EXPERIMENTAL WIRELESS & The WIRELESS ENGINEER

VOL. III. JUNE, 1926. No. 33.

Editorial.

Historical Wireless Apparatus at Munich.

A NEW science museum, known as Das Deutsche Museum, was officially opened in Munich a year ago. In it has been brought together a great amount of original apparatus illustrating the historical development of various branches of science, and the collections representing electrical science are so rich in original apparatus actually used by many of the pioneers whose names are now household words, that Munich will now have a still greater attraction for those tourists who to a love of art add an appreciation of scientific achievement.

There one can see the apparatus used by Otto von Guericke, Ampere, Ohm, Fraunhofer, Helmholtz, Hittorf, Röntgen, Hertz, and many others. Wireless telegraphy is very well represented, a room being specially devoted to this subject. Feddersen's apparatus, with which in 1862 he demonstrated the oscillatory nature of the spark discharge, was presented in 1906 by Feddersen himself, who personally superintended its installation. Some of the original photographic negatives of the spark discharges are shown.

In a neighbouring case is the apparatus with which Hertz first noticed the effect at a distance when a Leyden jar was discharged, and the apparatus with which in 1870 von Bezold demonstrated the nodes and antinodes of stationary electric waves on wires. Then we come to the original Hertz transmitter and receiver, presented to the Museum by the Baden Government, and a small collection of apparatus most of which was actually made by Hertz himself and presented by his widow in 1906. Here we see the original oscillators and resonators of various sizes and shapes, the wire cage polarisers, the large zinc parabolic reflectors, and the 12 cwt. pitch prism with which he refracted the waves.

The original Lecher wires of 1890 and the Arons tube of 1892 in which the Lecher wires are run in a vacuum are both here.

There is a collection of early wavemeters, including those of Zenneck, Slaby, Dönitz, Rendahl and Scheller.

Unfortunately, Braun's original coupled transmitter which he presented in 1906 was sent to America for Patent purposes during the war and has been lost, but an exact model has been made by Prof. Zenneck.

As an actual commercial transmitter of historical interest there is the Cuxhaven station, installed by Siemens in 1900 to work to Heligoland. All the subsequent developments are illustrated, including Poulsen's original laboratory arc transmitter, presented to the Museum in 1908. Among frequency doublers there is an experimental apparatus with rectifying cells made by Zenneck in 1899 and the original apparatus of Epstein (1902) and Goldschmidt (1908). There is also the original experimental Goldschmidt alternator giving 10 kilowatts at a frequency of 15,000. There is a very complete collection of the various types of detectors which have been employed at various times in the development of radio telegraphy, and naturally, thermionic valves in all their manifold applications are well represented.

The Correlation of Some Recent Advances in Wireless.*

By Balth. van der Pol, D.Sc.

[R010

Section 1.

WIRELESS telegraphy and telephony are mainly based on the study of the theory of oscillations. Transmitters generally consist of an apparatus by means of which free oscillations are produced. Receivers on the other hand are principally designed to deal with forced oscillations, whilst the transmission through the intervening space between transmitter and receiver is a typical example of wave propagation problems.

"Wireless" may thus be said to be the Science of Oscillations. The first question is: "How are these oscillations, and especially electric oscillations, produced?" This may be effected in three different ways:—

(A) Assuming that oscillations of a frequency ω have been set up and are therefore available in one circuit, it is possible, by electrically coupling a second circuit to the first, to set up in the second circuit oscillations which, generally speaking, will have the same frequency as the primary oscillations. A wireless receiver will thus oscillate under the influence of the oscillations in the transmitter. Oscillations which are of the same frequency as those by which they are produced are generally called *forced oscillations*. An instance of this is furnished by the well-known resonance phenomenon, where the receiving circuit is tuned to the transmitter oscillations.

(B) It is also feasible to produce oscillations by applying a constant force, or in electric parlance, to generate alternating from direct current. The *arc-transmitter*, *triode-transmitter*, electric bell and organ pipe are instances of this method of producing oscillations. A further example is the reciprocating steam engine, where a rotary motion (*i.e.*, a particular form of oscillation) is imparted by a constant pressure of steam. Further on an electrical analogy of the last example will be given when discussing the *multi-vibrator* and the *oscillating Neon lamp*.

(C) Given that electric oscillