miles away, showed no fading whatever. When it was finished I listened to the other station which was a ship about the same distance and power, and the fading was very bad indeed. The speed of words per minute was about the same. The fixed station was not fading, every dot was as clear as possible; but from the ship station about two-thirds of the dots were not audible at all, and the others were very faint. This fading of dots is rather difficult to account for; is it due to the fact that it takes an appreciable time for the power to get through? It looks like that, and I wonder if the commercial stations using these short waves find that difficulty, that their dots are missed and their automatic receiving tapes spoiled by it. It would be very interesting to know. Another effect is that the stations make long dashes to finish up signals. I have heard those long dashes with an audible note rising and falling in different pitch and strength. At other times the fading has a long period of perhaps a minute, with another period of five or ten seconds superposed on it. It would be very interesting to see how the mechanism of this upper layer can be worked out to meet these peculiar cases. We are very much indebted to Professor Marchant for bringing this subject clearly before us. (Applause.)

Dr. W. H. Eccles, F.R.S.: The subject that Professor Marchant has been treating is an enormous one. The accumulated information and the number of observations are so massive that we are very grateful to anyone who will, as Professor Marchant has done, try and trace some path through the subject that will enable us to understand it better. I think the burden of Professor Marchant's address is that most or all fading is due to the Heaviside layer. I think it would be helpful if I were to point out that there are other possible causes. For instance, we all know that the waves are bent round the world by at least three agencies. There is diffraction, which means bending of waves round a corner. Then there is, in the case of electric waves in the air, the effect of diminution of density upwards. Therefore the specific inductive capacity decreases and the velocity of the waves increases with height, with the result that the wave front tilts forward as it goes over the face of the earth. There is, besides, the influence of water vapour which has been shown to have a considerable effect when distances of hundreds of miles are concerned. It seems to me possible that a great deal of fading is due to the action of water vapour or of alterations of air density at fairly low levels. An explanation of fading on that ground would resemble the explanation of the quivering of objects seen by rays of light passing over the top of a chimney where a fire is burning. These rays of light have to pass through air whose refractive index is slightly different from that of the air around it. Moreover that air is quivering, and the consequence is that objects seen through such a patch of hot air seem to be shaking. A good deal of the ordinary fading such as bothers the broadcasting listener may be due to the operation of similar causes. As regards the effect of water vapour, I think there is no doubt that the presence of clouds, or the occurrence of a thunderstorm that removes water vapour by making the rain fall, have their effects on signals; and I know quite well, by my own observations in the tropics, that the presence of cyclones or hurricanes between the transmitting station and the receiving station has great effect on signals. It is not likely that a cyclone will extend to a greater height in the atmosphere than, say, eight miles, and therefore it does seem that the lower atmosphere can produce very great changes of signal strength by these variations. I might just mention that it is well known to meteorologists that the atmosphere is rather wobbly, if I may use the expression, at a height of about ten miles, because pilot balloons—the very light balloons which the meteorologists send up in order to observe the upper atmosphere and measure the wind currents there—these balloons at a height of about ten miles, move up and down through some hundreds of yards once every two or three minutes as they travel. That suggests that fading may be due sometimes to actual bodily movement of the layers that are below ten miles in height. When the ionised parts of the atmosphere come into the phenomenon, a third element enters to cause fading, namely, the variability of the amount of ionisation. That is the matter on which Professor Appleton has done such very valuable work, and on which Mr. Hollingworth has made the wonderful deductions described by Professor Marchant. While I was looking at the diagrams from Professor Appleton's paper, thrown on the screen by Professor Marchant, it occurred to me again that perhaps we were taking the Heaviside layer as being too localised. We ought, perhaps, to think of it as more gradual than we do, and instead of drawing, as you see on the board now, a triangle, perhaps we ought to draw a parabolic arch. You could start at the same angle upwards, make a parabolic arch of the same span and descending at the same angle on the other side, without the apex of the arch being as high as the apex of the triangle. If there is much bending in the lower parts of the atmosphere, then the apex is really lower than ninety kilometres; and for a longer wave would be still lower than the height calculated by Mr. Hollingworth. As to all the other points that Professor Marchant has discussed I am in accord with his conclusions, and it would be merely a repetition if I were to say anything about them. I agree very cordially with practically all his views. (Applause.)

Mr. P. R. Coursey, B.Sc.: Mr. Chairman and gentlemen, I am sure we are all very grateful to Professor Marchant for the interesting matter he has brought before us to-night. The many measurements that have been made, amongst those to which he has referred which bear upon the apparent height of this ionised layer, are certainly very interesting, as giving a more or less generally consistent figure between them. In reference to what Dr. Eccles said just now, the figures which have been obtained from different sources, all point to an apparent height of much around about the same figure; and it would appear that the bending to which Dr. Eccles has just referred, would simply reduce the height calculated by an amount which while not constant is nearly so, depending somewhat on the wavelength.

There is perhaps just one point in which Professor Marchant's paper is lacking, if I may be permitted to say so, and that is with regard to the methods by which these observations have been carried out. The only contribution in an experimental way which I have made to the subject, was made several years ago with an Einthoven string galvanometer of the type to which Professor Marchant made reference. That apparatus provides a nice way to carry out readings of this type, but is far too expensive an instrument for most of us; and a simple way of carrying out these measurements would be very desirable if it could be produced—provided the apparatus involved was fairly simple and, what is more important, subject to reasonable calibration and constancy of operation. The use of a valve amplifier and detector with the addition of some means of calibrating the equipment each time a measurement is made, would seem to be the obvious method if properly set up and provided some means of definitely calibrating each time it is used. If Professor Marchant can suggest anything further of this type I am sure it will be a useful addition to the very excellent paper he has already given.

The fading effects due to the reception of two waves, one coming direct from the transmitter and one refracted in the higher levels, seem to be connected very intimately with the distortion of telephonic reception which occurs when receiving at night speech over distances since the telephone modulation itself will introduce variations of frequency at the transmitter. It seems very possible that the same effect may be the basis of the missing of dots to which Admiral Jackson referred just now. Many transmitters, if they are operating with a simple valve oscillator, particularly on short waves, frequently show small changes of wavelength at the moment of switching off and on, and with a dot signal those frequency changes must be a more important proportion of the whole length of the signal than they are when a dash is being transmitted. If then there is any fading effect caused by variations of frequency causing interference of valves at the receiver, it would be possible that those effects would be more important with a short signal like a dot than with a long one. I do not know whether that is what actually happens but it occurs to me that that is the possible cause of the observed effect. The considerable fading noticed with a great many short wave stations is possibly also due to variations of wavelength of similar nature during transmission. Since the majority of these stations are not very rigidly controlled in frequency, and any variations of frequency on short wavelengths must be much more important than with long wavelengths, and if there is any difference in the length of the two paths traversed by the waves, a small change of wavelength must have a very much greater effect as far as interference is concerned. In conclusion, I would repeat that I am sure we are very grateful to Professor Marchant for all the interesting material he has brought before us to-night. (Applause.)

Mr. E. C. Atkinson, M.A.: At least one regular observer of transatlantic messages appears to attribute the variation in signal strength of messages coming across water to variations in barometric conditions over the Atlantic, and he seems to be satisfied that if there is a regular pressure gradient between the receiving station and the transmitting station, the signals are likely to be strong; whereas they are likely to be weak if the barometric pressure is erratic between the two stations. It seems at first sight quite likely that what you may call a ripply atmosphere between the two stations would be a condition for bad reception; but if you are to attribute the reception over long distances to one or, as Professor Marchant points out, possibly more than one reflection from the Heaviside layer, you seem really concerned with the smoothness of the reflecting surface at one or at most two points, and consequently you would expect to have good reception with a steady barometer in one or two places, and be entirely independent of those local depressions which we read about in the papers —generally approaching the British Islands. (Laughter.) I should like to ask Professor Marchant what his views are as to the possible connection between barometric conditions and the periods of good and bad reception of long distance wireless signals.

Mr. H. Bevan Swift, A.M.I.E.E.: Mr. Chairman, I am afraid my remarks will be more from the practical side, because I have not made any theoretical investigation of the subject. Professor Marchant opened his lecture by saying that he could not get Cardiff at Liverpool. Cardiff I think is also the most difficult of the broadcasting stations for us Londoners to get. Some friends of mine at Aberystwyth cannot get Cardiff at all but get London perfectly. I suppose it is the local conditions there which make it so difficult to receive elsewhere. The fading we get seems to be of two kinds, total obscurity and periodic fading. In the case of a house on the Penistone Hills in Yorkshire recently we were listening to London broadcasting at full loud-speaker strength. Seven minutes afterwards it was totally gone. A few minutes afterwards it came up to full loud-speaker strength again. To practical listeners that periodical fading is most troublesome of all. With total obscurity you do not expect anything, but you like continuity if you are listening to a programme at a distance. On a superheterodyne set you do not appear to notice the fading to the same extent; that is possibly due to some peculiar circumstance of the set itself. Distance does not seem to make the great difference in strength to the stations. When listening on the 45-metre band, fading is extremely irritating. On certain nights you cannot get stations, on other nights those stations are quite good; and it is a mysterious thing that if you ever try to carry out a schedule of transmission with anybody, that night invariably he cannot be heard, which is a most awkward circumstance. I was very much interested in a remark by Professor Marchant upon the Heaviside layer not being concentric with the surface of the earth, that is to say that during the night presumably the gap between it and the earth is different from that in the daytime. I would like to know if Professor Marchant can tell us if this is due to the effect of the sun upon the ionisation of the atmosphere which actually lifts the Heaviside layer away. At sunset those peculiar observations, that we have observed on the screen to-night, are very erratic. This might be due to the peculiar cooling of the ionisation of the air with a definite lag of phase, if we might put it that way, due to the rays of the sun going off. I do not know whether there is anything in that idea; perhaps Professor Marchant can tell us. I would like to congratulate him upon his excellent paper. (Applause.)

Mr. C. W. Goyder : May I ask Professor Marchant a question with regard to the way in which waves travel to distant stations. Would not you consider that at 3,000 miles the direct wave would be entirely absent, especially on the short wavelengths of about 45 metres? If you had only a reflected ray arriving at the station 3,000 or 6,000 miles away, surely there would be a great number of paths by which it could arrive; so that the integration of all those paths ought to allow a fairly good signal to be received at the distant end. I do not see why the rays should take just one path; they might take hundreds which would be slightly different in the length and so the average result would be fairly constant. What has surprised me is that although distant amateur signals, and New Zealand signals from 12,000 miles, are quite constant in strength, with KDKA on 63 metres the fading is extremely violent and also the commercial station on 44 metres. I cannot see why fading should be bad at a distance of 3,000 miles when the direct ray is absent. Another thing is that with 45 metres, even at a distance of five miles from the transmitter, fading is very bad at times. Surely the waves could not be reflected down at such a critical angle from the Heaviside layer as to arrive at the earth at a distance of five miles. But at a greater distance than five miles, say 35 miles, on the 45-metre band you do not hear anything at all, practically speaking. It is the well-known skip distance. Further on, at 300 miles, the signals become normal again. I cannot quite see why that should be so. If fading occurs at five miles I do not see why it should not occur right through and beyond the skip distance. With regard to the constancy of frequency and its effect on fading, I think if you use crystal control you can rely on the frequency being constant, and as far as I can find from experiments the distortion of speech is entirely absent when you are using crystal control; as Mr. Coursey mentioned to-night frequency variation would vary the quality of the speech; ever since I have tried the experiment of using crystal control I have never had a report of speech distortion. But the fading has not been affected; it is as bad as ever it was, and does not seem to be affected by frequency. With regard to the barometer, or any weather effect on the signals, for two weeks at a time I have noticed that a five kilowatt station on 45 metres has not been audible at all. No signals at all. Yet one night it goes up to its normal strength, R8, in the ordinary code, without any change in the weather. Another day it dies away to inaudibility. Surely these changes are too rapid to be accounted for by the weather. I wonder if there is any simple explanation of this! (Applause.)

Mr. G. P. Nicholson : One possible experiment occurred to me while Professor Marchant was speaking about the Heaviside layer—if it is as sharp as the picture on the board indicates. A short wireless wave transmitted from a Hertz dipole is plane polarised. That is the vibrations of the electric field are in one plane only, and those of the magnetic field in another plane at right angles to the first. Now it is known that if light is incident upon a reflecting surface at a certain angle it will be largely reflected if polarised in one plane, but mostly transmitted if polarised in the plane at right angles. I should like to know whether any experiment has been made which bears on this point. It appears that rays from a vertical dipole are actually reflected from the Heaviside layer. It might occur that rays from a horizontal dipole using a parabolic reflector with its axis horizontal might not be so reflected, if they were directed so as to strike the layer at the correct angle. I should like to know whether Professor Marchant knows of any such experiment.

Brig.-General Sir H. C. L. Holden, K.C.B., F.R.S. (*Chairman*) : If no one else wishes to speak I would like to make a remark or so myself. I am afraid I cannot add very much to the discussion, and I feel rather diffident about speaking at all, because I feel that if I ask the few questions that I want to, I shall be more or less overwhelming the lecturer, because he has already a number of points to answer. The first thing I should like to ask is whether any information has been obtained from the experiments that have been made by, I think, one or two Polar expeditions that have been made during the last eighteen months or two years. The reason I ask is because I have seen in the papers some remarks on the difficulty of obtaining signals in the Polar regions. Whether there is anything in it or not I do not know. Another point that strikes me is this, the ionised air, the Heaviside layer; according to the diagrams that have been shown to us on this and other occasions, the ionised layer seems to be able to move—I am speaking from diagrams—some fifty or sixty miles vertically in an exceedingly short period of time. What I should like to know, if Professor Marchant can tell us, is the nature of the movement, and whether it has been calculated in any way what sort of movement in height is necessary in order to produce the results that have been obtained. I think here I should congratulate Professor Marchant very strongly on the data that he has collected and brought forward this evening, because one feels that there has been in the past a great deal of scepticism on the Heaviside layer theory; and one has felt all along that what was wanted to prove its being right or wrong was practical data. Those practical data seem to be coming forward almost daily. There is just one point I am a little bit doubtful about; it was a minor matter, but he mentioned that he thought that the strength of the signals from Paris, from the Eiffel Tower, was because rain had washed the air and insulation improved. Paris is better than London it is true, but I do not think any shower of rain, unless accompanied by hot soda water and soap, and possibly a scrubbing brush, would do anything to clean insulators. When taking them down, and finding the difficulty of removing the layer of soot and sulphuric acid, I sometimes wonder how they insulate at all. I would like information on that point if there is time. One other question I can give corroborative evidence upon. Cardiff has been mentioned as a difficult station to hear. I have had a certain amount of experience of a station close to Cardiff, about 18 miles away. The aerial is very high; I think from the top of the mast you ought to be able to see Cardiff. However, the reception is very poor, compared with what it is from Bournemouth, which is five times the distance away. Another curious thing about it is that Aberdeen is, I may say, very easy to get and very clear. The signals are very strong, but Birmingham, which is in the direct line between the place that I mentioned and Aberdeen, is practically impossible to get at any strength that is worth hearing. So that there is something curious about Cardiff and possibly Birmingham that wants explanation, I think there is no doubt. Now it is my pleasant duty to call upon Professor Marchant to reply to the various points that have been raised by members of the audience. (Applause.)

Professor E. W. Marchant, replying to the discussion, said: I must first of all thank all the speakers for the very kind way in which they have received this lecture. It does not describe any original observations, but is an attempt to summarise and collect information that has recently been published.

Sir Henry Jackson mentioned the differences in short wave fading he had observed over long distances. It is most interesting to find that the differences are so great.

In some tests that were described by Mr. Franklin in connection with his experiments on short waves near Holyhead, the waves were strongly absorbed when the station was on the sea level; but when the transmitter was carried some 300-400 feet up a hill, the absorption rapidly decreased. It seems to me that there may be great differences in absorption due to conditions in the neighbourhood of the transmitter, and it is possible that varying local conditions may be the explanation of some of the variations that have been observed with different short-wave stations. With regard to the fading of dots, Mr. Coursey has given a very likely explanation. All who have had experience with valve oscillators have noticed the change in frequency that occurs when the valve filament is first switched on, and if there is a variation of this kind at the beginning of a dot, it may possibly be the explanation of the "fading" of the dot at the receiver.

With regard to what Dr. Eccles said as to atmospheric conditions, I wish he had given us rather more information about the effects he has observed due to clouds. There must be slight changes in the velocity of wave transmission due to variations in density, because the velocity of light is different in air of different densities. There may be effects due to changes in velocity at quite low levels but the effect is very small, since the difference between the velocity in a vacuum and in air at atmospheric pressure is only 0.03 per cent.

With regard to the effect of thunderstorms and cyclones, I may perhaps be permitted to refer to some observations recorded by General Ferrié at the Eiffel Tower last January. On a particular day in January, there was an enormous increase in strength of signals at a time when there had been heavy electric storms. We have all observed these remarkable increases in signal strength on certain days. Last Sunday, one of my friends told me, was a remarkable day for listening to European Broadcasting Stations.

As regards reflection from the Heaviside layer, the actual angle at which the waves were reflected in Appleton's experiments was of the order of 60 or 70 degrees. He estimated the reflection coefficient for that angle of incidents as of the order of 2 per cent. Therefore, of course, the variation at these distances is relatively small. Mr. Coursey referred to methods of observation. I purposely left out any reference to methods of observation, because there was not room for it in this lecture. The method of observation with a galvanometer is, I think, more reliable than observation with telephones; the method we now use for weak signals is quite satisfactory within certain limits of accuracy; it is that suggested by Round and Lunnon.

A local signal is produced by a valve oscillator, the high frequency current is measured by a thermopile, and the local signal is matched against the incoming signal by using a variable coupling.

Austin shunted his telephone with a resistance and varied the resistances until the signal just disappeared. I have never been able to get accurate results by this method. I think it depends very largely on the personal qualtiies of the observer, some people can get much better results with it than others. The matching method has proved much more reliable. He refers to fading due to variations in wavelength: this is probably due to interference; the strength of signals due to interfering waves may vary within wide limits for small changes in wavelength.

Mr. Atkinson referred to the effect of barometric pressure. I think that unequal distribution of barometric pressure across the Atlantic might be expected to produce bad conditions for signalling. The same thing is true of the variations observed during summer and winter. In summer the atmospheric conditions are usually steadier than in winter, and recently published results have shown less variation in signal strength in summer than in winter. The barometric pressure is rather more uniform in summer, hence it may be expected that, on the whole (apart from atmospherics), signalling conditions will be more uniform. I do not think, however, that any very definite relation has been established between barometric pressure and signal strength.

Mr. Bevan Swift referred to Cardiff. I was very much interested to hear that it is difficult to listen to Cardiff at Aberystwyth. I think there must be abnormal absorption in some directions due to the ground at Cardiff. If the cliffs and ground contain a great deal of mineral matter, one would expect local absorption. I am told that to the north of the Cardiff Station there is a rather high hill. One would expect that hill to prevent the waves going out strongly northwards. I have been told by an observer on the Wirral peninsula, that Cardiff comes through much better on a loop than on an aerial, though I have never proved that myself. There is, of course, some difference between aerial and loop reception, though, as a general rule, as Appleton showed, variations are greater with loop reception. Were they using loop reception on the super-heterodyne ?

A Member : Yes.

Professor Marchant : That is the only apparent reason why there should be any difference between the two cases.

Professor Appleton's results showed that variations with loop reception were greater than with a vertical aerial. It is interesting to know that in this case, loop reception is more constant. As regards the effect of the sun on the Heaviside layer, it is difficult to determine with precision the variation in the effective height of the Heaviside layer. If one takes Mr. Hollingworth's results, one can make an estimate of the increase in height from the diminution in strength after sunset. That is the difference in height necessary to produce minimum instead of maximum signal strength. If one takes the curves given in his paper, at a distance of 400 kilometres, there is maximum signal strength with a height of about 72 kilometres, and minimum signal strength at about 82 kilometres, the difference between these two should represent roughly the difference in effective height of the Heaviside layer, before and after sunset at Slough. I do not think the variation in effective height of the Heaviside layer can exceed 10 or 15 kilometres.

With regard to the statement by Mr. Goyder about signals that were inaudible at a distance of five miles, and become audible again at three hundred miles, I should have expected the explanation to be local conditions. If there happened to be a hill, some houses, or even large buildings, which might act as reflectors, it is conceivable that at a relatively short distance there might be interference between a direct ray and a reflected ray. I do not think the Heaviside layer would explain the phenomenon. The Heaviside layer might produce a certain amount of variation, but the angle of incidence for such a short distance is so near to the normal that the reflection coefficient is very low—it is of the order of 2 per cent. at angles of sixty or seventy degrees, and would be less at nearly normal incidence. With regard to the fading from KDKA, being very marked, and that due to New Zealand being less marked, that result, I think, is what one might anticipate. With a station at the Antipodes the waves go over the same length of path whichever way they travel, and therefore variations in signal strength, due to interference between waves in different directions, should not be very marked ; whereas, assuming variations are due to interference between waves going in different directions across the world, a station like KDKA will show more marked fading. I do not think, as a matter of fact, the fading with a station like KDKA is due to interference. As Mr. Goyder suggests the direct ray at this distance must be very weak. It is more likely to be due to variations in the shape of the Heaviside layer, and in the angle at which the waves are reflected. The Heaviside layer must have an irregular surface, and the amazing thing is that reflection and refraction from it are as regular as they actually are.

Mr. Nicholson referred to polarisatfon. I think there is no doubt that a plane polarised beam reflected from the Heaviside layer has its plane of polarisation rotated ; Appleton has showed that. A loop aerial may be used to determine the plane of polarisation of an incoming wave, and it is found that the wave that is received as the result of the combination of a direct beam and a reflected beam is not a plane polarised wave. It is elliptically polarised.

General Holden was asking whether there is any information about the Polar regions. Captain Round's paper made some reference to it. He found that when the path between the transmitting and the receiving station was across the Polar region the signals diminished very markedly, so that it would appear as if the Polar regions, for some reason we do not at present understand, absorbs waves more than other regions of the earth. I have already mentioned the possible motion of the Heaviside layer that one would estimate in explaining the sunset effect. Of course it is not actually a motion of the Heaviside layer. What happens is that the air or gas at these altitudes becomes less ionised as the sun disappears. The ions recombine, and therefore the effective height of the layer is raised. There is no actual motion of air, but the conditions in the upper atmosphere vary. I was very interested to hear what he said about insulators. That the rain thoroughly cleans insulators, I think is very unlikely ; the increase in signal strength after rain is much more likely to be due to the " clearing " of the atmosphere.

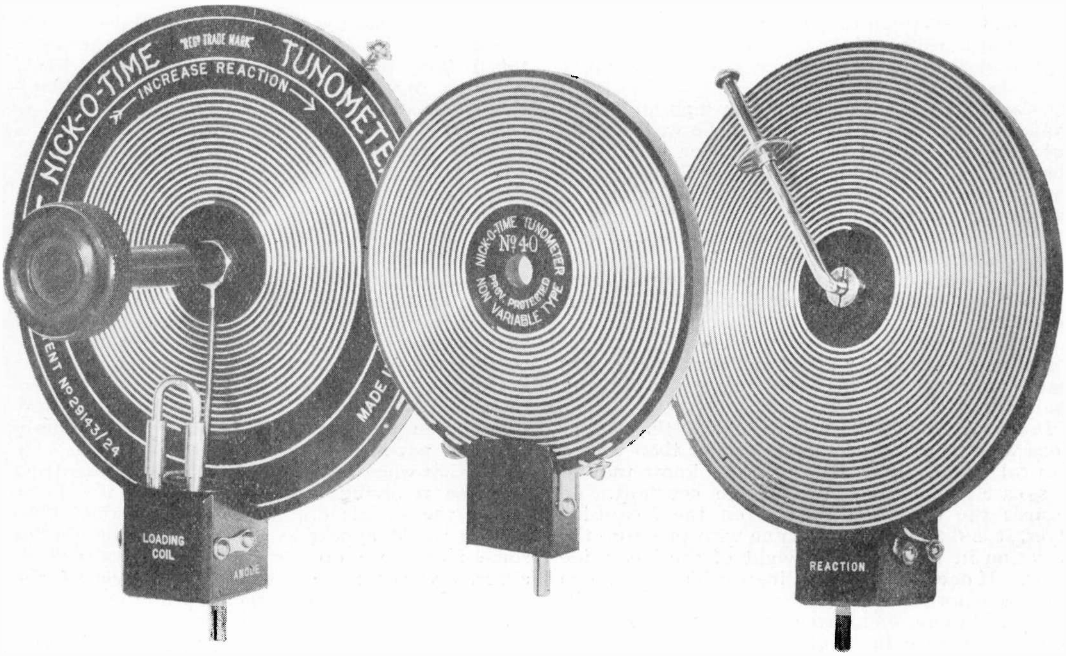
Birmingham, like Cardiff, is in a coal district. I do not know what the exact geological formation in the neighbourhood of Birmingham is, but if there is a large amount of iron ore and good conducting material in the ground, one would expect to notice a good deal of absorption.

I must thank you once more for the very kind way in which you have received what I have had to say. (Applause.)

Nick-o-Time Tunometer Coils. [R382.009

A SERIES of these coils—the aerial inductance tuner, the reaction tuner, the aerial series vernier, and two other coils wound in the same fashion, but without any tuning arrangements—have just been tested by us for inductance, self-capacity and H.F. resistance.

The construction is unusual and beautifully carried out, and consists of tinned copper wire



wound in spiral grooves cut in both faces of an ebonite disc. In the first three coils tuning is effected by a rotating arm carrying a small grooved wheel which runs on the wire, and as the arm is rotated the number of turns of the coil in circuit is altered. The arm and wheel are held in good contact with the wire by means of a fairly strong spiral spring concealed in the long bearing for the arm.

Provision is made for adding loading coils to both tuners, the plugs and sockets being short-circuited by link pieces when no loading is required. The makers state that it is intended to substitute for the tinned copper, nickel plated wire, which, although it will keep clean and give a better contact with the wheel, is likely to have a slightly greater H.F. resistance than the tinned wire, so that the overall gain is not likely to be much, if any at all.

The test results are as follows :—

The reaction tuner and aerial tuner were almost identical in size and constants, the maximum inductance being 116μH and the minimum 28μH; self-capacity 6$\mu\mu$F. H.F. resistance at 750 kilocycles (400m.) 4 and 4.4 ohms respectively.

The two plain coils had inductances of 116μH, and 88μH; self-capacities of 19$\mu\mu$F and 10$\mu\mu$F, and resistances at 750 kilocycles of 3.8 and 2.8 ohms respectively.

The aerial series vernier has a maximum inductance of 36μH.

These figures compare quite well with other well-known makes of coils, but an objection which might perhaps be raised to the tunometer coils is their large size, giving a large stray field and thus necessitating good spacing in any set in which they are used.

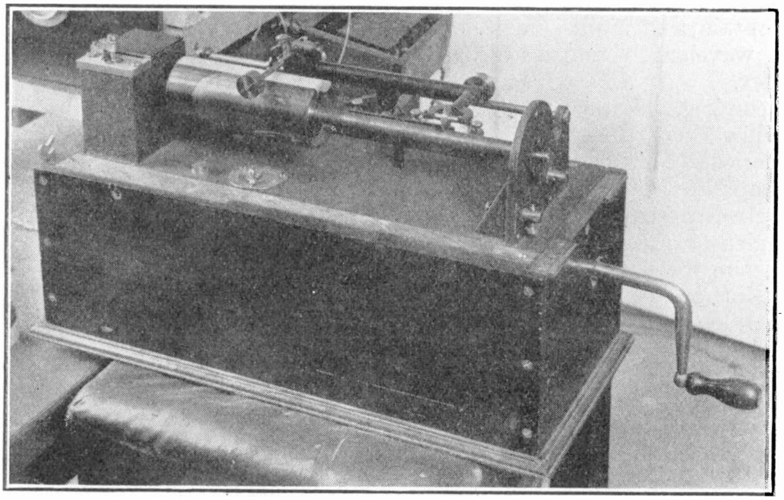
A. P. C.

Wireless Phototelegraphy. [R582

MUCH interest has been centred during the past few weeks on the development of practical simple methods for the wireless transmission of pictures. The first article on this subject, particularly with regard to the transmitting of pictures from the broadcasting stations, appeared in a recent issue of *The Wireless World.** Since the publication of that article tests have been conducted from the London broadcasting station, and it is understood that the results obtained have been satisfactory and tolerably good pictures recorded, making use of the Thorne Baker apparatus both for transmission and reception.

In this system the picture is re-photographed on to copper foil so that the surface of the copper is left clean for those parts of the picture representing shadow, whilst the high lights are marked by a deposit of a non-conducting film. The copper plate is attached to the face of a cylinder, which is traversed by a needle in the same way as the needle of a phonograph recorder passes over the surface of a cylindrical record while the cylinder revolves at a speed of 30 revolutions a minute. An intermittent contact is thus made with the surface of the copper, the circuit being broken for the high lights and made at those portions representing deep shadow.

The fluctuating potentials thus obtained are caused to break up the continuous waves at the transmitting station into a series of wave trains of varying duration. At the receiving station the C.W. signals are detected and amplified and applied between a platinum point and a cylinder wrapped with a chemically treated paper, the cylinder being exactly synchronised with corresponding cylinder at the transmitter. The paper on which the image is recorded is moistened with a mixture of potassium iodide and starch solution and a current of one milliampere applied to the paper for even a brief interval of time is sufficient to produce a deep blue coloration.



In the Thorne Baker picture transmitting apparatus a copper plate bearing the image is traversed by a metal needle forming part of an electrical circuit. The receiving and transmitting equipments are exactly similar, and the cylinder on which the picture is recorded by an electrolytic process is kept in synchronisation with the transmitter by means of accurately-timed pendulums.

A simple method of synchronisation is employed in the Thorne Baker system, and makes use of accurately adjusted pendulums at the transmitting and receiving stations. The pendulums are accurately timed to make one swing a second or one complete oscillation in two seconds, and by means of spring contacts circuits are broken at regular two second intervals so as to control an electro-magnetic action arranged to release the rotating cylinder with a constant time period between each revolution. The mechanism comprises an electro-magnet and armature which engages on the revolving cylinder at each revolution, holding it stationary until two seconds have elapsed from the time of its commencement. The driving clockwork is adjusted so that the cylinder revolves in just under two seconds, and by this means the cylinders of the synchronised transmitting and receiving stations commence each revolution in unison.

For any system of picture reception to be used as an auxiliary to broadcast reception, it is essential that only minor modifications shall be necessary to change over to the picture-recording equipment, the tuning and amplifying apparatus being used without modification. It is obvious, therefore, that unless the receiver is to be used in a state of oscillation or a separate heterodyne is employed, that the continuous wave trains cannot be amplified by the low frequency equipment of the broadcast set.

For this reason the development which has recently taken place consists of interrupting the note emitted from an audio-frequency oscillator set up either in front of the microphone of the broadcasting station or applied into the circuits of the intermediate amplifiers. Thus at the receiving station an interrupted note is picked up. To bring about the electrolytic action required for recording the picture, a uni-directional current is required and can be produced either by negatively biassing the last low frequency valve to operate at the lower bend of its grid volts anode current characteristic, or by making use of a valve rectifier with leaky grid condenser. The experimental transmissions which have been so far carried out will encourage the development of picture transmission in association with broadcasting.

* 24th March, 1926, p. 437.

The Straight-Line Relationship.

Comparison between Semi-Circular and Square-Law Vanes.

By Oliver Hall, D.Sc. **[R381.4.01**

IN this country there are at the present time two well-known types of variable condenser. The difference between these two types lies in the shape of the moving vanes, the older of the two types having semi-circular vanes and the more recent type vanes of a so-called "square law" pattern. As is within the knowledge of most wireless experimenters, the more recent type with its peculiarly shaped vanes represents an attempt to obtain a straight-line relationship between wavelength and dial setting of the condenser.

A third type of variable condenser, known as a "straight-line frequency" condenser, is now being used in America. This condenser represents an attempt to obtain a straight-line relationship between frequency and dial setting of the condenser.

So great has been the desire for variable condensers with a straight-line relationship of some kind or other, that, on both sides of the Atlantic, the old familiar variable condenser with the semi-circular moving vanes has been referred to by many writers as a "straight-line capacity" condenser.

What is there in this idea of "straight-line relationship," and what is the use of it when it has been attained?

Briefly stated, a straight-line relationship between two varying quantities means that, over a particular range of values, an increase in one of those varying quantities indicates a proportionate increase or decrease in the other varying quantity. As with most mathematical ideas, the thing becomes clearer in the light of actual examples.

Let us consider then the diagram shown in Fig. 1. This diagram shows the relationship obtained between wavelength and dial reading for a well-known type of square-law variable condenser. The observations on which the diagram is based were made one evening recently with a one-valve receiver.

First of all, let us confine our attention to the upper portion of the diagram. If a ruler is applied to this portion of the diagram, it will be found that a straight line can be drawn with a good degree of accuracy through the points for 2BD, 5IT, 2BE, and 5SC. That is to say, a straight-line relationship holds between wavelength and dial reading for the upper portion of the diagram.

In what way does this straight-line relationship help us? The most important way in which it helps us is this: It indicates that, over that part of the condenser dial, the wavelengths are evenly distributed, each scale division of the dial representing the same amount of wavelength. We can easily calculate this amount. The wavelength for 5SC is 422 metres and the dial reading 50. The wavelength for 2BD is 495 metres and the

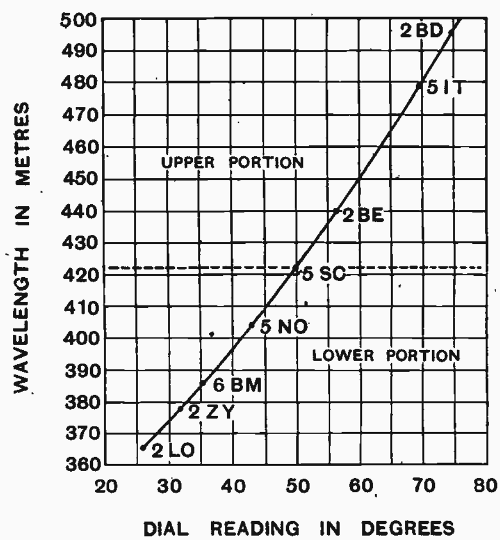


Fig. 1.

dial reading 75. Subtracting 422 from 495 we get 73. Subtracting 50 from 75 we get 25. Dividing 73 by 25 we get 2.92 which gives us the wavelength value of *each* scale division from 50 to 75 on the condenser dial.

Let us now consider the lower portion of the diagram in Fig. 1. There are four points in this portion of the diagram. Let us consider these four points along with the point for 5SC. If we apply a ruler to this lower portion of the diagram, it is at once evident that we cannot draw a straight line through the five points. Hence we may conclude that, for that portion of the condenser dial from 25 to 50, a straight line relationship between wavelength and dial reading does not exist.

Considering the diagram as a whole, it is even more evident that a straight-line relationship between wavelength and dial reading does not exist for the whole condenser dial. Indeed, the straight line drawn in the upper portion of the diagram, when continued in the lower portion, misses the points for 6BM, 2ZY and 2LO completely.

The manufacturer of the particular variable condenser used in taking the observations from which Fig. 1 was drawn, has therefore failed in his attempt to design a condenser giving a straight-line relationship between wavelength and dial reading over the whole range of movement of the condenser. The result obtained in that figure is the rule rather than the exception for the modern "square-law" variable condenser.

How is it that the hunt for this straight-line relationship in variable condensers almost invariably ends in failure? To answer this interesting question we shall have to obtain an understanding as to the part capacity plays in the determination of the frequency or wavelength of a circuit containing that capacity.

Let us start then with the well-known formula

$$\text{Wavelength} = 1{,}885\sqrt{\text{Inductance} \times \text{Capacity}}.$$

Let us assume that the inductance is a pure inductance and that the capacity is made up of two parts, F and C, F being the total *fixed* capacity in the circuit and C the variable capacity determined solely by the variable condenser. Further, let us include in the term F all the stray capacities in the circuit *and the minimum capacity of the variable condenser*. We may then write our formula in this way

$$\lambda = 1{,}885\sqrt{L(F+C)} \quad \ldots \quad \ldots \quad (1)$$

where λ = wavelength in metres,

L = inductance in microhenries,

and F and C are measured in microfarads.

Since F includes all the fixed capacities, the stray capacities and the minimum capacity of the variable condenser, if we denote by W the *minimum* wavelength of the circuit, we can write

$$W = 1{,}885\sqrt{LF} \quad \ldots \quad \ldots \quad (2)$$

Now by squaring equation (1) we get

$$\lambda^2 = 1{,}885^2 L(F+C)$$

or

$$= 1{,}885^2 LF + 1{,}885^2 LC \quad \ldots \quad (3)$$

By squaring equation (2), we get

$$W^2 = 1{,}885^2 LF \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

From (3) and (4) we may write

$$\lambda^2 = W^2 + 1{,}885^2 LC \quad \ldots \quad \ldots \quad (5)$$

The result obtained in equation (5) is one of considerable importance and one which does not appear to have received the attention it deserves. Its importance lies in the term W^2, for that term provides us with an explanation as to why the hunt for a straight-line relationship in a variable condenser is so frequently unsuccessful.

If it were only possible for that term W^2 to disappear, all would be plain sailing, but that term does not disappear. Were that term to be zero, it would mean that, when the variable condenser was set at 0, in other words set in its position of minimum capacity, the wavelength value of the circuit would be *zero*, an impossible state of affairs. It is very largely because designers of variable condensers of the "square-law" type have ignored that term W^2 that many of our square-law variable condensers fail to give a straight-line relationship between wavelength and dial reading of the condenser.

Strictly speaking, a straight-line relationship between either wavelength or frequency and the dial reading of a variable condenser cannot be attained in actual practice. What can be done, however, is to obtain an approximation to such a straight-line relationship.

It may come as a surprise to many that a better approximation to a straight-line relationship can be obtained with a variable condenser having semi-circular plates than with a condenser with the modern "square-law" type of plates.

Consider the old type of variable condenser with its semi-circular plates. With such a condenser, the increase in capacity over the minimum capacity is directly proportional to the dial setting. In other words, the C of our equation (5) is equal to aD, where D is the dial setting, and a is some number definitely fixed for that particular condenser. Let us put $C=aD$ in equation (5) and we get

$$\lambda^2 = W^2 + 1{,}885^2 LaD.$$

In order to simplify this result, let us write k for $1{,}885^2La$. We then have the important result

$$\lambda^2 = W^2 + kD \quad .. \quad .. \quad (6)$$

This equation, which is of somewhat novel form, is extremely important in that it shows

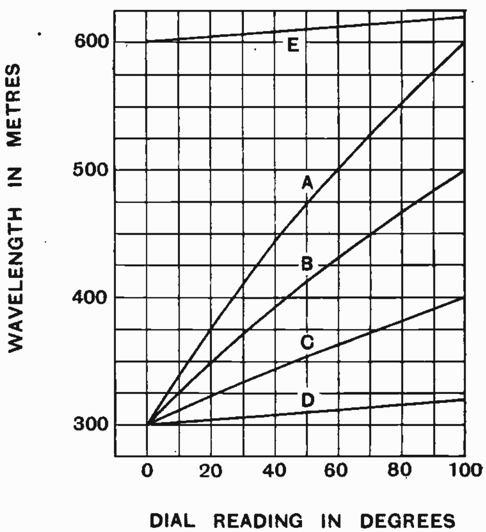


Fig. 2.

the part played by the minimum wavelength of a circuit in determining the actual wavelength to which the circuit may be adjusted by a variable condenser.

The result we have called equation (6) can be put to great use in connection with semicircular vane condensers. Suppose that we have such a condenser connected in a circuit and that the maximum wavelength to which the circuit will tune is 600 metres. Suppose also that the minimum wavelength to which the circuit will tune is 300 metres. Further, suppose that the dial of the condenser is divided into a hundred equal divisions. Putting $\lambda = 600$, and $W = 300$, and $D = 100$ in equation (6), we have $600^2 = 300^2 + k \times 100$. This gives us a value of k for the particular condenser under consideration, namely $k = 2{,}700$. We may therefore write for this condenser

$$\lambda^2 = 300^2 + 2{,}700\ D.$$

Giving D the values 20, 40, 60, and 80 in succession and calculating the corresponding values of λ, we obtain the set of values given in the section marked A in Table I. This set of values is illustrated diagrammatically by curve A in Fig. 2.

Section B in Table I. gives a set of values obtained in exactly similar fashion for a variable condenser which tunes a circuit from 300 to 500 metres. Section C gives a set of values for a variable condenser which tunes a circuit from 300 to 400 metres. Sections D and E of the same table give sets of values for condensers which tune a circuit from 300 to 320 and from 600 to 620 metres respectively. Each section of Table I. is illustrated by a curve bearing the same distinguishing letter in Fig. 2.

Looking at Fig. 2 in conjunction with Table I., we see that, as the range of the variable condenser is reduced, the curve showing the relationship between wavelength and dial setting gets nearer and nearer to a straight line relationship. In fact, for the two condensers having a 20-metre tuning range, the relationship between wavelength and dial setting is actually a straight-line relationship.

Now a variable condenser with a range of 20 metres corresponds very nearly to the

TABLE I.

	A		B		C		D		E	
Dial Reading.	Wavelength.	Difference in Wavelength.	Wavelength.	Difference in Wavelength.	Wavelength.	Difference in Wavelength.	Wavelength	Difference in Wavelength.	Wavelength.	Difference in Wavelength.
0	300		300		300		300		600	
20	380	80	350	50	323	23	304	4	604	4
40	445	6[illegible]	393	43	343	20	308	4	608	4
60	502	57	432	39	363	20	312	4	612	4
80	554	52	467	35	382	19	316	4	616	4
100	600	46	500	33	400	18	320	4	620	4

Variable Condensers with Semi-Circular Vanes.

separate single vane of a so-called vernier condenser. Hence we have the most interesting indication that the vernier vane of a variable condenser *with semi-circular vanes*, gives a straight-line relationship between wavelength and dial reading. We must emphasise the point that we are speaking of a variable condenser with semi-circular vanes.

It is interesting to note, in passing, that Table I. indicates quite as clearly as Fig. 1 the straight-line relationship for Sections D and E. The "difference in wavelength" columns in these two sections show a constant difference of 4 metres for every 20 divisions on the condenser dial. Equally true is it to say that Table I. shows that there is not a straight-line relationship in Sections A, B, and C of the table. There is a *varying* difference of wavelength per 20 scale divisions of the condenser dial in each of these three sections.

We have stated that, for a variable condenser with semi-circular vanes, the capacity of the condenser for any setting D of the dial may be written aD, where a is some number. For a variable condenser with vanes of the

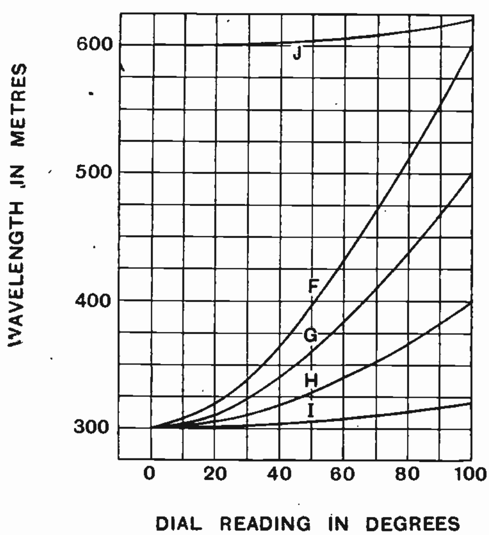


Fig. 3.

"square-law" pattern, the corresponding relationship is $C = aD^2$, a being a number as before, definitely fixed for a particular condenser.

If we put $C = aD^2$ in our equation (5) we obtain the result

$$\lambda^2 = W^2 + 1{,}885^2\ LaD^2$$

Let us again write k for $1{,}885^2\ L\ a$. We then have the result

$$\lambda^2 = W^2 + kD^2 \quad \ldots \quad \ldots \quad (7)$$

We shall be able to use our equation (7) in much the same way as we used our equation (6). Suppose that we have a "square-law" variable condenser which will

TABLE II.

Dial Reading.	F Wavelength.	F Difference in Wavelength.	G Wavelength.	G Difference in Wavelength.	H Wavelength.	H Difference in Wavelength.	I Wavelength.	I Difference in Wavelength.	J Wavelength.	J Difference in Wavelength.
0	300		300		300		300		600	
20	318	18	310	10	305	5	301	1	601	1
40	365	47	340	30	318	13	303	2	603	2
60	433	68	384	44	340	22	307	4	607	4
80	513	80	439	55	367	27	313	6	613	6
100	600	87	500	61	400	33	320	7	620	7

Variable condensers with "square law" vanes.

tune a circuit from 300 to 600 metres, and that the dial of this condenser is divided into 100 equal divisions. Putting $\lambda = 600$, $W = 300$ and $D = 100$ in equation (7) gives us $600^2 = 300^2 + k\ 100^2$. From this we can calculate the value of k for this particular condenser. We get $k = 27$.

Hence for this particular "square law" condenser we may write

$$\lambda^2 = 300^2 + 27\ D^2.$$

Giving D the values 20, 40, 60 and 80 in succession and calculating the corresponding values of λ, we obtain the set of values given in the section marked F in Table II. This set of values is illustrated in the form of a curve as curve F in Fig. 3.

Section G in Table II. gives a set of values obtained in the same way for a "square law" variable condenser which tunes a circuit from 300 to 500 metres. Section H gives another set of values for a similar condenser which tunes a circuit from 300 to

400 metres. Sections I and J refer to small "square law" condensers which tune a circuit respectively from 300 to 320 metres and 600 to 620 metres. These sets of values are all illustrated by curves in Fig. 3 bearing the same distinguishing letters.

The most important point to note with regard to Fig. 3 is that none of the curves shown there approximate very closely to a straight-line relationship. The same thing is evident from Table II. None of the difference of wavelength columns show a constant increase in wavelength per 20 scale divisions on the dial.

From Figs. 2 and 3 we have this definite result. While a "square law" variable condenser possesses the advantage that over certain parts of its dial, a fairly close approximation to a straight-line relationship between wavelength and dial reading is

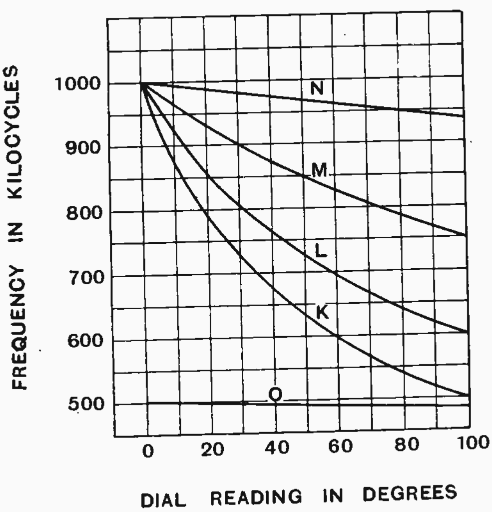


Fig. 4.

obtainable (see Fig. 1 and parts of the curves in Fig. 2), the older type of variable condenser with semi-circular vanes possesses the advantage that, as its tuning range is reduced, the relationship between wavelength and dial reading approaches more and more closely to the straight-line type. With a small condenser having semi-circular vanes (tuning range 20 metres or thereabouts) there is a most definitely defined straight-line relationship between wavelength and dial reading.

Let us now see how the two types of variable condensers compare when we consider the relationship between frequency and dial reading. For each wavelength given in Table I., it is easy to find the corresponding frequency in kilocycles. The frequency

TABLE III.

Dial Reading.	K Frequency.	K Difference in Frequency.	L Frequency.	L Difference in Frequency.	M Frequency.	M Difference in Frequency.	N Frequency.	N Difference in Frequency.	O Frequency.	O Difference in Frequency.
0	1000		1000		1000		1000		500	
		210		143		75		13		3
20	790		857		925		987		497	
		112		90		53		13		4
40	678		767		872		974		493	
		78		71		47		13		3
60	600		696		825		961		490	
		60		56		40		12		3
80	540		640		785		949		487	
		40		40		35		12		3
100	500		600		750		937		484	

Variable condensers with semi-circular vanes.

values obtained are shown in Table III. For ease of calculation, the formula

$$\underset{\text{(kilocycles)}}{\text{Frequency}} = \frac{300{,}000}{\text{Wavelengths}}$$

has been used.

Sections K, L, M, N, and O of Table III. correspond respectively with Sections A, B, C, D, and E of Table I. The variable condensers are all of the semi-circular vane type.

The numerical results given in Table III. are illustrated in Fig. 4, the same distinguishing letters being used. It will again be noticed that there is a decided approach to a straight-line relationship between the two quantities under consideration (frequency and dial reading in this case) as the tuning range of the condenser is decreased.

Curve *N* is practically a straight line. Curve *O* is also very nearly a straight line. The frequency difference per 20 divisions on the condenser dial is different however for the two curves, being 13 for curve *N* and 3 for curve *O*.

The numerical values given in Table IV. are obtained directly from Table II. by means of the above frequency wavelength formula. The different sections of Table IV. are illustrated in Fig. 5, the same distinguishing letter being used for section of table and corresponding curve.

The peculiar shape of the curves *P* and *Q* in Fig. 5 should be noticed. These two curves bend to the right at the top of the diagram and to the left at the bottom of the diagram. The corresponding difference in frequency columns in Table IV. show this peculiarity, for the numbers in those columns first increase and then decrease. In none of the five curves shown in Fig. 5 is there a close approach to a straight-line relationship between frequency and dial reading.

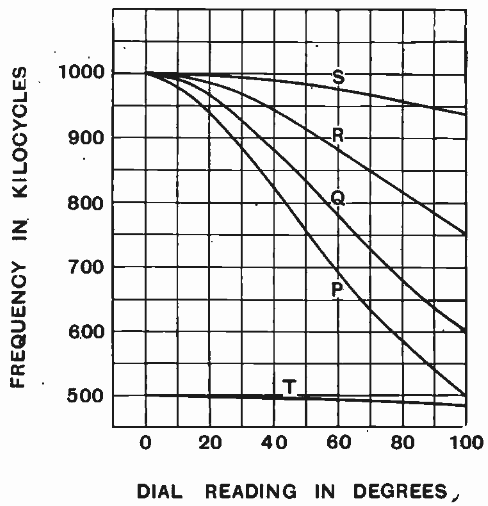


Fig. 5.

Hitherto we have dealt with variable condensers with moving vanes of the (i.) semi-circular and (ii.) "square law" type which tune circuits over the following ranges :—

Wavelength 1. 300 to 600 metres ;
2. 300 to 500 metres ;
3. 300 to 400 metres ;
4. 300 to 320 metres ;
5. 600 to 620 metres ;

or in frequencies 1. 1,000 to 500 kilocycles ;
2. 1,000 to 600 kilocycles ;
3. 1,000 to 750 kilocycles ;
4. 1,000 to 937 kilocycles ;
5. 500 to 484 kilocycles.

Our results may be summarised thus :—

As the tuning range of a variable condenser with semi-circular moving vanes is reduced there is a rapid approach to a straight-line relationship between wavelength and dial reading. For a small semi-circular vane condenser, tuning range 20 metres, there is a practically exact straight-line relationship between wavelength and dial reading.

With a variable condenser having "square law" moving vanes, a straight-line relationship between wavelength and dial reading exists only for a certain portion of the dial,

TABLE IV.

Dial Reading.	P Frequency.	P Difference in Frequency.	Q Frequency.	Q Difference in Frequency.	R Frequency.	R Difference in Frequency.	S Frequency.	S Difference in Frequency.	T Frequency.	T Difference in Frequency.
0	1000		1000		1000		1000		500	
		60		32		17		3		1
20	940		968		983		997		499	
		118		86		40		7		2
40	822		882		943		990		497	
		129		101		61		13		3
60	693		781		882		977		494	
		108		105		65		19		6
80	585		676		817		958		490	
		85		76		67		20		6
100	500		600		750		938		484	

Variable Condensers with "square law" vanes.

usually embracing the higher readings. There is no marked approach to straight-line relationship as the tuning range of the condenser is decreased, or at least there is not the same degree of approach to a straight-line relationship as in the case of a condenser with semi-circular vanes.

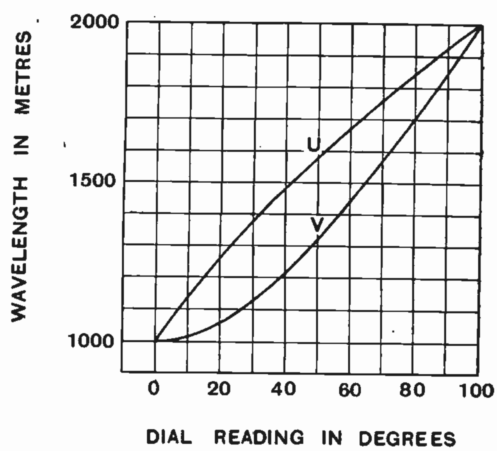


Fig. 6.

When dealing with frequency, the variable condenser with "square law" moving vanes gives nothing like a straight-line relationship between frequency and dial reading. The variable condenser with semi-circular moving vanes shows the same approach to a straight-

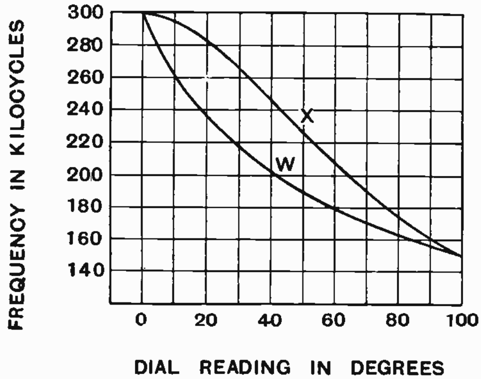


Fig. 7.

line relationship between frequency and dial reading as the tuning range is decreased as it did in the case of wavelength and dial reading.

All the above points indicate that the older type of variable condenser with semi-circular moving vanes is a better instrument for obtaining a straight-line relationship than the newer condenser with so-called " square law " moving vanes.

Figs. 6 and 7 show curves indicating the type of relationship between wavelength and frequency and the dial reading of both types of condenser having a tuning range of 1,000 to 2,000 metres (300 to 150 kilocycles). There is here in each case a big divergence from a straight-line type of relationship.

Long-Distance Work.

By Hugh N. Ryan (5BV). [R009.2

After the weather which prevailed at Easter, the winter can be considered to have come to a definite end, and as it has been our first winter on 45 metres it is interesting to look back and see what winter means to us now. We all know what it meant before, on 100 and 200 metres—it was just the only time of the year when any long-distance work could be done, and even then one had to sit up all night for it. The old-timers will never forget those cold nights.

After a steady descent in wavelength, starting at 1,000 metres soon after the war, I think we have now found our final and most useful waves to be between 35 and 50 metres. Having used these waves for a year there is no doubt that they are much more useful in the summer than in the winter. Contact with the whole world has been maintained throughout the winter, with no very large gaps, but not on anything like the same scale as last summer, when there were many less stations on this wave. This being the case, we may look forward to a pretty busy summer.

6VP, who was recently reported to have worked U.S.A. on very low power, is now doing it regularly, and has also added Brazil to his QSO list. Judging by results, this must be about the most useful low-power station in the country.

5QV's long-awaited change of QRA will be an accomplished fact by the time this appears, and he will be glad of reports from all parts on signals from the new station.

6TD, who has for a long time been doing excellent work with both the Americas, is now at last in touch with Australia.

2LZ, who used to be heard working every part of the globe, has become interested in the " weather and DX " problem, and is now engaged exclusively on its systematic investigation, in collaboration with an American station.

5NJ has some fairly high-power phone going now, and I have heard him working to Australia with it, but it does not yet appear to be functioning very well. No doubt it will soon be as good as his low-power speech, which is very good indeed.

The most noticeable thing about all the month's work is the comparative ease with which one can still work Australians, and the great difficulty of working New Zealanders.

Effective Resistance of Inductance Coils at Radio Frequency.—Part II.

By S. Butterworth. **[R144**

(*Admiralty Research Laboratory, Teddington.*)

5. Alternating Current Resistance of Two Parallel Wires.

This is the simplest case in which the theory may be applied. If the current is I and the axes of the wires are separated by a distance c, then each wire is situated in a field of intensity $2I/c$ due to the current in the other wire. The eddy loss due to this field is obtained by replacing H by $2I/c$ in (10) and we then have for both wires

$$W_h = RI^2Gd^2/c^2 \quad .. \quad (15)$$

so that the increment in resistance due to this loss is

$$R_h = RGd^2/c^2 \quad .. \quad (16)$$

Adding this to the A.C. resistance R_s of a solitary wire the total resistance is

$$R_c = R_s + R_h = R(I + F + Gd^2/c^2) \quad .. \quad (17)$$

This formula is only accurate if d/c is not too large.

When the wires are close together so that d/c is nearly unity we can no longer neglect the fact that the induced eddy currents distort the field in the plane containing the axes of the two wires. In fact the two terms of (17) are the first two terms of an infinite series. The next term has been calculated and it has been found that (17) must be replaced by

$$R_c = R(I + F + Gd^2/c^2 + GHd^4/c^4 + \ldots.) \quad (18)$$

in which H is a new function of z having the following values :—

If we assume that the remaining terms are in geometrical progression and therefore write

$$R_c = R\left(I + F + \frac{Gd^2/c^2}{1 - Hd^2/c^2}\right) \quad \ldots \quad (19)$$

we obtain a formula which is in close agreement with experimental results for values of d/c up to 0.9.

6. Single-Layer Systems of Spaced Parallel Wires. Short Coils.

Formula (17) will clearly also hold for a two-turn coil provided that c is small compared with the radius of the coil and that d/c is not too large.

If we take three coplanar parallel wires of equal axial separation c, the field acting on each of the outer wires due to the current in the remaining two is $3I/c$ and there is no field acting on the middle wire.

Thus the mean square field for all three wires is

$$(3^2 + O + 3^2)I^2/3c^2 = 6I^2/c^2$$

Using this in (10) we obtain for the mean value of R_h

$$R_h = 1.5\ RG\ d^2/c^2$$

where R is the D.C. resistance of one wire. For all three wires in series we simply multiply by 3, or, what is the same thing, regard R as the D.C. resistance of the whole system. Thus for a system of three wires the A.C. resistance formula is

$$R_c = R(1 + F + 1.5Gd^2/c^2) \quad .. \quad (20)$$

z ..	0	1	2	3	4	5	large	
H {	0.042	0.053	0.169	0.348	0.466	0.530	0.750	Go and Return
	0.042	0.033	—0.056	—0.152	—0.176	—0.185	—0.250	Currents in same direction

The same procedure may be applied to any number of coplanar, equally spaced, parallel wires and in general we get

$$R_c = R(1 + F + u\dot{G}d^2/c^2) \quad .. \quad (21)$$

in which u depends upon the number of wires in the system. Thus we have

No. of wires	2	4	6	8	10	12	16	24	32	Inf.
u	1.00	1.80	2.16	2.37	2.51	2.61	2.74	2.91	3.00	3.29

The last number has been obtained by integration, the exact value being $\pi^2/3$.

Formula (21) is clearly applicable to solenoidal or disc coils provided they are single layer and of winding length or depth which is very small compared with the coil radius.

7. Single-Layer Spaced Solenoids.

Turning now to the case where the ratio of winding length to coil radius is no longer small we may still regard the wire in an individual turn as practically straight, as our loss formulæ would only cease to be valid if the curvature of the wire were comparable with the wire diameter. Such a condition will scarcely ever occur in practice. The general field acting upon the wire is, however, considerably altered by the curvature of the surface of the coil.

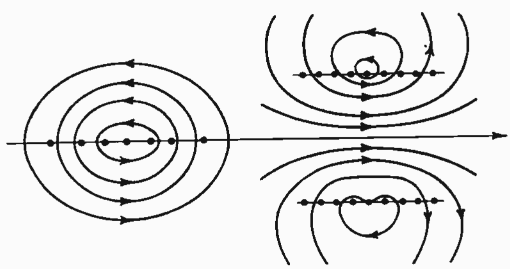


Fig. 4 (a) *shows the symmetrical distribution of the lines of force about the central turn of a very short solenoid*; (b) *shows the distribution of the lines of force in a long solenoid when the central turn is present (upper part of figure) and when it is absent (lower part of figure).*

In the case of the straight system of wires the field acting upon one wire is perpendicular to the plane of the system, so that in very short solenoids the field is practically parallel to the coil radius, the lines of force being disposed symmetrically about the central turn as in Fig. 4 (a). As the length of the solenoid gets greater, however, the concentration of the lines in the interior of the solenoid causes the lines of force to cut across the wires of the coil in a direction inclined to the radius, so that we have to consider two components of the field, which are parallel to the coil axis and the coil radius respectively. For the central turn the axial field only is present, but for the outer turns the radial field predominates. The existence of a field parallel to the axis at the central turn will be understood when we bear in mind that the field playing on the wire is that due to the *remaining* turns. Thus (see Fig. 4), if we suppose the central turn removed, the lines of force within the coil extend into the gap as shown and thus give an axial field component through the centre of the central wire. Although this field is distorted by the field due to the current in the central wire, it is the true field to use in calculating the general field losses, as has already been explained in the preliminary survey.

In the case of an infinitely long solenoid, if the pitch of the turns is c the field inside the solenoid is $4\pi I/c$ and outside the solenoid is zero. If a turn be supposed removed, then in the neighbourhood of the gap the field changes rapidly from $4\pi I/c$ to zero as we pass through it, so that the field acting in this space may be taken as $2\pi I/c$. Using this in the loss formula (10) and proceeding as in the last section we obtain for the A.C. resistance of any one turn a formula precisely similar to (21), in which the value of u is π^2.

In the case of finite solenoids it is necessary to calculate the axial and radial field components at every point and then determine the mean square value throughout the turns. It is convenient to distinguish between the contributions of the two field components; otherwise our formula is precisely the same as (21), the following values of u holding for various ratios of coil length to coil diameter.

TABLE II.

VALUES OF u FOR SINGLE LAYER SOLENOIDS OF MANY TURNS (SPACED).

D = diameter of coil. b = length of coil.
u_1 = contribution of radial component of field.
u_2 = contribution of axial component of field.

b/D	u_1	u_2	$u=u_1+u_2$
0.0	3.29	0.00	3.29
0.2	3.13	0.50	3.63
0.4	2.83	1.23	4.06
0.6	2.51	1.99	4.50
0.8	2.22	2.71	4.93
1.0	1.94	3.35	5.29
2	1.11	5.47	6.58
4	0.51	7.23	7.74
6	0.31	8.07	8.38
8	0.21	8.52	8.73
10	0.17	8.73	8.90
Inf.	0.00	9.87	9.87

The above values will not hold for coils of few turns, as u depends upon the turns as well as the shape of the coil. It is probably possible to calculate the value of u in these cases by assuming each turn to be a separate circle. The above values are, however, probably sufficiently accurate for purposes of design, as the approach to the final value as the turns increase appears to be fairly rapid in the case of the short coils of Section 6.

It is interesting to notice that if the length of the coil is less than its diameter u is very nearly $3.29+2b/D$.

8. Single-Layer Disc Coils.

Single layer disc coils may be treated by a method similar in principle to that for solenoids. The field is in this case entirely perpendicular to the plane of the coil. If D is the overall diameter of the coil and t is the winding depth, the factor u in formula (21) is a function of t/D which is given in Table III.

9. Closely-Wound Single-Layer Coils.

The simple formula (21) is only accurate when d/c is not too large. When the coil is closely wound and the frequency is high, the distortion of the current distribution in each turn becomes so pronounced that it is no longer permissible to regard this current as concentrated at the centre of the wire in calculating the field acting on each turn. If we recall the principle that the effect of the eddy currents is to force the magnetic field round rather than through the wire, it will be seen that in the case where the field is cutting across the wires transversely the eddy currents induced in any one turn increases the intensity of the field acting upon its neighbours, so that the simpler theory underestimates the losses. If, on the other hand, the field is tangential to the turns the eddy currents in one turn reduce the intensity of the field acting on neighbouring turns and the simple formula overestimates the losses. Thus in the case of an infinite solenoid at very high frequencies, we find, on inserting in (21) the appropriate values of u, F and G, that when the turns are practically touching, the A.C. resistance of the coil should be 5.94 times the A.C. resistance of the same wire when straight. If, however, the field due to the eddy currents is taken into account the multiplier is reduced to 3.41.

TABLE III.

VALUES OF u FOR SINGLE-LAYER DISC COILS OF MANY TURNS (SPACED).

D=overall diameter of coil.
t=winding depth of coil.

t/D	u	t/D	u
0.000	3.290	0.250	4.749
0.025	3.315	0.275	5.041
0.050	3.373	0.300	5.364
0.075	3.459	0.325	5.718
0.100	3.567	0.350	6.104
0.125	3.702	0.375	6.523
0.150	3.859	0.400	6.968
0.175	4.042	0.425	7.436
0.200	4.251	0.450	7.911
0.225	4.486	0.475	8.354
0.250	4.749	0.500	8.638

The mathematical theory taking into account the external field developed by the eddy currents is rather complicated, but the writer[13] has succeeded in developing

[13] For the full theory of closely-wound coils see *Proc. Roy. Soc.*, A, Vol. 107, p. 693, 1925.

The experimental example is from Professor Howe's paper, "The High Frequency Resistance of Wires and Coils," *Journ. I.E.E.*, Vol. 58, p. 152, 1920.

relatively simple formulæ to cover the case of closely-wound coils which hold for solenoids of any length when the turns are many and for very short coils when the turns are few.

The formula for the many-turn coils is

$$R_c = R\,\{a(1+F)+(\beta u_1+\gamma u_2)\,Gd^2/c^2\} \quad \dots \quad (22)$$

where a, β, γ depend both on d/c and on z as in the following Table.[14]

[14] Formula (22) is applicable to disc coils as well as solenoids, the value of u_2 being zero in this case.

as to show that it is not advisable to employ very closely-wound coils; so that the simple formula may still be used for *efficient* coils for practically all frequencies. The more elaborate formula has, however, been useful in checking the experimentally found resistances for closely-wound coils, and it has been shown that in coils where reasonable precautions have been employed in regard to the surrounding dielectric the measured resistances agree with the experimental values. In fact in a case where the losses were measured by determining the rise in

TABLE IV.

Values of a, β, γ in Formula (22).

d/c	$z=1$.			$z=2$.			$z=3$.		
	a.	β.	γ.	a.	β.	γ.	a.	β.	γ.
1.0	1.01	1.02	0.96	1.09	1.34	0.67	1.31	2.29	0.49
0.9	1.00	1.02	0.97	1.06	1.29	0.72	1.20	1.99	0.55
0.8		1.02	0.98	1.04	1.23	0.78	1.13	1.73	0.62
0.7		1.02	0.98	1.02	1.18	0.83	1.08	1.52	0.68
0.6		1.01	0.99	1.00	1.13	0.87	1.04	1.36	0.75
0.5		1.01	0.99		1.09	0.91	1.02	1.24	0.82
0.4		1.01	0.99		1.06	0.94	1.01	1.14	0.88
0.3		1.00	1.00		1.04	0.97	1.00	1.06	0.93
0.2					1.01	0.99		1.03	0.97
0.1					1.00	1.00		1.01	0.99

d/c	$z=4$.			$z=5$.			$z=$inf.		
	a.	β.	γ.	a.	β.	γ.	a.	β.	γ.
1.0	1.43	3.61	0.43	1.50	4.91	0.41	1.71	inf.	0.35
0.9	1.30	2.75	0.49	1.37	3.39	0.46	1.55	12.45	0.39
0.8	1.21	2.12	0.55	1.25	2.48	0.53	1.41	4.83	0.44
0.7	1.12	1.71	0.62	1.15	1.94	0.60	1.27	2.87	0.52
0.6	1.07	1.51	0.70	1.09	1.60	0.68	1.16	2.03	0.60
0.5	1.03	1.32	0.78	1.04	1.37	0.76	1.08	1.59	0.69
0.4	1.02	1.19	0.85	1.02	1.22	0.84	1.03	1.33	0.78
0.3	1.00	1.10	0.91	1.00	1.11	0.90	1.01	1.17	0.87
0.2		1.04	0.96		1.05	0.96	1.00	1.07	0.94
0.1		1.01	0.99		1.01	0.99		1.02	0.98

It will be seen that the factors a, β, γ trend towards unity as d/c and z get smaller. When z is less than unity the simple formula (21) will cover all possible values of d/c. For greater values of z, the simple formula, as will be shown below, indicates a value of d/c giving minimum losses which is such

temperature of the central turn of a fairly long solenoid, the theory shows that it is the losses due to the tangential field only that are being measured, the losses due to the transverse field, occurring as they do mainly at the ends of the coil, having very little effect upon the central temperature.

In a particular case when z was equal to 21.6, the ratio of A.C. to D.C. losses was found by the above method of measurement to be 21.8 when the spacing was such that $d/c \doteqdot 0.9$. The above formula gave the loss ratio as 27.8 when all the losses were taken into account and 22.5 when the transverse field losses were ignored. The latter value is in very fair accord with experiment, particularly when it is remembered that the theoretical formula assumes "infinite" turns. For a loosely-wound coil ($d/c \doteqdot 0.5$), theory gave the ratio of the losses as 14.1 and experiment 14.0. In this case the losses are largely the mere skin losses, and are therefore distributed practically uniformly over the coil. The example seems to indicate that the "central" temperature method of estimating the A.C. losses fails to take into account the extra end losses, and this is borne out by a consideration of the thermal constants of the coil.

10. The Correction for Self-Capacity.

In establishing the formula for the copper losses we have assumed that the current is the same in every turn of the coil. Actually this is not so at radio frequencies, because of the distributed self-capacity. As regards the reactance, the self-capacity is allowed for by assuming that the coil is shunted by a small condenser, and this assumption is justified by measurement. As regards the resistance, we can no longer appeal to experiment, but if we assume that the distributed self-capacity, is sufficiently represented by an end capacity, it is easy to show that when the reactance of the coil is large compared with the resistance the measured A.C. resistance of the coil is given by

$$R' = R_c / (1 - \omega^2 LC)^2 \quad \ldots \quad (23)$$

where L is the inductance of the coil, C is its self-capacity and $\omega/2\pi$ is the frequency.

As to whether this end capacity assumption is justifiable has been the subject of a great deal of discussion, but Breit[15] has shown that in the case of very short coils there is theoretical justification for the formula, and has supplied the correction which will carry us right through the resonating frequency of the coil. His corrected formula shows that (23) is good enough for most practical purposes for frequencies lower than about one-third the resonating frequency. Now, although the writer does not entirely agree in regard to the truth of Breit's formula, yet his conclusion in regard to the range of (23) is probably sound. In the neighbourhood of the resonating frequency, Breit's more elaborate formula is only valid for that portion of the copper resistance which we have represented by R_s. There is a different correction for the portion of the resistance which depends upon the mean square field acting upon the coil, as the latter does not follow the same law of distribution as the mean square current when we take into account the variation of current from turn to turn of the coil due to the flowing off of the dielectric current. It is not proposed, however, to deal with this in the present article.

It will be seen from formula (23) that it is a distinct advantage to use coils of low self-capacity even from the point of view of copper losses, as the circulating currents due to the self-capacity cause loss of energy in the copper portions of their paths. This added resistance due to self-capacity is thus a true copper loss. It is sometimes found that stray wires attached to coil terminals cause an appreciable increase in resistance of the coil. This may be in part accounted for by the resulting increase in the apparent self-capacity of the coil, especially when the coil is being used near its own natural frequency.

11. Single-Layer Coils at High Frequencies.

When the frequency is so high that the approximations (9) and (14) hold for $1+F$ and G, formula (21) assumes the simple form

$$R_c = \frac{A}{\sqrt{\lambda}} + B \quad \ldots \quad \ldots \quad (24)$$

where λ is the wave-length in metres and, for copper, A and B have the values

$$A = 660\, Rd\left(1 + \tfrac{1}{2}u\frac{d^2}{c^2}\right)$$
$$B = \tfrac{1}{4}R\left(1 - \tfrac{1}{2}u\frac{d^2}{c^2}\right) \quad \ldots \quad (25)$$

Now, in such cases it has been found experimentally that the measured effective resistance, after due correction for self-capacity, fits very closely a formula of the type

[15] *Bureau of Standards*, Scientific Paper No. 430, 1922.

$$R_m = \frac{A'}{\sqrt{\lambda}} + \frac{B'}{\lambda^2} \quad \ldots \quad \ldots \quad (26)$$

and the value of A' required to fit (26) agrees closely with the value of A in (24). We need not trouble much about the term B in (24) as it is usually so small that it is within the error of measurement. There seems to be no doubt therefore, that the first term in (26) is that due to the copper loss in the coil. As regards the second term it must be noted that in all cases where a formula of this type has been found to fit the experimental facts, the method of measurement employed has been the well-known resistance variation method, in which the coil forms part of a resonating circuit containing an air condenser which is assumed free from loss. It may be that a portion of this term is really due to loss which does not occur in the coil at all. This view seems to be supported by the few reliable measurements which have been made in which the method does not involve a resonating condenser. There is not, however, sufficient evidence at present to decide this question.

As regards the relative values of the two terms in (26) the following experimental results are of interest: Table V. gives the details of measurement and analysis in the case of a single-layer coil of 23.5 cm. diameter and winding length 1.0 cm. wound with 13 turns of No. 22 D.S.C. wire, the whole being held together by wax and silk tape. The measured inductance of the coil was 100μH and the self-capacity 20μμF.

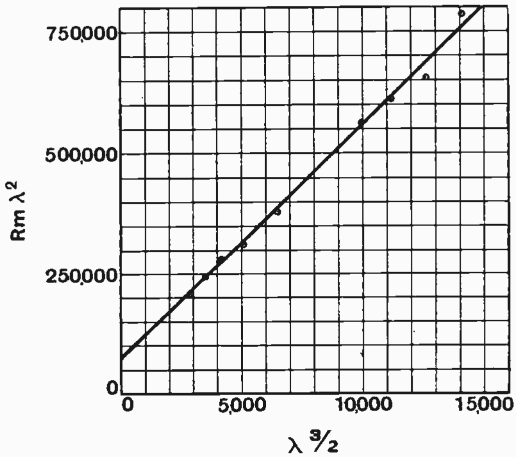


Fig. 5. *Showing how* A′ *and* B′ *in the formula* $R_m = \frac{A'}{\sqrt{\lambda}} + \frac{B'}{\lambda^2}$ (26) *may be found by plotting* $R_m \lambda^2$ *against* $\lambda^{3/2}$ *and finding the slope* (A′) *and the intercept on the vertical axis* (B′) *of the resulting straight line.*

The values of A' and B' used in the Table are

$$A' = 49.7, \; B' = 7.0 \times 10^4.$$

TABLE V.

Separation of Losses in Single-Layer Coil.

R_1 = measured A.C. resistance. $R_m = R_1(I - \omega^2 LC)^2$. (See formula 23.)
$A'/\sqrt{\lambda}$ = term due to copper loss. B'/λ^2 = term due to remaining losses.

The values of A' and B' are found by plotting $R_m\lambda^2$ against $\lambda^{3/2}$ as in Fig. 5. If (26) is valid the result should be a straight line the slope of which determines A' and the intercept on the vertical axis determines B'. The figure and the smoothed values of R_m show that the law holds for this coil.

λ (Metres.)	R_1 (Ohms.)	R_m (Ohms.)	$A'/\sqrt{\lambda}$	B'/λ^2	Smoothed R_m (Ohms.)	Cu. loss. / Total loss.
206	7.2	5.00	3.40	1.65	5.05	0.67
229	6.2	4.64	3.30	1.34	4.64	0.71
260	5.2	4.16	3.09	1.02	4.11	0.75
294	4.3	3.61	2.90	0.81	3.71	0.78
350	3.5	3.10	2.66	0.57	3.23	0.82
463	2.8	2.62	2.31	0.33	2.64	0.87
500	2.6	2.46	2.22	0.28	2.50	0.89
543	2.5	2.38	2.14	0.24	2.38	0.90
584	2.3	2.30	2.06	0.20	2.26	0.91

The D.C. resistance of this coil was 0.444 ohm, so that we find from (25)

$$R_c = \frac{51}{\sqrt{\lambda}} - 0.05$$

Thus the term depending upon wave-length agrees very closely with the value deduced from the measurements, while the constant term is very small.

The values for six other coils are given in Table VI. below.

12. Effect of Spacing in Single-Layer Coils.

Suppose a single layer coil to be wound with various gauges of wire, keeping the pitch of the turns constant. Under these circumstances the inductance would remain practically constant, but an examination of (25) shows that the resistance will pass through a minimum value for a particular gauge of wire. To prove this, notice that since R is inversely proportional to the

TABLE VI.

Coil.	D cm.	b cm.	d mm.	c mm.	Inductance (μH.)	Observed A'	Observed B'	Calcd. A'	B'/L^2.
1	31	1.8	2.2	2.6	36	9.5	2.14×10^4	10.4	16.4
2	19.5	2.6	2.0	2.4	43	11.8	2.15 ,,	11.2	11.5
3	22.6	2.0	0.7	1.5	75	25.1	7.4 ,,	25.5	13.1
4	20.0	6.5	3.0	3.6	80	14.3	7.0 ,,	13.2	10.9
5	19.6	2.15	1.1	1.4	84	25.5	7.0 ,,	25.6	10.0
6	23.5	1.0	0.7	0.8	100	50	7.0 ,,	51.0	7.0
7	17.5	7.3	1.62	1.8	320	56	1.7×10^6	55.0	16.5

It is interesting to notice that if B is divided by the square of the self-inductance of the coil, as in the last column, the result is of the same order of magnitude for all the coils. This is the result we should expect if the coils were all shunted by a constant high resistance of the order of 0.2 to 0.4 megohm.

The values for coils 3, 6 and 7 are from measurements taken at the N.P.L. about six years ago using the best condensers then available. It is understood that since then better condensers have been constructed, and it would be of interest to have a corresponding series of values with these new condensers.

The remaining coils were measured by Lindemann and Hüter.[16]

Although great stress has been laid in this section upon the loss outside the copper, the copper loss is usually the predominant factor, as is seen from the last column of Table V. The coil of this Table is one which would normally be used at a wave-length in the neighbourhood of 350 metres, so that then the copper losses are 82 per cent. of the total losses.

[16] *Verh. Deutsch. Phys. Gesellschaft*, Vol. 15, p. 219, 1913.

square of the wire diameter, the quantity A is proportional to $\frac{1}{d} + \frac{1}{2} u \frac{d}{c^2}$. Thus A is equal to the sum of two terms which have a product independent of the diameter.

The two terms may therefore be regarded as the two sides of a rectangle, and variation of the diameter is equivalent to alteration of the shape of this rectangle keeping its area (product of sides) constant. The sum of the two sides is half the periphery of the rectangle, so that the periphery of the rectangle measures the size of the quantity A. Now, for rectangles of equal area, the one with the least periphery is a square. The value of A is then the least when

$$\frac{1}{d} = \frac{1}{2} u \frac{d}{c^2}$$

or

$$\frac{d}{c} = \sqrt{\frac{2}{u}} \quad \ldots \quad \ldots \quad (27)$$

Now, at very high frequencies, (24) shows that the copper loss is proportional to A, so that the condition of minimum loss is then given by (27). Using this value of d in (24) and neglecting B we find that the minimum value of the copper resistance at very high frequencies is given by the formula

$$R_c = 0.0020 \frac{l}{c} \sqrt{\frac{u}{\lambda}} \quad .. \quad (28)$$

the D.C. resistance having been expressed in terms of the length l of the wire, the resistivity of copper (1.7×10^{-6} ohms cms.) and the diameter of wire as expressed by (27). R_c is in ohms when l, c are in cms, and λ is in metres.

In support of this theory we may quote the following experimental results* : A set of coils were wound on formers each of diameter 3 in. and winding length 2 in. and each having 53 turns. The gauges of wire varied from coil to coil, and curves were obtained connecting d/c with resistance for various wave-lengths. Thus for the case of $\lambda = 300$ metres the following smoothed values were read from the curves.

d/c ..	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
R_m	12.5	7.4	5.4	4.7	4.6	4.8	5.5	7.1	ohms.

* The writer is indebted to the Federal Telegraph and Telephone Co., New York, for permission to make use of these results.

Now, for this coil u=4.62, so that by (27) the best value of d/c should be 0.66 and then by (28) the copper resistance is 3.3 ohms. The best spacing is in close agreement with experiment, and the value of the copper resistance is then 70 per cent. of the measured value.

The curves for 200 and 500 metres show similar minima at d/c=0.6 and the minimum values indicate that the copper losses as given by (28) are 65 and 78 per cent. respectively of the total losses. These percentages are of the same order as those discussed in the last section.

As regards the measured resistances at closer spacings, the theoretical formula (21) does not give as rapid an upward trend as the curves indicate, but comparison with the more elaborate formulæ for close windings shows that this upward trend may still be mainly due to copper loss.

Theory and experiment therefore show that formula (27) is reliable for determining the best gauge of wire to use for a single-layer coil of any given shape. The question of the best shape of coil is deferred until we have dealt with the formulæ for multilayer coils.

Mercury Contact Switches and Connecting Boards.

By T. B. Baker. [R387

NUMEROUS articles have appeared, dealing with switches of various types and their application to experimental work. Those of the mercury contact type appear to have been quite overlooked. However, they are extremely adaptable for all purposes, especially where quick changes of connections are required, and a perfect electrical contact of practically negligible resistance is assured, this being a very important item, especially in wireless work. They also have the advantage of being very simple to construct, are practically indestructible, have no mechanical parts to wear, and are inexpensive.

Switches of this type are frequently used in experimental laboratories, but probably have not found more general favour on account of the use of mercury, which is so easily upset. This is overcome by using a plastic amalgam in the place of pure mercury, which, being made in a fairly stiff paste, is not easily upset, and can be picked up and replaced if accidentally knocked out. The amalgam consists of a combination of mercury and tin, or mercury and lead; the former is possibly the better as it amalgamates rather more readily, and there is not so much tendency to oxidise as with the lead, though lead amalgam answers quite well.

The best way to prepare the amalgam is to take by weight about two parts of mercury to one part of clean metal, and heat them together in a porcelain crucible or iron vessel—which must not be tinned—until the solid metal just melts. It should then be well stirred with a glass or iron rod to assist the thorough amalgamation of the two, and while still liquid any dirt should be taken off. When cold, the amalgam should be a fairly stiff paste, so that when a copper wire is inserted the amalgam will entirely close in around the wire. If, when the amalgam is cold, the paste is too stiff, a little more mercury must be added, or if too liquid a little more of the metal, and the whole again heated until it becomes just liquid. If there is no immediate hurry the amalgam can be made by putting the mercury and metal in a glass or earthen vessel and left for some time, an occasional shake or stir being given to assist the amalgamating.

It may be advisable to mention for the benefit of those who have not previously used mercury, that it will amalgamate with most metals, upon many of which it has a very detrimental affect. Care should therefore be taken to avoid their coming into contact with it or with the amalgam. After the latter has been standing in the cups for a time, without use, the top surface will often appear to be hard, but a slight stir with the connector, when inserting, will make it quite plastic again.

The bases for these switches and boards can be made either of ebonite or wood, and if the latter are thoroughly dried and impregnated with pure paraffin wax, the insulation will be very good. A good hard wood should be used, about $\frac{1}{2}$ in. to $\frac{5}{8}$ in. thick, teak being probably the best. When impregnating wood bases, they should first be dried out as far as possible in a warm oven, care being taken not to scorch the wood; they should then be entirely immersed in boiling paraffin wax, and left until all the air is driven off. The actual time required will depend upon the nature of the wood used. They are then taken out, the superfluous wax shaken off, and hung or stood on edge to dry; any wax adhering can afterwards be scraped off.

The general arrangement of all the bases is the same, consisting of holes or holes and slots, into which terminals are inserted. The holes can be made with either a wood centre bit or a twist drill. If a centre bit is used, care must be taken that the centre point does not go right through the base, except in the case where contact screws are to be inserted from below. The slots are easily made by drilling a series of holes side by side and finishing with a chisel or gouge. It will be found an advantage, and will also save time, to fix a depth gauge to the drill, to ensure that all the holes are the same depth.

This can be accomplished by slipping a metal or wood collar over the drill and fixing with a set screw as shown in Fig. 1. The diameter of the holes and width of the slots should be kept as small as possible, so as not to require too much amalgam. About $\frac{5}{16}$ in. will be found ample for the switches and $\frac{1}{4}$ in. or even less for the connecting boards. It is best to make the holes and slots fairly deep, say

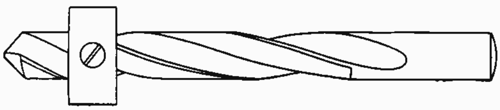


Fig. 1.
Drill fitted with collar to control drilling depth.

about $\frac{3}{8}$ in., so that the amalgam is kept well below the surface of the switch, and thus less likely to be knocked out, only just sufficient amalgam being used to ensure a good contact. Any standard type of terminal will answer, and the screw should be just long enough for the tip to enter the cups and troughs. Fig. 2 shows in section a cup with the screw inserted.

If ebonite is used for the bases, the hole should be drilled and tapped, the terminal screw being dipped in shellac varnish and screwed up tight. The varnish, when set, will prevent any tendency for the screw to turn, and also will seal it to the ebonite and prevent any creeping out of the mercury. If taps are not available, the hole should be drilled slightly smaller than the terminal screw, the screw being warmed and inserted. The ebonite will become pliable when warm and will set firmly around the thread when cold.

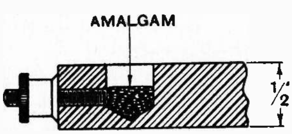


Fig. 2.
Section showing the cup and terminal making contact.

When wood bases are used, all the holes and slots should be made before they are impregnated with the wax, the holes for the terminal screws being made slightly smaller than the screw. These are inserted into the wood without any previous tapping, but they should be slightly warmed in order to melt the surrounding wax so that when cold they will be firmly sealed in. If the bases are not to be impregnated, the screws should be put in with shellac varnish in the same way as described for ebonite bases. The wood bases should previously have been well dried, and it will be advisable under these conditions to give them finally a good coat of shellac varnish all over.

The ends of all screws that project into the cups and troughs should be amalgamated with mercury before they are screwed into position; this will ensure the amalgam adhering to the screw to form a perfect electrical contact. The simplest method of doing this is to dissolve a very small quantity of mercury in a little nitric acid; dip the tip of the screw into the solution for a moment, and immediately wash thoroughly in water, when a fine deposit of mercury will be left on the part that was immersed in the liquid. The solution is very poisonous and must therefore be used with great care,

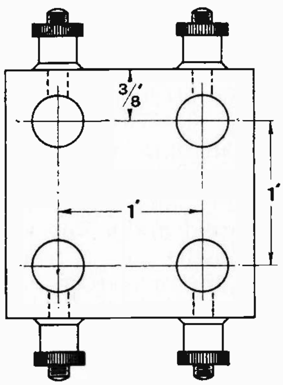


Fig. 3. *Plan view of base.*

and it should be kept in a glass stoppered bottle. If the ends of the screws have been lacquered, this must be cleaned off first, and should be kept free from grease until the amalgamating is done. If they are merely tarnished, the acid will remove that at the same time as the mercury is being deposited.

The four-cup base shown in Fig. 3 is probably the most simple, but at the same time it is an extremely adaptable type of connector. It consists of four cups at an equal distance from each other. Three types of connectors are used in connection with this base: a single, two-way of double-pole, and a two-way cross-over. The single way will be required in two sizes, one for straight over connections, the other for diagonal connections. These connectors can be made either of fairly stout copper wire, say about 14 S.W.G., or of copper strip, the latter being probably the easier to mount up for the double-pole and cross-over connectors.

Fig. 4 shows two methods of constructing the single-way connector, the one of copper strip with an ebonite knob, the other of copper wire with a Systoflex sleeve. It is not absolutely essential to insulate the simple connectors, but it is preferable, as earthing through the body is avoided when making changes; also, where high voltages are used, there is less chance of a shock.

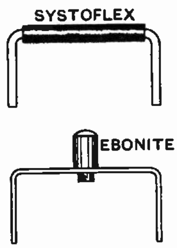


Fig. 4.
Single way connectors.

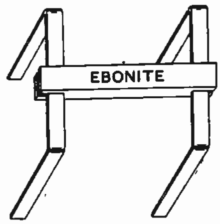
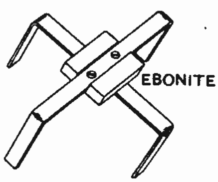


Fig. 5.
Double way connector.

Fig. 5 shows a simple double-way connector. The easiest way to mount these is to cut a slot with a fine hack saw in the end of the ebonite cross piece which will just take the strip; this can be held in by shellac, or better, can be drilled and pinned. If copper wire is used, a small hole should be drilled in which the wire makes a tight fit, being held with shellac or pinned.



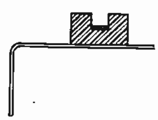


Fig. 6. Fig. 6*a*.
Cross-over connectors.

Fig. 6 shows a cross-over connector, Fig. 6*a* showing the method of mounting. A small square of ebonite about $\frac{1}{4}$ in. thick has one limb fixed to the under side, the other being fixed to the upper side, which is better recessed to take it, so as to keep it well insulated from the body when handling. The ends of all connectors should be amalgamated where they enter the mercury cups and troughs, about $\frac{1}{8}$ in. being quite sufficient.

It will be seen that any pair of cups can be connected by means of the single connec-

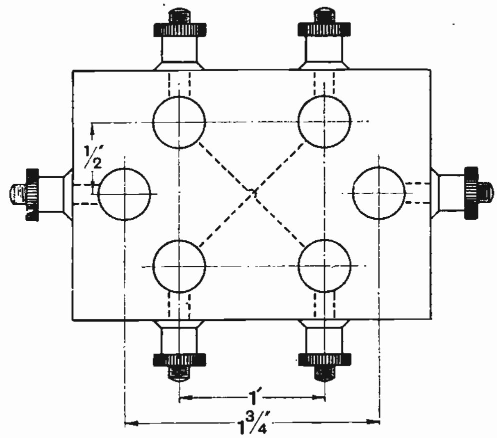
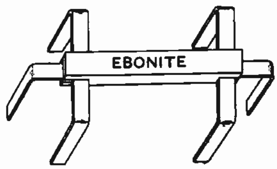


Fig. 7. *A six cup base.*

tors, so that circuits can be put in series or parallel or disconnected at will. Using the double connector it becomes a double-pole switch in either direction, and with the two-way cross-over it can be employed as a reversing switch.



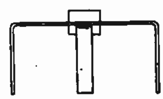


Fig. 8. Fig. 8*a*.
Special forms of connector.

Fig. 7 shows another type of base containing six cups, with which a special type of connector is usually employed. This combination can be obtained commercially from any firm supplying physical apparatus, and

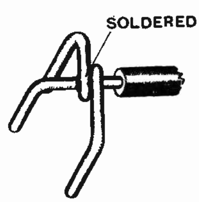


Fig. 9.
Connector formed of wire.

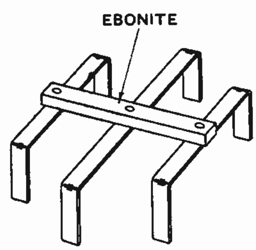


Fig. 10.
Diagonal connectors.

is known as a Pohl Commutator. The construction of the special connector is shown in Figs. 8 and 8*a*. It is somewhat similar to the double connector shown in Fig. 5, except that an extra limb is attached at each end,

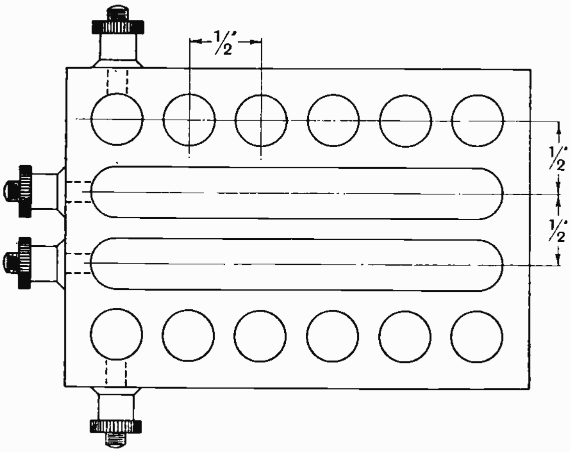


Fig. 11. *A simple type of connecting board.*

these being in electrical contact with the crossing limbs. These outer limbs act as a pivot for the connector, which is rocked over from one position to the other so that very rapid changes can be made.

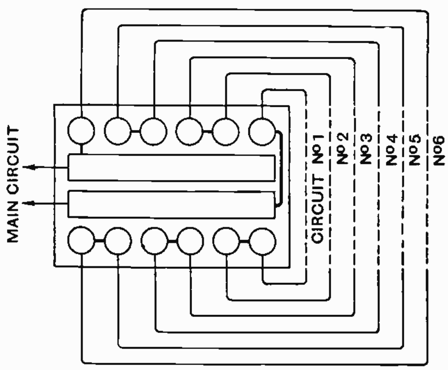


Fig. 12*a*. *Indicating the method of inserting connectors with all circuits in series.*

Fig. 9 shows a method of constructing a connector of this type with wire, the cross limb being a single twist around the end limb and soldered. The soldered portion must be well covered with enamel or paint to keep it from contact with the mercury, which would quickly act on the solder and spoil the joint. By connecting diagonally the two inner pair of cups with two single connectors, as shown by dotted line in Fig. 7, and still utilising the throw over, it becomes a double-pole reversing switch. The connectors described for the four-cup base can be utilised with this base, and a further type that will be found very useful is shown in Fig. 10, making diagonal connections and also making a good reversing device.

Fig. 11 shows a simple type of connecting board, in this case for six pairs of cups with two main troughs. Any pair of cups can be connected singly or in parallel to the troughs, or the cups can be arranged in series or series-parallel and connected to the troughs. Fig. 12*a* shows the manner of inserting the connectors for connecting all circuits in series, Fig. 12*b* all circuits in parallel, and

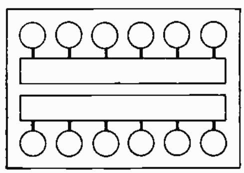


Fig. 12*b*. *Circuits in parallel.*

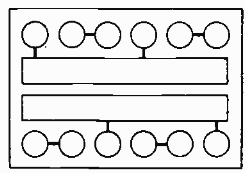


Fig. 12*c*. *Three circuits in series, paralleled to the cups.*

Fig. 12*c* three circuits in series, paralleled to the troughs. The external circuits have been omitted in Figs. 12*b* and 12*c*, but they would be the same as in 12*a*.

In conclusion, it might be mentioned that for small automatic switches or relays, mercury contacts are exceptionally good. They can be manipulated with very small forces, having practically no contact friction, especially if pure mercury is used, and quite heavy currents can be dealt with in the switching circuit if required. If currents are heavy enough to cause sparking, such as in the break of a highly inductive circuit, the cups can be filled up with paraffin which will prevent the contacts from burning.

Book Reviews.

OSCILLOGRAPHS. By J. T. Irwin, M.I.E.E. pp. 164 +xii. Pitman, 7s. 6d.

No one is better fitted than Mr. Irwin to write an authoritative book on this subject. For many years as a lecturer at the Central Technical College, as it was then called, he devoted his energies and his great experimental skill to improving the known types and devising new types of oscillographs. In the laboratory at South Kensington, oscillographs were always in daily use and senior students were always being initiated into new developments in hot-wire and electrostatic oscillographs or new ways of damping or otherwise controlling instruments of the Duddell type. The book under review is the long promised fruit of these activities, written in a simple style and covering the whole field of oscillographs, their theory, construction and use. The recent developments in Cathode Ray oscillographs are described fairly fully in a concluding chapter. There is a bibliography of the subject which should prove useful to those wishing to consult the original papers. The book is very fully illustrated.

G. W. O. H.

DIE AUDIONRÖHRE UND IHRE WIRKUNG. By Dr. Gustav Liebert (Berlin, Hermann Meusser), pp. xiv.+126, with 66 Figs., M.5.80. (6 sh.)

This volume forms the fifth of a series on " Die Hochfrequenztechnik," edited by Dr. Carl Lübben. This is an admirable book on the principle, construction and use of the valve. It is intended for amateurs, but for those amateurs who wish to learn more of the subject than is given in the more popular books. At the same time, it is mainly non-mathematical. It is very clearly written and well illustrated and can be recommended to anyone with the necessary knowledge of the language. The book is divided into five sections, entitled " The Electromagnetic Wave," " Application of the Valve," " Properties of the Valve," " Principles of Operation," " Technical Construction and Use of Valves."

We have not read a better discussion of the relative advantages and disadvantages of the various types of valves now available, nor of the precautions which should be taken in using the various types.

The book concludes with a table giving the principal characteristics of the valves most in use by German amateurs. As this will undoubtedly be of great interest to English readers, we reproduce the table on the next page.

G. W. O. H.

ELECTRICAL ENGINEERS' DATA BOOKS. Vol. III. Radio Engineering with Special Sections on Telegraphy and Telephony. Wedmore and Reyner, pp. 258+cxciv.+xxii. 15s. Ernest Benn.

This volume is intended to be " a handy volume of reference which will be indispensable to everyone concerned with the technique of radio." It is made up as follows: Lists of contents and illustrations, 22 pages; Radio Data, 218 pages; Telegraphy and Telephony, 40 pages; Mathematical and Miscellaneous Tables, 42 pages; Electrical, Mechanical and Physical Tables, etc., 51 pages; Electricity and Magnetism, 30 pages; Wiring Rules, Regulations, etc., 70 pages. The book contains a lot of information, but the arrangement, indexing, type, etc., leave much to be desired. The last 70 pages appear to have little to do with the book under review and we do not know whether they are here under some strange idea as to the meaning of radio engineering or whether they have been dumped here for lack of room elsewhere in Vols. I. and II. The last three pages are headed Index to Vol. III.; but here again things are not what they seem, since the index only refers to the first 258 pages. Had the index merely ignored the wiring regulations, it would not have been so bad, but that it completely ignores the whole of Appendix A, containing 123 pages of electrical data, is very regrettable and quite inexcusable in view of the title of the book. As an example, we wished to look up the specific inductive capacity of ebonite and we searched the index for any reference to ebonite, or specific inductive capacity, or dielectric coefficient or constant, but all in vain. On writing to the author about it, he pointed out that it was in the book, but in the Appendix of data and therefore not in the index. The whole volume suggests a too hurried publication and a lack of care in checking data, in choosing suitable type—some of the mathematical data require a microscope to decipher them—in arranging tables and, above all, in a book of reference, in indexing. Tables should be numbered consecutively and not 37, 39, 38, 40, which is apt to lead the person wishing to calculate the resistance of a piece of copper wire from its weight in grains per yard—if there is such a person—to the conclusion that Table 39 has been omitted.

The book naturally contains a great amount of most useful information in the collection of which much time and trouble must have been taken, but it is a pity that a little more time and trouble were not expended in the final preparation of the volume.

G. W. O. H.

ERRATA.

April issue.

Page 245, 1st column, line 9 from bottom, *for* "dimming" *read* "dummy."

Page 247, 2nd column, line 22, *for* 8, *read* i_1.

PARTICULARS OF GERMAN AMATEUR VALVES.

(From *Die Audionröhre und ihre Wirkung*, by Dr. Liebert.)

No.	Type.	Maker.	Filament. Current.	Filament. Volts.	Filament. Watts.	Anode Volts.	Ampl. Factor.	mA per Volt.	Diff. Resist.	Uses.
				Tungsten Valves.						
1	RE 11 }	Telefunken	0.5	2.8	1.4	50–70	8.3	0.15	65,000	DRA
2A	RE 71 }									
2	"A" ...	,,	0.5	3.5	1.75	30–75	10.0	0.2	50,000	,,
3	"C" ...	,,	0.5	3.0	1.5	30–75	10.0	0.2	50,000	,,
4	VT 17 ...	Tekade ...	0.52	3.5	1.5	40–90	8.0	0.25	32,000	,,
5	LEA 229	Huth ...	0.5–0.6	2.4–3.1	1.5	40–90	9.0	0.20	45,000	,,
6	Valvo-normal	Müller ...	0.45–0.5	3.0–3.5	1.5	20–100	8.3	0.2	42,000	,,
7	LV 27/90K	Lorenz ...	0.55	2.9	1.5	45–90	8.7	0.25	35,000	,,
8	AR 23 ...	Loewe ...	0.45–0.50	3.5	1.5	50–100	7.1	0.25	28,500	,,
9	VT 106 ...	Tekade ...	0.5	4.5	2.2	50–150	12.5	0.4	31,000	DRAL
10	VT 49 ...	,, ...	1.1	3.6	4.0	220	14.3	0.5	30,000	L
11	RE 88 ...	Telefunken	1.0	4.0	5.0	40–100	8.3	0.3	28,000	,,
12	BF ...	S. & H. ...	1.1	3.5	4.0	220	14.3	0.5	30,000	,,
				Thorium Valves.						
13	{ RE 78 } RE 79 }	Telefunken	0.07	2.5	0.18	40–80	8.0	0.3	25,000	DRA
14	LA 74 ...	Loewe ...	0.06	3.0	0.18	50–100	10.0	0.25	40,000	,,
15	LA 75 ...	,, ...	0.15–0.17	2.0–2.5	0.35	50–100	10.0	0.25	40,000	,,
16	LA 101 ...	,, ...	0.3	3.8–4.0	1.2	60–200	12.5	0.8	16,000	,,
17	{ RE 83 } RE 89 }	Telefunken	0.2	2.5	0.5	50–100	5.0	0.4	12,500	,,
18	L 06 ...	Lorenz ...	0.06	2.2–2.5	0.15	30–90	6.7	0.25–0.3	25,000	,,
19	L 09 ...	,, ...	0.09	2.0–2.5	0.25	30–90	6.7	0.25–0.3	25,000	,,
20	Valvo-Reflex	Müller ...	0.3–0.35	1.5–2.0	0.6	10–100	4.2	0.5	8,500	,,
21	Valvo-Okonom H	,, ...	0.06–0.07	3.5–4.0	0.25	20–100	6.7	0.6	11,000	,,
22	Valvo 201A	,, ...	0.25–0.27	5.0–5.5	1.2	10–100	6.0	1.0	6,000	L
23	,, 201B	,, ...	0.3–0.32	3.5–4.0	1.2	10–100	6.0	1.2	5,000	,,
24	,, C ...	,, ...	0.32	4.0	1.2	60–140	10.5	1.0	10,500	,,
				Oxide Valves						
25	VT 105 ...	Tekade ...	0.15	1.1	0.15	40–90	8.3	0.25	28,000	DRA
26	VT 107 ...	,, ...	0.15	1.5–1.8	0.25	40–90	10.0	0.45	22,000	RA
27	VT 110 ...	,, ...	0.15	1.2–1.6	0.20	40–90	10.0	0.40	25,000	DRA
28	VT 111 ...	,, ...	0.15	3.2	0.50	50–120	6.7	0.60	11,000	DRAL
29	VT 112 ...	,, ...	0.07	2.5	0.18	40–90	9.0	0.40	20,000	DRA
30	{ RE 84 } RE 88 } RE 95 }	Telefunken	0.25	1.5	0.35	50–100	3.3	0.4–0.5	10,000	,,
31	{ RE 86 } RE 96 }	,,	0.2	1.5	0.3	50–100	12.5	0.4	30,000	,,
32	U 45 ...	Nickel ...	0.04–0.06	1.0–1.5	0.1	50–100	7.0	0.5	22,000	,,
33	U 110 ...	,, ...	0.15	1.8	0.3	50–100	6.3	0.4	16,000	,,
34	LE 244 ...	Huth ...	0.08–0.09	1.2	0.1	40– 90	10.0	0.25	40,000	,,
35	LE 245 ...	,, ...	0.2–0.23	0.9–1.0	0.2	50–100	9.0	0.20	45,000	,,
36	LE 251 ...	,, ...	0.56	1.5	0.8	60–200	7.0	0.80	9,000	L
37	LE 344 ...	,, ...	0.08	1.25	0.1	20–70	3.3	0.35	9,500	DRA
38	LE 252 ...	,, ...	0.50	1.8	0.9	200–220	14.3	0.55	27,000	L

NOTES.—Column 8. The amplification factors have been calculated from the "Durchgriff."
Column 9. This gives the slope of the grid-volts anode-current characteristic in milliamperes per volt.
In the last column, D=Detector, R=Radio-frequency amplifier, A = audio-frequency amplifier. L=Loud-speaker.

Correspondence.

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

Another Question of Nomenclature.

The Editor, E.W. & W.E.

SIR,—All readers of *E.W. & W.E.* will be grateful for Col. Edgeworth's letter in your March issue and your editorial in the same number. In venturing to supplement what has been said on this important subject, I am concerned solely to simplify a rather complicated situation.

It is obvious at the outset that any notation must be adequate to the purpose, compact, and self-explanatory. The concepts to be represented, too, must be clear-cut and defined. Looking at the problem, one is conscious of much confusion of thought, due partly to the ill-defined nature of some of the symbols in current use. In particular is this true of the symbol "j" which so frequently occurs in so-called "vector notation."

It is a desideratum that any conventional representation for impedance should be applicable equally to R.M.S. and instantaneous values of voltage and current. In this respect, I submit, the j notation is defective. If we apply the operator $R+jX$ to the current vector I, we obtain

$$(R+jX).I=IR+j.IX,$$

which represents the sum of the two vector quantities IR and IX, of which the first is in phase with I and the second 90° ahead. If, however, we take instantaneous values

$$(R+jX).I \sin \omega t=IR \sin \omega t+j.IX \sin \omega t$$

which according to convention is written

$$=IR \sin \omega t+IX \cos \omega t$$

we must conclude that

$$j \sin \omega t=\cos \omega t$$

a result which, on the assumption that $j=\sqrt{-1}$ is algebraically untrue. The symbol j is, in fact, an operator, and the equation $j=\sqrt{-1}$ is misleading without qualification.

I would urge for the consideration of readers the desirability of replacing the symbol j by the fractional operator D/ω, a notation first introduced by the late Dr. Heaviside, and developed with striking success by Dr. Eccles in his work on C.W. Telegraphy. Although the symbol D is, of course, the differential operator d/dt, there is no question of introducing calculus methods, as the uses of D are sufficiently defined by the equations

$$D \sin \omega t=\omega \cos \omega t$$

$$D \cos \omega t=-\omega \sin \omega t$$

whence $D^2=-\omega^2$

In this notation, for R.M.S. values we have,

$$(R+(D/\omega)X)I=IR+(D/\omega).IX.$$

With the convention that the operator D/ω applied to a vector rotates it positively through 90°, we have the same result as by using j.

Taking, however, instantaneous values,

$$(R+(D/\omega)X)I \sin \omega t=IR \sin \omega t+(D/\omega)IX.\sin \omega t$$

which, according to convention, is written

$$=IR \sin \omega t+IX \cos \omega t.$$

We have now the consistent relation

$$(D/\omega) \sin \omega t=\cos \omega t$$

agreeing with the defining equations given above.

The simplifications obtained by the use of this notation are enormous, not least among its advantages being the extreme ease with which the operators LD and $1/CD$ and their combinations may be handled. Its chief merit, in the eyes of the writer at any rate, lies however in the entire absence from the notation of any necessary reference to the imaginary unit.

For the impedance operator $R+\frac{D}{\omega}X$, we may write (Z, ϕ), the brackets indicating the operational character of the symbols, and avoiding any necessity for special type. The ohmic impedance Z associated with this operator is written without brackets and denotes the quantity $\sqrt{R^2+X^2}$, while ϕ is, of course, $\tan^{-1}\frac{X}{R}$. The impedance operator thus denotes the presence of both Z and ϕ, a useful reminder which will prevent confusion with Z alone.

May I here be permitted a reference to the final sentence of your editorial, in which you refer to both $\sqrt{R^2+X^2}$ and $R+jX$ as expressions for "impedance"? In my submission, the important distinction between the two calls for special recognition, and the terms "ohmic impedance" and "impedance operator" respectively would, I think, supplement the convenient symbolic expressions Z and (Z, ϕ).

In conclusion, it is well to remember that all questions of impedance can ultimately be expressed in terms of sine and cosine. The Heaviside operator enables us to shorten the work efficiently, and more important still, logically.

W. A. BARCLAY.

Murtle, Aberdeenshire.

The Editor, E.W. & W.E.

SIR,—Questions of nomenclature are partly questions of convenience and partly questions of usage, and they are necessarily matters of opinion. Your Editorial suggestion that the word impedance should be applied to all combinations of resistance and reactance has undoubtedly a good deal to recommend it.

The principal object of my letter, however, was to draw attention to the inconvenience which arises when the same word is used without qualification in several different meanings. The question, "What is the impedance of a circuit," should admit of only one answer and not of several answers. If, therefore, the word impedance is applied to the expression $[R+j(L\omega-1/C\omega)]$, it should be qualified by calling it operator impedance, complex impedance, or something of that sort.

The word operator does not appear to make a very happy adjective although it has no doubt been so used to a considerable extent.

K. E. EDGEWORTH.

Bexley Heath.

Valve Nomenclature.

The Editor, E.W. & W.E.

SIR,—May I endorse, with a reservation, Professor Howe's suggestion of the term "differential resistance" for what is frequently misnamed the "impedance" of a valve? It certainly should be called Resistance, implying that there is no phase-difference between current and E.M.F. (I believe the time-lag in an R valve with 70 volts on the anode is of the order of 2×10^{-9} seconds); but I would suggest "Slope-resistance" as an improvement, because :—

(A) It is shorter to say or to write.

(B) It may claim priority of use. ("Slope-Conductance" was used in 1921, *Wireless Telegraphy and Telephony*, L. B. Turner.)

(C) "Slope" is a less terrifying and mysterious word than "Differential" to the non-mathematical mind.

With reference to Col. Edgeworth's letter in the March issue, "Complex Resistance" is, I suggest, definitely wrong; "Resistance" implies no phase-difference between P.D. and current; it must be something which, when multiplied by the square of the current, gives power (I^2R). "Complex Impedance," is the proper term for $R+j(\omega L—1/C\omega)$. (See, for example, Prof. Kennelly's "The Application of Hyperbolic Functions to Electrical Engineering Problems.")

Col. Edgeworth's own definition of "Impedance" as "The terminal voltage of an A.C. circuit divided by the current" leads, indeed, to a complex quantity, unless the voltage and current are in phase (when the "impedance" reduces to a pure resistance).

For, let $e=E.\cos \omega t = E.\epsilon^{j\omega t}$ be the terminal voltage; and let $i=I.\cos(\omega t-\phi)=I.\epsilon^{j(\omega t-\phi)}$ be the current; then the expression for "impedance" by Col. Edgeworth's definition is :—

$$\text{Impedance}=\left(\frac{E}{I}\right)\epsilon^{j(\omega t-\omega t+\phi)}=\frac{E}{I}\epsilon^{j\phi}=Z\epsilon^{j\phi}=\mathbf{Z}.$$

The part of this expression E/I represents the numerical value of the impedance, no regard being paid to phase-difference; it is the "Modulus" of the complete expression; while the part $\epsilon^{j\phi}$ signifies that the terminal voltage leads the current by an angle ϕ, it is the "argument" of the complete expression.

Strictly speaking, therefore, the word "impedance" alone should refer to the complete complex expression, it might be referred to at greater length as the "Complex impedance"; while the term "Modulus impedance" might be used for E/I; though unless confusion is likely to arise in any particular case, the simpler word Impedance may well be used for both, as at present.

In any case, when using symbols, it is easy to print all vector or complex quantities in Clarendon type $\mathbf{Z}$ (or in manuscript to overscore, $\overline{Z}$); using ordinary Roman or Italic Type (Z, z) for quantities essentially real, or for moduli; and, after all, it is more important for symbols to be unambiguous than for words, for symbols are a universal language.

C. R. COSENS.

Cambridge.

Transformer Curves.

The Editor, E.W. & W.E.

SIR,—After reading Mr. Appleton's further letter in the January issue of *E.W. & W.E.*, may I be allowed to give my views on the subject? I have no commercial interest in any components.

I can bear out Mr. Appleton's statement that with *extremely weak* input values, resistance coupling will actually give greater amplification than transformer coupling. However, Mr. Appleton seems to admit that the amplification factor of a well-designed intervalve transformer does not fall off appreciably until the input values become *minute*. Now, who on earth would think of L.F. amplification under these conditions for Broadcast reception? In order to obtain efficient and distortionless rectification by means of crystal or anode rectification, it is necessary to have a good H.F. amplitude, sufficient in my opinion to give good phone strength without L.F. amplification. In these circumstances I think Mr. Appleton's contention that minute input values are all important falls to the ground. If grid rectification is used, I do not think that quality in the L.F. amplifier is of great importance. There is another point we must not overlook, that is the steady magnetising current in the anode circuit, which surely brings the permeability to a reasonable value.

Derby. H. H. DYER.

Power Loss in Condensers.

The Editor E.W. & W.E.

SIR,—I have read Mr. Hartshorn's excellent article on "Power Loss in Condensers" with great interest, but am still in the dark in regard to certain points in the measurement of the power factors of air condensers at radio frequencies. I should therefore like to put the following question :—

Has the power factor of an air condenser of capacity less than 200$\mu\mu$F ever been measured at radio frequencies without assuming another air condenser free from loss?

I am aware of Mr. Wilmotte's work (*Proc. Roy. Soc. A.*, Vol. 109, p. 508, 1925), in which he measures the losses in mercury coils apart from the losses in an associated condenser and thence deduces the losses in the condenser, etc.; but if I have interpreted his results correctly, the method has only been applied to condensers of capacities greater than about 600$\mu\mu$F.

Claygate, Surrey. S. BUTTERWORTH.

From the World's Wireless Journals.

Abstracts of Technical Articles.

R000.—WIRELESS IN GENERAL.

R038.—DEFINITIONS OF TERMS, ETC., USED IN RADIO ENGINEERING. (*Supplement to Proc. I.R.E.*, February, 1926.)

This is a report of the Institute's Committee on Standardisation for 1926. It is in the form of 240 definitions of terms used in radio engineering, arranged under the headings, (1) Waves and Wave Propagation; (2) Transmitting; (3) Receiving; (4) Vacuum Tubes; (5) Circuit Elements and Properties; (6) Antennæ; (7) Direction Finding. Standard Graphical Symbols are also illustrated.

R100.—GENERAL PRINCIPLES AND THEORY.

R113.—TRANSATLANTIC RADIO TELEPHONE TRANSMISSION.—Espenschied, C. N. Anderson and A. Bailey. (*Proc. I.R.E.*, February, 1926.)

A report upon two years' measurement of Transatlantic signals, etc., preparatory to the arrangements for commercial telephony. The measurements were initiated to show the conditions obtaining throughout the twenty-four hours of the day and the various seasons of the year. The work was done under the auspices of the American Telephone and Telegraph Company, The Bell Telephone Laboratories, and the Radio Corporation of America on the United States side, and on the British side by the International Western Electric Company and the G.P.O. In America measurements were made at three stations on signals from Northolt on 52,000 cycles, and from Leafield on 34,130 cycles and 24,050 cycles. In England, measurements were made at New Southgate and Chedzoy, Somerset, on the transmissions from Rocky Point 2XS on 57,000 cycles, Marion WSO on 25,700 cycles and Rocky Point WQL on 17,130 cycles.

Data are available from 40,000 individual measurements, and have been subjected to careful analysis to disclose what physical factors affect radio transmission.

Curves of the field strength for 24 hours received at America and at England are shown. These are seen to be subject to substantially the same decimal variation and the conclusions drawn are: (1) Relatively constant field strength prevails during the daylight period; (2) A decided drop accompanies the occurrence of sunset in the transmission path; (3) The advent of night time conditions causes a rapid rise to high values, which are maintained until daylight approaches; (4) The encroachment of daylight on the eastern terminal causes a rapid drop. This drop sometimes extends into a morning dip similar to, but smaller than, the evening dip. After this, relatively steady daylight strengths again obtain. Monthly average curves for all months of the year are shown, the chief features shown being: (1) The continuance of the high night-time values throughout the year; (2) The persistence of the night-time values for a longer period in winter than in summer; (3) Daylight values show comparatively small range of variations; (4) The extreme range of variation between the minimum sunset dip and the maximum night value is 1 to 100 in field strength, or 1 to 10,000 in power ratio.

General consideration of the results gives a transmission formula of the usual form, but with the constants shown as compared with other values (due to Sommerfeld, Austin-Cohen, Fuller, etc.). This may be written in the usual form

$$E\,(\mu v/m) = \frac{377HI}{\lambda D}\,\varepsilon^{-\frac{0.005D}{\lambda^{1.25}}}$$

or in terms of power.

$$E = \sqrt{P}\,\frac{298\times 10^3}{D}\,\varepsilon^{-\frac{0.005D}{\lambda^{1.25}}}$$

Where P is radiated power in kilowatts, D distance and λ wavelength, both in kilometres.

A correlation was sought between wireless transmission and the earth's magnetic phenomena, and result curves are given, showing close correspondence.

The paper next considers atmospheric measurements. Curves are shown for U.S.A. and for England of the atmospheric strength received on three different wavelengths. The distribution of light and dark over the communication path is very fully considered and it is concluded that the major source of atmospheric disturbance on long waves, both in England and in U.S.A., is indicated to be of tropical origin. In general the disturbance due to Xs is less on the higher frequencies, *i.e.*, shorter wavelengths. At night the decrease with increase of frequency is exponential. In daytime, the decrease with increase of frequency is linear in the range of 15 to 40kC. The difference between day and night is apparently due largely to daylight attenuation.

The ratio of signal to atmospheric is then dealt with. It is concluded that the effect is generally similar on both sides of the Atlantic. Curves are given for results on 5,700 and on 17,130 cycles. It is noticeable that although the latter (*i.e.*, longer wavelength) gives generally lower ratio of signal to atmospheric, it is more level and stable.

Lastly, experiments are described on both sides on the use of a Beverage antenna in place of an ordinary loop. Result curves show an average improvement in the Signal to Atmospheric ratio of about 5 as compared with loop reception. Test of percentage reception of disconnected words understood also shows considerable improvement.

A large number of signal strength curves is appended.

R113.—SOME STUDIES IN RADIO BROADCAST TRANSMISSION.—R. Brown, De L. K. Martin and R. K. Porter. (*Proc. I.R.E.*, February, 1926.)

An abstract of this paper—prepared from the account given in the *Electrician* of 12th February. 1926—appeared in *E.W & W.E.* for April, 1926.

R113.—SUR LA PROPAGATION DES ONDES COURTES EMISES À BORD DU "JACQUES CARTIER."—General Delcambre and R. Bureau. (*Onde Elec.*, February, 1926.).

The paper described extensive observations on transmissions (chiefly of meteorological messages) from the *S.S. Jacques Cartier*, on waves of 115 metres downwards. Six voyages were made as follows: (1) 30th October, 1924—31st January, 1925. Bordeaux to Panama, Vancouver, Panama to Le Havre—115 metres; (2) 20th February—4th April, 1925, Le Havre, Galveston, Pensacola, to Le Havre—115, 62, and 48 metres; (3) 26th April—11th May, 1925, Le Havre to Mobile—115 and 31 metres; (4) 24th May—9th June, 1925, New Orleans to Le Havre—115, 31 and 21 metres; (5) 10th—30th August, 1925, Le Havre, Mobile, Le Havre,—31 metres; (6) 26th October—17th December, 1925, Le Havre, Pensacola, Galveston to Le Havre—31 metres.

In the second section of the paper is considered the effects of the time of day. About sunrise in France there was generally an interruption of the reception from great distances. A table shows the steadiness of this effect as noted for 10 successive days on one of the voyages. The most unfavourable time was about mid-day, "as if" (to quote the authors) "the local meridian was an obstacle to propagation. The reappearance in the afternoon or evening seemed to vary within wider limits than the disappearance of the morning, and seemed also to depend more on the wavelength. In a section on geographical influences, it is stated that the north and south regions of transatlantic transmission show different characteristics. A great circle from Paris to south of the Banks of Newfoundland, Cape Hatteras and Florida to the Gulf of Mexico shows roughly the line of division. South of this the transmissions on different wavelengths were easily received in France; north of this they were either not received or received irregularly.

In the last section, reference is made to the fact that the same transmission from the ship was very differently received by different receiving stations, sometimes being subjected to considerable variation in the course of a single meteorological message. The actual transmissions being held steady, this is attributed to deformation of the waves in transit. Considerations of the appearance and disappearance at certain points suggest that this effect travels or migrates with a velocity of the order of 60 kilometres per hour. This is the mean rate of propagation of meteorological phenomena and the need for correlation between meteorological and radiotelegraphic observations is urged.

R113.1.009.—THE MYSTERY OF FADING. Dr. O. Hall. (*E.W. & W.E.*, April, 1926.)

R114.—THE PRESENT STATUS OF RADIO ATMOSPHERIC DISTURBANCES.—L. W. Austin. (*Proc. I.R.E.*, February, 1926.)

A short review of the present position of knowledge of atmospherics. References are made to various recent works on atmospherics in America and Europe, especially to work of the Radio Research Board. It is stated that the differences of opinion mentioned in the paper show that there is still much to be done on the subject. The author sums up the position as follows: (1) In general, atmospherics are stronger at the longer wavelengths; (2) Except for local storms, they are nearly always stronger in the afternoon and night, while for the higher frequencies this increase is confined usually to night alone; (3) They are stronger (*a*) in summer than in winter, (*b*) in south than in north, (*c*) on land than on sea; (4) A large proportion are directive, *i.e.*, to come from definite regions, such as mountains, rain areas or thunderstorms. It is also reasonably certain that: (5) Most of the long wave disturbances travel along the earth with a practically vertical wave front; (6) A considerable portion are oscillatory in character, though a certain portion are non-oscillatory and give short excitation at all wavelengths; (7) Disturbances sometimes occur simultaneously at stations thousands of miles apart.

R141.1—NOTES ON WIRELESS MATTERS. STEADINESS IN TRANSMITTER FREQUENCY.—L. B. Turner. (*Electrician*, 12th March, 1926.)

The article deals with the need for steadiness in transmitter frequency to prevent interference effects. After briefly reviewing the general use of resonance as applied to a spark transmitter, the writer considers the case of a modern C.W. transmitter working at hand speed. It is shown that with a receiver circuit decrement of 0.005, the signal strength is halved by a distune of 0.14 per cent., hence a C.W. transmitter should not vary in frequency by as much as this value. Additional consideration of heterodyne note and the L.F. end further demands great steadiness. The cases specifically considered are about 15,000 metres, which is a very congested region in the commercial spectrum. A frequency difference between stations of only 200 cycles per second may be allowed. The effects of frequency variations from a desired station and one or two jamming stations is then illustrated numerically and it is concluded that stations of such wavelength should not wander in frequency by anything like 20 cycles, *i.e.*, 0.1 per cent. The article concludes by describing a recent German method of measuring fluctuations of frequency. Measurements were made on 39 transmitting stations; 10 to 12.5 cycles per second is regarded as the largest permissible frequency wandering, irrespective of wavelength, corresponding to 0.05 per cent. at 15,000 metres. Taking this permissible maximum as 100 per cent., about half the stations showed under 50 per cent.; the maximum variation was 208 per cent. for Grodno, and the minimum 22 per cent. for Kootwijk.

R144.—HIGH FREQUENCY RESISTANCE.—P. K. Turner. (*E.W. & W.E.*, March, 1926.)

R144.—EFFECTIVE RESISTANCE OF INDUCTANCE COILS AT RADIO FREQUENCY. PART I.—S. Butterworth. (*E.W. & W.E.*, April, 1926.)

R145.5.—POWER LOSS IN CONDENSERS.—L. Hartshorn. (*E.W. & W.E.*, April, 1926.)

R200.—MEASUREMENTS AND STANDARDS.

R201.—AN EXPERIMENTER'S WIRELESS LABORATORY—L. A. Sayce and J. Taylor. (PART II.—*E.W. & W.E.*, March, 1926. PART III.—*E.W. & W.E.*, April, 1926.)

R208.6.—A METHOD FOR GENERATING AND MEASURING VERY WEAK RADIO-FREQUENCY CURRENTS.—W. van B. Roberts. (*J. Franklin Inst.*, March, 1926.)

The chief method described is based on the fact that when two oscillatory E.M.F's are impressed in series upon a circuit containing an assymetric conductor (a detector) or its equivalent, the resulting current contains in general components of the following frequencies: (A) Zero frequency or D.C.; (B) Twice each of the impressed frequencies; (C) The sum of the impressed frequencies; (D) Their difference. It is shown (in an appendix) that under certain conditions, a simple relation exists between the value of the D.C. component and that of the frequency difference component or "beat frequency," and that the

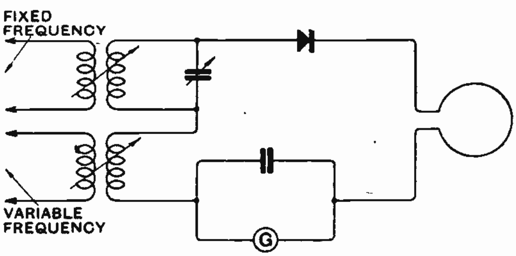


Fig. 1.

amplitude of this beat frequency may be accurately inferred from measurement of the D.C. component. One frequency may be kept constant and the other varied to produce beats, 3,000kC being quoted as a convenient fixed frequency with which the variable can produce beats up to 1,000kC. The fixed frequency may be modulated if necessary. Fig. 1 shows a simple scheme of applying the arrangement, while a further arrangement, using an amplifier in each component and a valve rectifier, is also illustrated in the paper.

An alternative arrangement is also illustrated and described, using only one oscillatory frequency. It is shown that rectification will then produce a double frequency current, whose value is approximately equal to that of the D.C. current, and this double frequency component is used as the desired current. A third arrangement is also described using rectification in the grid circuit of the generating valve, and employing the second harmonic as the desired frequency.

It is concluded that for the production of the very smallest currents the first system is complex but ideal, while the last, due to its simplicity, should be valuable in portable measuring sets.

R240.—INDUCTANCE COILS QUANTITATIVELY COMPARED.—A. L. M. Sowerby. (*E.W. & W.E.*, April, 1926.)

R251.5.—A VERSATILE GALVANOMETER.—*Electrician*, 5th March, 1926.)

A description of the "Versatile" galvanometer and its accessories. The instrument is of the well-known Paul "Unipivot" pattern (made by the Cambridge Scientific Instrument Co.). Details are given of the constants of the instrument and the volt range and ampere range multipliers available. Ranges of 0.24 volt to 600 volts and of 0.012 amp to 24 amps are possible. Details are also given of available thermo-junctions for A.C. measurements, and mutipliers given ranges of A.C. voltage from 1.2 to 120 volts and A.C. currents from 1.2 to 24 amps.

R300.—APPARATUS AND EQUIPMENT.

R321.—RADIO RECEIVING AERIALS.—P. D. Tyers. (*Elect. Review*, 26th March, 1926.)

The writer draws attention to the carelessness frequently displayed in the erection of an aerial, and emphasises the points to be noted in the erection and leading in to the set.

R330.—LES PROGRÈS RÉCENTS DANS LA CONSTRUCTION DES LAMPES À PLUSIEURS ELECTRODES.—R. Jouaust. (*Onde Elect.*, March, 1926.)

A lengthy paper on the present position of the valve. The general principles of thermionic emission are first discussed, and the laws of emission traced from Richardson's fundamental equation. The function of thoriating is then considered, and the process of thoriation described. The powerful emission is not due to the properties of thorium but to the difference of potential at the thorium-tungsten surface of contact, which facilitates the emission of electrons. The thorium surface is very sensible to traces of gas in the bulb, which produces ionisation, the positive ions bombarding the filament and tending to destroy the thorium coating. The necessity for the removal of all gas from the electrodes, etc., is considered, and the use of magnesium as a "getter" is described. It is pointed out that for valves of the same geometry the characteristic with a thoriated filament is not exactly the same as that with a tungsten filament. The contact potential difference in the former case has the effect of moving the characteristic to the right by an amount equal to about 1.5 volts of grid potential. The general properties and behaviour of dull emitter filaments are considered reference being made to various recent fundamental tests.

Valve noises are then considered, with their effect in limiting amplification. The noises are distinguished as (A) "a continuous breathing like the sound of waves," (B) crackles. The former is attributed to traces of gas remaining in the valve. The cracklings seem to proceed from the filament, and have also been attributed to inequalities of electron absorption by the grid. The Schottky effect is discussed in some detail. This suggests that abrupt changes of anode current are not due to accidental causes, but constitute a physical phenomenon characteristic of thermionic emission. Secondary emission is then considered at some length. The literature on the subject is contradictory, and experimental tests with different valves give widely different results. The general effects of initial velocity, space charge and secondary emission are reviewed. Excessive grid potential is undesirable, resulting in heating of the grid without increase of anode output. It is pointed out that the maximum grid voltage should never exceed 80 per cent. of that of the anode.

The paper next deals with very short waves generated by means of the valve. Experiments by Professor Whiddington in 1919 are referred to when oscillations corresponding to 77 centimetres wavelength were generated *within* a soft valve. Similar results have been found possible with hard valves. Work of Barkhausen and Kurz in Germany, and of Gill and Morrell in England, are discussed. (Certain of the latter work has already been described in *E.W. & W.E.* for October, 1923.) The presence of oscillations was evidenced and their wavelength measured by Lecher wires. The wavelengths were of the order of 2 metres. The theory of the effects involved is discussed. A short note then follows on the effect of traces of gas in giving irregularity of characteristic, followed by a very brief note on the double-grid valve. The last section deals with new patterns of valves, etc. Large power valves with water-cooled metallic anodes are described, and the design of a stranded thoriated filament for transmitter valves is discussed. Finally a few remarks are given on the use of valves for short wave (*e.g.*, 20 metre) transmitters.

R342.5.—A Power Amplifier for the Low Powered Transmitter.—R. P. Turner. (*Q.S.T.*, March, 1926.)

The writer refers to the unsteadiness of amateur transmission frequencies, and emphasises the need for using a master-oscillator with a power-amplifier working to the aerial. The master-oscillator and power-amplifier elements are described. The oscillator is a Hartley circuit, with the operating key. The power amplifier is of conventional circuits, the inductance of the master oscillator being coupled to a coil in the grid circuit of the amplifier. A closed oscillatory circuit is included in the anode in the usual way and coupled to the aerial. The circuits described are for 40 metres, and details of components are given.

R342.5—Neutralising the Crystal Amplifier. —J. M. Clayton. (*Q.S.T.*, March, 1926).

It is stated that requests have been received for information as to the stabilising of the power-amplifier in a crystal controlled transmitter. The arrangement now described and illustrated is effectively that shown in Abstract "Practical Crystal-Controlled Transmitters" in *E.W. & W.E.* for March, 1926, (p. 192), where C_6 of .00025μF maximum capacity is shown as a neutralising condenser. The method recommended for determination of the correct adjustments for neutralisation is to insert in the closed oscillatory circuit of the Amplifier a thermal meter of 25 to 50mA maximum. Cut off the anode voltage of the amplifiying valve but leave the filament lit. The milliameter will probably show some deflection, indicating that there is "pick up" from the crystal oscillator. C_6 and the tapping on the inductance should be varied until there is no deflection on the milliammeter.

R342.7.—Note sue un Récepteur à Réglage Automatique. — J. Abelé. (*Onde Elec.* March, 1926.)

After reviewing the disadvantages of the usual arrangements of high frequency coupling and reaction, the author describes the circuit shown in Fig. 1 as a convenient method giving independence of tuning and of reaction controls. As the L_2C_2 circuit is independent of reaction adjustment, it can be calibrated and used as a tuning standard in the receiver. A milliammeter in the detector anode circuit affords control of the reaction condenser C_4, and permits tuning of the aerial to that of L_2C_2. This circuit can be set to a desired wavelength and oscillated by sufficient reaction. This

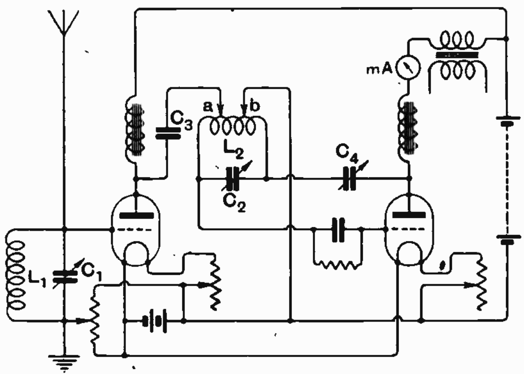


Fig. 1. *Récepteur réglage automatique.*

can be checked by extinguishing the first valve, the milliammeter dropping when L_2C_2 is oscillating, and returning to its normal reading on relighting the valve. The aerial can then be tuned until the milliammeter is again a minimum, when the aerial is in tune with L_2C_2. Reaction can then be loosened to eliminate self oscillation for the reception of telephony, or to a weaker oscillation for the autoheterodyne reception of C.W. signals.

R342.7.—A Modern Regenerative Receiver.— F. Anderson. (*Q.S.T.*, March, 1926.)

The receiver described is a "straight" three valve set, using a detector with reaction from its anode, and followed by two L.F. stages. Plug facilities are provided for the use of one or of three valves. The aerial is aperiodic and coupled to a tuned secondary. Details of construction are given, including a schedule of parts, panel lay-out, coil dimensions, etc.

R342.7.—LE RÉGLAGE DE LA RÉACTION DANS UN RÉCEPTEUR À CADRE.—E. Fromy. (*Onde Elec.*, February, 1926.)

It is pointed out that with a frame aerial the use of reaction is delicate and difficult in practice. The circuit shown in Fig. 1 is given as a suitable solution.

It will be seen that this turns the frame aerial *LC* into a self-oscillating system, whose oscillations can be controllably damped-out by the damping circuit (" amortisseur ") consisting of the resistance

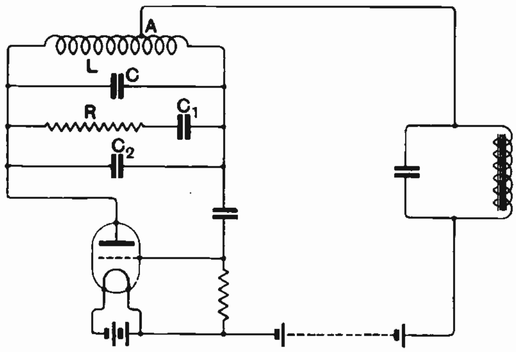


Fig. 1.

R and condenser C_1. Variation of C_1 varies the energy consumption in *R*, and therefore the damping of *LC*. A further condenser C_2 is preferably placed across the damper to compensate for change of tune, C_1 and C_2 being varied in opposite senses so that their total capacity remains constant. The controls of tune and of reaction are said to be practically independent of each other over a large tuning range.

C_1 and C_2 should be small condensers of about 0.0001μF maximum if used with a frame tuning condenser *C* of about 0.001μF maximum. The value of *R* may vary within wide limits, depending on C_1 and the position of the tapped point *A*. If *A* is near to the limit of extinction of oscillation, feeble damping will suffice and *vice versa*. A non-inductively wound coil of 2,000 ohms is stated to have been found suitable. The position of *A* is guided by the conditions that without the damper the circuit should oscillate at all values of the tuning condenser but the oscillations should be as weak as possible in order that they may be extinguishable by the damper. For a frame of 1 metre side the following typical positions are quoted.

Total	turns	35,	Anode	circuit	3,	Grid circuit 32.
,,	,,	18,	,,	,,	3,	,, ,, 15.
,,	,,	9,	,,	,,	2,	,, ,, 7.
,,	,,	6,	,,	,,	2,	,, ,, 4.

Grid condenser and leak are of the customary values.

R344.—FREQUENCY VARIATIONS IN THERMIONIC GENERATORS.—Lt.-Col. K. E. Edgeworth. ((*J.I.E.E.*, March, 1926.)

Paper read before the Wireless Section, I.E.E., on 6th January. A lengthy abstract appeared in *E.W. & W.E.* for February, 1926.

After considering some properties of mechanical oscillating systems, *e.g.*, a pendulum, the author discusses the phase relationships of current and voltage in a valve oscillator, and shows that the frequency is affected by the nature of the coupling between the grid and anode circuits. Various types of coupling are considered, *i.e.*, normal inductive coupling, reversed coupling, capacity coupling and resistance coupling, and expressions for frequency derived. The design of an oscillator using the resistance method of coupling is then discussed, with practical notes on the adjustments. The next section deals with the design of an oscillator employing reversed coupling, the arrangements recommended being such as to employ part inductive and part capacitative coupling. The paper finally illustrates experimental results obtained with different types of circuit, and compares the characteristics of various types of constant-frequency generator.

R345.—LA RÉGULATION AUTOMATIQUE DE LA MODULATION DANS LES STATIONS D'EMISSIONS RADIOTÉLÉPHONIQUE.—O. de l'Harpe. (*Radio Electricité*, 25th February, 1926.

A description of a scheme of automatic regulation of modulation for broadcast transmission, stated to be in satisfactory operation at the station Radio Toulouse. It is pointed out that fortissimo and pianissimo passages, for example, call for different degrees of amplification, and that this has to be under the control of an operator.

The arrangement described makes this control automatic. It consists in interposing in the modulation amplifier an intermediate circuit containing a device whose resistance is not constant but is greater for higher voltages applied to it. The device used is a metal filament flash lamp bulb, whose resistance is shown in a curve to be about

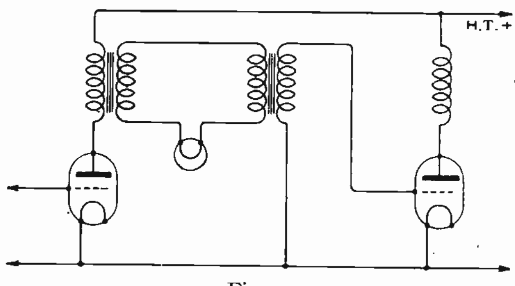


Fig. 1.

1.5 ohms when cold (or under very small applied voltages), and in the neighbourhood of 16.5 ohms when 3.5 volts are applied to it. The essentials of the scheme are shown in Fig. 1. The actual modulation arrangements used at Radio Toulouse are also illustrated, several lamps being used in parallel.

R351.218.—THE PIEZO ELECTRIC EFFECT AND ITS APPLICATION TO WIRELESS.—PART II.—C. W. Goyder. (*E.W. & W.E.*, March, 1926.)

R381.5.—PERFECTIONNEMENT DANS LES CONDENSATEURS VARIABLES.—C. Guével. (*Onde Elec.*, March, 1925.)

A note on a new pattern of slow-motion dial and control. Multiplications of 8, 12 and 18 are possible. The arrangement is also applicable to the motion of variometers, reaction controls, etc.

R386.—ESSAI SUR LA THÉORIE DES FILTRES ELECTRIQUES.—P. David.—(*Onde Elec.*, February, 1926).

A continuation and conclusion of the article in the previous month's issue (see abstract in *E.W. & W.E.*, April, 1926). The first case considered is the calculation of the current in a filter working to any impedance, followed by its particular adaptation to the impedance of a receiver. The effect of internal impedance in the supply source is then considered and it is shown that it is advantageous that this impedance should be equal to that of the receiver; *i.e.*, input and output impedances to the filter should be the same. The use of filters in wireless technique is then considered generally, the case illustrated being that of a filter whose input and output are transformers in anode and grid respectively. The article concludes by considering the effect of mutual induction between the elements of a filter system, and the effect of transient and damped phenomena, as distinguished from the sustained cases dealt with in mathematical considerations. A bibliography on filter literature is appended, along with a discussion on the paper before the Société des Amis de la T.S.F. on 20th January, 1926.

R386.—FINDING THE INDUCTANCE OF THE FILTER CHOKE.—E. W. Berry. (*Q.S.T.*, March, 1926.)

The method recommended is first to measure the ohmic resistance R of the coil, *e.g.*, with D.C. milliammeter and voltmeter. The total impedance Z can then be ascertained by using similar A.C. instruments with the supply mains. The calculation of the inductance from these quantities is then illustrated, and curves are given from which the inductance can be directly read from the value of $Z^2—R^2$, for 25 and for 60 cycles.

R386.—FORD COIL FILTERS.—C. Provins. (*Q.S.T.*, March, 1926.)

An article describing the use of Ford ignition coils as elements of a filter for amateur transmitter supply. The arrangement recommended is to use two secondary coils in parallel, when their joint resistance of 2,500 ohms is not serious in the anode circuit. As 1μF condensers are already built into the coils, these may be utilised for the complete filter, and a method is described and illustrated for doing so without dismantling the coils. Other filtering arrangements using these components are also discussed.

R387.1.—THE SHIELDING PROBLEM.—D. R. Clemons. (*Q.S.T.*, March, 1926.)

An extensive treatment of shielding effects, with results of a large number of experiments. The general effect of a non-conductor and of a conductor in proximity to a coil is first discussed, and the subsequent discussion confined entirely to measurements at wireless frequencies. Experimental results of H.F. resistance measurements are shown for two similar lengths of wire, one wound as a solenoid and the other as a layer coil, the latter having about twice the minimum (natural) wavelength and more than five time the H.F. resistance of the former. The proximity of a condenser to a coil is then considered. Placed inside the coil it increased the self-capacity of the coil from 4.4 to 9.05μμF, and the effective resistance at 1,200kC from 30.5 to 38.5 ohms with the plates closed and to 47.5 ohms with the plates opened. Near the coil in various positions—the maximum proximity being 0.6cm.—increases of H.F. resistance of 27 to 63 per cent. were shown. A metal sheet, 10 in. by 12 in., is then considered. With the plate 1cm. away from one end of the coil the self capacity increased 25 per cent. which was slightly augmented if the plate was commoned to the nearer end of the coil. Commoned to the other end it increased this capacity by 486 per cent., raising the natural wavelength from 76 to 186 metres. With a single layer spiral or pancake winding and the plate with its plane parallel to that of the coil at a distance of 1cm., the self-capacity increased 790 per cent., which dropped to 608 per cent. on commoning the shield to one end of the coil. A honeycomb coil of 8.4μμF self-capacity showed no change when the shield plate was 1cm. away, and an increase of 204 per cent. on commoning it to one end of the coil.

Experiments are then described on inductors in completely closed boxes. A solenoid completely enclosed in a metallic box of 8 in. by 8 in. by 5 in. was measured for H.F. resistance and self-capacity. Result curves for the former (up to 1,600 kilocycles) show an increase of 2 to 2½ times in the screen, and of 3 to 3½ times if one end of the coil is connected to the screen. Connection of the screen to one end of the coil increased the self-capacity from 4.4 to 34.2μμF, the other end giving only 13.6μμF. Similar measurements for a smaller and more compact coil show much smaller increases, while a spiral coil shows an increase of H.F. resistance of from 2½ to 3 times on enclosing in the box, increasing to over 3 as either end of the coil is commoned to the screen. Experiments are then described with sheets of copper and of lead. With two solenoids 1.7cms. apart, a current of 44 milliamperes was induced in the secondary with a lead screen midway between the coils. This dropped to 1.8 milliamperes on substituting the copper screen, while aluminium gave nearly the same result. Separating the coils by 12 cms. with the copper midway between them the secondary current rose to 6.3. It is concluded that a thickness of more than 0.02 in. does not better conditions and that completely enclosing a coil improves the efficiency so far as actual linkage is concerned. The article is also illustrated by several photographs showing the screening arrangements employed in various commercial receivers.

R387.7.—PORCELAIN INSULATOR MANUFACTURE.—(*Electrical Review*, 5th-19th March, 1926.)

A description of a visit to the works of Messrs. Taylor, Tunnicliff & Co., with illustrated remarks on the manufacture of various types and sizes of porcelain insulators for wireless, telegraph, telephone and other purposes. Electrical tests are described and well illustrated by photographs of various insulators under test at commercial and radio frequencies.

R388.—A NOTE ON THE CATHODE RAY OSCILLOGRAPH.—Juichi Obata. (*J. Franklin Inst.*, March, 1926.)

A discussion of the arrangement (described by F. R. Terroux, abstract in *E.W. & W.E.*, February, 1926) of using a quartz window to permit external photography of short exposures. The present writer states that the sensitivity of the beam for ordinary dry plates can be somewhat improved, but is still inferior to the Schumann plate specially sensitised for cathode ray work. The difficulty of obtaining simultaneously high electrical and photographic sensitivities still remains.

R400—SYSTEMS OF WORKING.

R421.—THE LORENZ HIGH, FREQUENCY SYSTEM FOR RADIO TRANSMISSION.—F. W. Gillard. (*E.W. & W.E.*, April, 1926.)

R460.—MULTIPLEX SHORT WAVE RECEPTION.—J. K. Clapp. (*Q.S.T.*, March, 1926.)

It is pointed out that the common use of the fixed-tune aerial circuit permits the use of multiplex reception under relatively simple conditions;

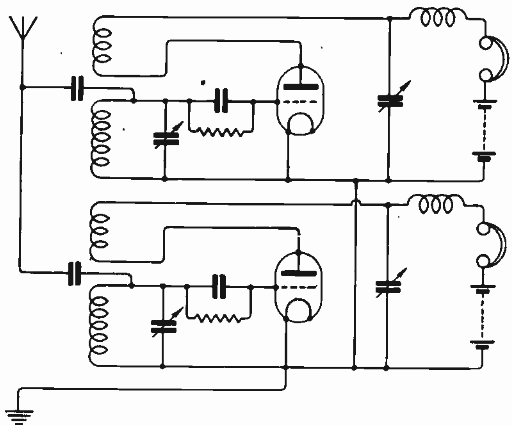


Fig. 1.

and that several receivers may be used on one aerial, even with the same L.T. and H.T. batteries. The circuit of Fig. 1 is shown for two different receivers. The coupling condensers should be very small. Split headphones can be used, one earpiece joined to each set, thus enabling simultaneous listening on two different wavebands. Arrangements are illustrated for a simple plug-and-jack arrangement for use of either or both earpieces, while a more elaborate switching arrangement is shown for the use of two telephones with four different receivers. The advantages of multiplex reception are discussed from the point of view of traffic improvement in relay work, and of observation of distances, fading, etc. on different wavebands. The arrangement is also useful in checking wavemeters, particularly on standard frequency signals.

R500.—APPLICATIONS.

R521.1.—RADIO AND THE SOUTH AMERICAN FLIGHT.—(*The Electrician*, 12th March, 1926.)

A description of the wireless D.F. receiving apparatus on the Spanish seaplane, "Ne plus Ultra," during its recent flight to South America. The metal construction of the machine adversely affected the receptive power of Bellini-Tosi or any other loops. Special arrangements had therefore to be made. The fore and aft loops consisted of two single turns arranged symmetrically on each side of the hull, and joined in series. For a wing coil of equal reception, a single turn loop was mounted in the plane of the wing. To increase reception for the small loops, it was found necessary to increase the overall amplification of the standard aircraft D.F. receiver. A 12-valve amplifier was divided into two units, the first containing 6 H.F. stages and a first detector, the second unit containing an oscillator two stages of intermediate frequency amplification, a second detector and note magnifier. Interesting details are quoted of the accuracy of the D.F. bearings obtained, and their great aid to navigation.

R545.—AMATEUR RADIO TO THE NORTH POLE AGAIN.—F. H. Schnell (*Q.S.T.*, March, 1920.)

A description of the apparatus to be taken for communication (by personnel of the American Radio Relay League) between the Detroit Arctic Expedition and stations in the United States. Photographs and circuit diagrams of the apparatus, which is highly portable, are shown. The transmitter uses two valves on the Colpitt's circuit arrangment, H.T. supply being by batteries of 300-400 volts. The tuning range is 24 to 78 metres. The receiver is a conventional three-valve set (detector and two L.F.), with reaction to the aerial.

R557.—TEACHING SPANISH BY RADIO.—(*International Telephone Review*, January, 1926.)

A description of an organised class of 15,000 persons who listen once a week for instruction by wireless in the Spanish language. The course of instruction teaches conversational Spanish to the students, with the aim of enabling them to travel in Latin-America and Spain, and converse in the native tongue. The transmission is from KOA, the Rocky Mountain Station at Denver, of the G.E.C.

A few other American broadcasting stations have similar but smaller classes for the study of the same language.

R800.—NON-WIRELESS SUBJECTS.

R533.85.—POMPE À CONDENSATION FONCTIONNANT SUR VIDE PRIMAIRE MÉDIOCRE.—L. Dunoyer (*Comptes Rendus*, 15th March, 1926.)

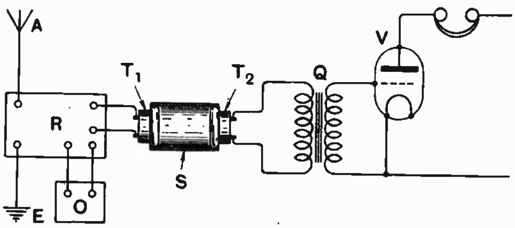
A description, with illustration, of a mercury-vapour condensation pump, capable of being used with a low backing vacuum, *e.g.*, 10-30 mm. of mercury, such as can be obtained from an inexpensive water-jet pump. Two stages of condensation pumping are provided from the one mercury vapour supply. A vacuum of 0.00001 of a millimetre of mercury is obtainable.

Some Recent Patents. [R008

SELECTIVE RECEPTION.

(*Application dates, 29th November,* 1924, *and 20th January,* 1925. *No.* 248,087.)

A rather interesting system of selective reception depending upon acoustic differentiation is described in the above British Patent by H. A. P. Littledale. Briefly, the invention consists in forming a beat note between incoming oscillations and a local oscillator, and causing the beat note to operate a single earpiece telephone receiver, which is connected to a sound column which resonates at

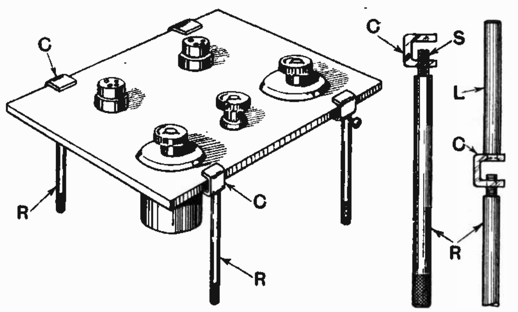


a definite frequency, a similar earpiece being placed at the other end of the sound column. This earpiece is connected either to an amplifier and telephone receiver, or another similar resonator. The accompanying diagram illustrates the idea very briefly. It will be seen that a receiver *R* is provided with the usual aerial *A* and earth *E*, and the local oscillator *O*. The frequency of the local oscillator is adjusted so that a beat note is obtained, the rectified output of the receiver and local oscillator being connected to the telephone receiver T_1. This is placed at one end of a tube or sound column *S*, while another telephone, T_2, is placed at the other end. The telephone T_2 is connected to the primary of a transformer *Q*, which in turn is connected to an amplifying valve *V*. This valve is shown provided with a pair of telephone receivers in the normal manner. The sound column *S* is tuned by moving one of the earpieces until the requisite length of air column is obtained. It is well known that the natural frequency of an air column which is closed at both ends is equal to half the wavelength. Thus, for a given frequency, that is, the pitch of the beat note, the length of air column for resonance can easily be calculated. The best beat note to use is that of the order of the natural frequency of the earpiece telephones. Under these conditions, if the diaphragm of the telephone T_1 is energised it will set the air column in the two into resonance, and the oscillations will impinge upon the diaphragm of the earpiece T_2, which will then respond at the same frequency. This will cause a potential to be set up across the ends of the windings which are connected by means of the transformer *Q* to the valve *V*. If now the diaphragm of the earpiece T_1 is energised at another frequency due to a different beat note caused by an interfering station, or, perhaps, a static or other similar interference, the telephone earpiece T_2 will not be affected to any material extent, since the sound waves within the air column at frequencies over that of resonance will be of very small amplitude, and consequently the diaphragm of the earpiece T_2, which, of course, is acting as a magneto-microphone, will not be affected to any material extent. The valve *V* can either be used as the last valve of the receiver, or the anode circuit may contain another resonator device, consisting, of course, of another earpiece similar to T_1. We should imagine that experimenters would find the system exceedingly useful for continuous wave reception when atmospheric disturbances are very bad. The specification is fairly detailed, and describes several modifications and uses of the system, such, for example, as measuring signal strength.

DETACHABLE PANEL LEGS.

(*Application date, 29th January,* 1925. *No.* 247,725.)

W. H. Liles and J. K. Pennington describe in the above British Patent specification the construction of detachable legs for supporting panels either required for experimental work, or particularly during the process of wiring. The idea of the invention can be seen by reference to the accompanying illustration. It will be noticed that the legs consist of a rod *R* provided with a screwed

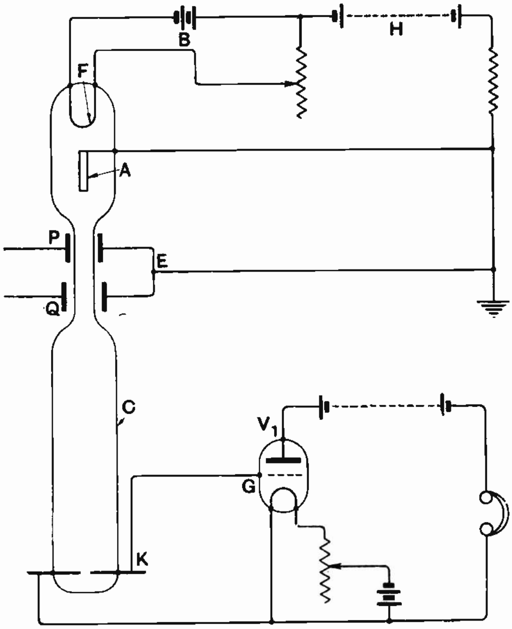


portion *S*, which co-operates with a thread in a small channel *C*. The legs are attached to the panel by placing the channel on the edge of the panel, and rotating the rod until the end of the screwed portion bites the under surface of the panel. Another modification of the leg consists in providing the channel *C* with another link or rod *L*, thereby enabling the panel to be inverted for the purpose of working on the opposite side.

CATHODE RAY RECEPTION.

(*Application date, 20th January,* 1925. *No.* 247,344.)

A system of selective reception embodying a cathode ray tube is described in the above British specification, No. 247,344, by C. Seymour, D.S.O., and C. A. Horton, B.A. The system functions by virtue of the fact that by applying the output of an amplifier to an arrangement of deflector plates associated with a cathode tube the cathode stream may be deflected, the deflection depending upon the nature of the applied voltages. The system is similar to the direct reading directional receiver of

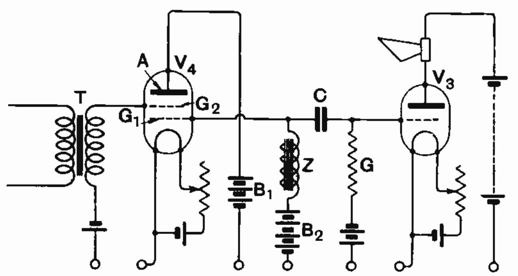


Watson Watt. The accompanying diagram illustrates the broad idea of the invention. *C* is a cathode tube comprising a filament *F* and an anode *A* of cylindrical formation, which tends to concentrate the cathode stream into a narrow beam. The filament is heated by the usual battery *B*, and the anode is connected to a high tension battery *H* through the usual resistance *R*, the anode being earthed. Two pairs of deflector plates are employed, *PE* and *QE*. The collector *K* comprises two wires separated by a distance of about 1 mm., the wires being connected between the grid *G* and filament of a valve V_1, which is associated with the usual telephones and batteries. Two directional loops, such as the well-known Bellini-Tosi combination, are connected through separate amplifiers to the deflector plates. For example, the anode circuits of the last valves may contain a resistance across which voltages will be produced, these voltages being transferred to the two pairs of deflector plates *PE* and *QE*. Thus, according to the phases and amplitudes of the two sets of voltages or deflection forces, so the nature of the deflection will vary. The cathode tube can then be rotated with respect to the deflector plates, the desired signal voltages thus causing the cathode stream to move with respect to the collector wires, this giving rise to potential variations in the anode circuit of the valve V_1. Thus it will be seen that undesired signals or atmospherics and other similar disturbances will give rise to totally different deflections, probably only causing the cathode stream to move about the collector wires while causing no change of potential to occur. The deflections, of course, is determined by the direction of the incoming signal and its frequency characteristic, and the phase relationship of the voltages.

A FOUR-ELECTRODE VALVE AMPLIFIER.

(*Application date, 27th November*, 1924. *No.* 248,076.)

A rather interesting method of utilising a four-electrode valve is described in the above British Patent granted to Marconi's Wireless Telegraph Company, Limited, and E. W. B. Gill. The invention simply consists in providing the inner grid with a fairly high positive potential so as to neutralise the effect of the space charge, and including in the inner grid lead an audio-frequency choke, very highly magnified voltages being set up across this choke, which are then applied to an ordinary valve, which may operate a loud-speaker. It is well known, of course, that if the anode of a four-electrode valve is made positive, and the potentials to be amplified are applied to the outer grid, and also if the inner grid is made positive the inner grid may be regarded as the output anode, and current in the inner grid circuit will vary in accordance with the outer grid potentials. If the relationship between the inner grid current and outer grid potential is plotted it is found that as the potential in the inner grid is increased by equal increments the outer grid current increases by decreasing amounts. It has been found that with certain types of valves and values of outer grid potential between certain limits the magnification is independent of the outer grid potential. The effect of this is as if the valve had an amplification factor which increased at a very rapid rate. Thus the valve is arranged as an amplifier in the manner shown in the accompanying illustration. The audio-frequency voltages to be amplified are applied by a transformer *T* to the outer grid G_2 of a four-electrode valve V_4. The anode *A* is given a positive potential by a battery B_1. The inner grid G_1 is connected through an impedance consisting of an audio-frequency choke *Z* to a battery B_2, a coupling condenser *C* being connected between the upper end of the choke and the grid of a three-

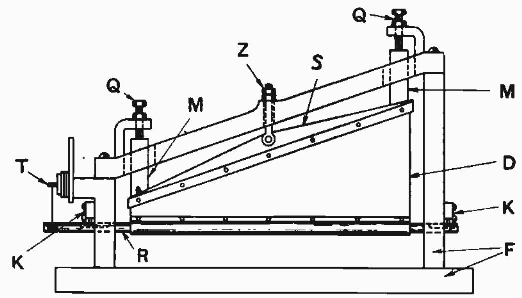


electrode valve, which is associated with the usual loud-speaker and batteries. The invention states that the overall magnification approximates to an inverse function of the frequency, and is very high for audio-frequencies. It is further stated that the magnification is dependent upon the self capacity, or, rather, the capacity in shunt with the choke. In the case of the circuit shown the choke has in parallel with it through the coupling condenser the grid-leak G. This shunt path tends to produce substantially equal amplifications at all frequencies, and this is further helped by the fact that the choke is never theoretically a perfect one. A resistance, of course, can be substituted for the choke Z, but necessitates a higher battery voltage.

A POLYGONAL DIAPHRAGM.

(*Application date*, 26*th May*, 1925. *No.* 248,228.)

A very novel form of diaphragm construction and energisation are described by the Western Electric Company, Limited, in the above British Patent, a specification which all those who are

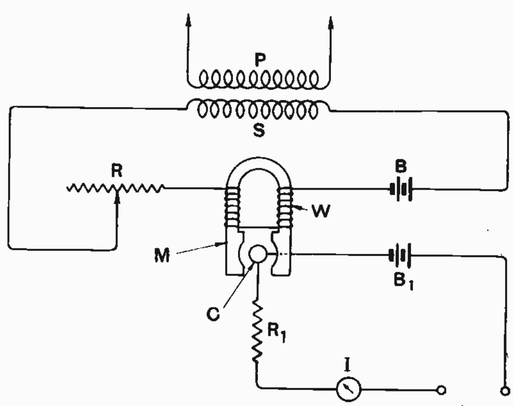


interested in the hornless type of loud speaker would do well to study. The diaphragm is made essentially in the form of a polygon, a trapezoidal construction usually being adopted. One modification is shown in the accompanying illustration, the diaphragm being in the form of a trapezoid. One long parallel side of the trapezoid is rigidly fixed, while the opposite side is provided with a means of energisation. Thus, in the illustration, a rigid framework and base F support the diaphragm D. The diaphragm is clamped along its upper edge to a support S, which is attached to the top of the framework by means of a screw Z and locking nuts. Two other screws and lock nuts Q are also fixed to brackets at each end, and co-operate with two members M. It will be seen that by adjusting the screws Q, Q, Z the diaphragm may be stretched more one end than the other, and also the tension as a whole may be varied. The lower end of the diaphragm is fixed to a rod R. This rod is carried on knife edge bearings K, at each end of the framework, this rod being used to drive or energise the diaphragm, and is linked to an ordinary telephone mechanism T. This is preferably of the Baldwin balanced type of armature, and is connected so as to tend to produce a rotation of the rod about the knife edges. In other words, a torsional effect is obtained which acts at right angles to the plane of the diaphragm. The diaphragm or sound radiator is preferably made of parchment paper, blotting paper, fabric, or light-weight metal such as aluminium. Another important feature of the diaphragm is its dimensions. The width of the narrow end should be approximately half the wavelength of the highest frequencies it is desired to obtain, while the other end should be half the wavelength of the lowest frequencies it is desired to obtain. At the higher frequencies the smaller end of the diaphragm will absorb and radiate to the air most of the vibrational energy, while for the lower frequencies the vibrations will tend to spread over the diaphragm as a whole, particularly towards the wider end of the area which is actually set into vibration while depending upon the frequency of vibration. Conversely, at the lower frequencies the sound impedance of the diaphragm will be low, and the energy will be transmitted along the rod to a point where the increased width will permit of resonance. Another interesting point is that the velocity of the sound in the driving member, *i.e.*, the rod R, may be made greater than that of the diaphragm, and consequently the distribution of the various components along this rod do not tend to produce any appreciable distortion owing to a time lag at the lower frequencies. The specification is very detailed, and describes several alternative forms of construction. Instead of making the diaphragm in the form of a plane it may be made hollow and stiffened so as to be polygonal in cross section.

A RECTIFICATION SCHEME.

(*Convention date* (*Australia*), 23*rd August*, 1923. *No.* 220,942.

A rather peculiar arrangement of electrical apparatus which, it is claimed, rectifies, amplifies, relays and transmits is claimed by S. le F. Farvel in the above British Patent. The invention is best understood by reference to the accompanying illustration. A source of oscillations is applied to the primary winding P of a high frequency transformer, the secondary S of which is connected in series with a variable resistance R_1, which is also in series with a battery B, and windings W, arranged round the limbs of a permanent magnet M. The poles of the permanent magnet M are brought close together so as to concentrate the field. Located

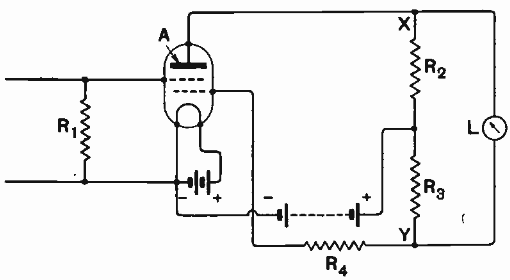


within the small air gap is a coil C made of bismuth or antimony alloys, the coil preferably being in the form of a ribbon. The coil is in series with another battery B_1, an indicator I such as a telephone or galvanometer, and a resistance R_1. It is stated that the passage of an oscillatory current through the windings of the permanent magnet alters the distribution of the lines of force, and at the same time alters the resistance of the coil in the gap, thereby causing variation of direct current through the indicating device. It is stated that two or three arrangements may be used to act as amplifiers, and also the apparatus may be employed as a generator of oscillations.

A PUSH-PULL AMPLIFIER.

(*Convention date* (*U.S.A.*), 11*th July*, 1924. *No.* 236,911.)

A method of connecting a four-electrode valve as a push-pull amplifier is described by J. C. Warner and The British Thomson-Houston Company, Limited, in the above British Patent No. 236,911. In the accompanying illustration a resistance R_1 is connected between the outer grid and filament of a four-electrode valve, *i.e.*, across a source of potentials to be amplified. Two resistances, R_2 and R_3 are connected in series. One end of the resistance R_2 is connected to the anode A, while the junction point is connected to a source of high voltage. The other end of the resistance R_3 is connected through a resistance R_4 to the space charge or inner grid. A load circuit, such as a telephone receiver or other indicating device, is connected across the free ends of the resistance R_2, and R_3, *i.e.*, across the points X and Y. The values of the resistance R_2, R_3 and R_4 are so adjusted that when any variation is applied across the resistance R_1 the current flowing through the resistances R_2 and R_3 are of such a value that the voltage drop across the two resistances is equal. In other words, there is no potential difference between the points X and Y. The object of the resistance R_4 is simply to lower the potential applied to the space charge grid. If, now, the potential of the outer grid increases due to a source of potentials to be amplified, the current flowing

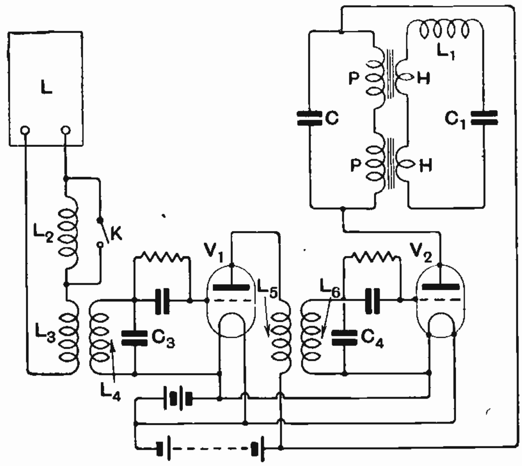


through R_2 will increase, *i.e.*, the potential of the point X will be lowered. Similarly, the current flowing through R_3 will decrease, which means that the potential of the point Y will be increased. Thus it will be seen that a current will flow through the load circuit L_1, thereby causing it to become operative. A modification of the invention provides for the amplification of alternating current, in which case the resistance R_1 is replaced by a transformer, and the two resistances R_2 and R_3 are replaced by a centre tap choke.

CONTROLLING A CONTINUOUS WAVE GENERATOR.

(*Convention date* (*France*), 10*th September*, 1924. *No.* 239,856.)

A rather interesting system of controlling a continuous wave generator either for the purpose of keying, or maintaining constant frequency, is described in the above British Patent, which has been granted to Société Francaise Radio-Eléctrique.

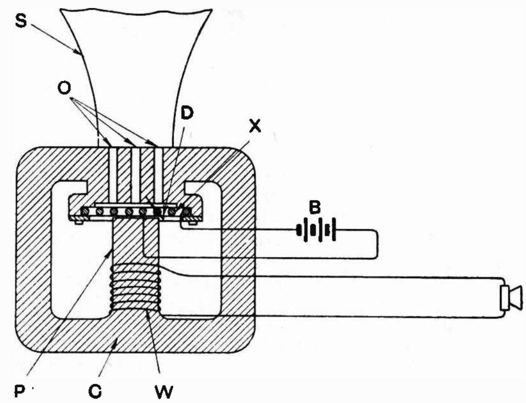


Briefly, the invention consists in beating the generator oscillations with those of a small local oscillator which is screened in a Faraday cage, rectifying the resultant beat current, rebeating at a lower frequency, and passing the rectified current through "saturation" chokes contained in the main oscillatory circuits of the generator. The main oscillatory circuits of the generator are shown diagrammatically as an inductance L_1 and a capacity C_1. Between this capacity and inductance are the high frequency windings of the saturation chokes, the primary P being shunted by a capacity C_2. A local screened and stable oscillator L is provided with two inductances L_2 and L_3, the inductance L_3 being coupled to an inductance L_4 tuned by a capacity C_3. Across the inductance L_2 is a key K, which short circuits the inductance, thus altering the frequency of the local oscillator. L_4C_3 is an oscillatory circuit tuned preferably to the mean frequency of the main emitter and the local oscillator, the frequency of which is slightly greater or less than that of the main oscillator. This is connected to a valve V_1, which acts as a rectifier. An inductance L_5 which offers a high impedance to the rectified beat frequency being contained within the anode circuit. This inductance acts as the primary of a transformer, the secondary of which, L_6 C_4, is tuned to a slightly higher frequency, and is suitably damped, with the result that another potential will be set up across them, which is again detected by the second valve. The anode circuit of the second valve contains the primary windings of the saturation chokes, which will then be traversed by a continuous rectified current, the value of which will be higher as the interference frequency approximates to the natural frequency of the circuit L_6 C_4. Thus it will be seen that altering the frequency of the local oscillations by short circuiting the inductance L_2 causes a change in frequency of the main oscillator, whereas, conversely, if the frequency of the local oscillator is maintained dead constant the frequency of the main oscillator will also remain constant.

AN ELECTRO-DYNAMIC LOUD-SPEAKER.

(*Application date, 27th October*, 1924. *No.* 248,026.)

W. Dubilier and The Dubilier Condenser Company (1921), Limited, describe in the above British Patent the construction of an electro-dynamic loud-speaker of a rather novel type. Referring to the accompanying illustration it will be seen that the loud-speaker comprises an electro-magnet consisting of a core *C* provided with a central pole piece *P*. The core is also provided with three openings *O* and communicate with the sound conduit or horn *S*. An internal extension, *X* of the core serves to hold a diaphragm *D*. The diaphragm comprises a light coil of aluminium or similar insulated wire, which is preferably interwoven with silk so as to act as a

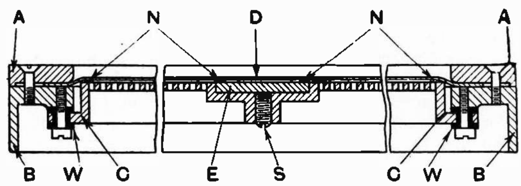


support and also tends to reduce any natural period. A central pole piece *P* is provided with a winding *W*, to which speech current is applied. The ends of the coil diaphragm are connected to a source of direct current in the form of a battery *B*. Thus it will be seen that there is a steady flux surrounding the actual diaphragm, due to the passing of the steady direct current, and when speech currents are applied to the windings *W* a considerable variation in flux will occur in the normal manner. This flux will link with that of the coil diaphragm, altering the attraction and repulsion, thereby causing the diaphragm to vibrate and thus energise the sound in the sound conduit.

AN ELECTROSTATIC MICROPHONE.

(*Convention date* (*Germany*), *9th July*, 1925. *No.* 248,255.)

The above British Patent, granted to Tri-Ergon Aktiengesellschaft, describes the construction of an electrostatic microphone, which should be of interest to experimenters. The difficulty of obtain-



ing constancy is overcome by the method of mounting the diaphragm. In the accompanying illustration it will be seen that the diaphragm *D* of mica or similar material is covered with foil coating, and acts as one of the electrodes of the condenser. This is clamped between two rings *A* and *B*, the inner edge of the ring *A* being chamfered as indicated. The other electrode of the condenser comprises another ring *C*, which is fixed to the ring *B* by means of a screw and insulating washer *W*. Before the microphone is assembled the diaphragm *D* is stretched perfectly tight. It will also be noticed that the inner ring *C* comprising the other electrode is provided with a movable disc *E* adjusted by a screw *S*. Insulating washers *N* are inserted as shown. Thus it will be seen that on screwing the microphone together the insulating washers *N* will bear upon the mica diaphragm, causing the latter to become heavily stretched, the diaphragm taking up the position indicated. A similar adjustment, of course, is carried out by the middle disc and screw. The specification mentions that the co-efficients of expansion of the metals used for the various rings should be as nearly as possible equal so as to avoid any sagging or change in tension of the diaphragm.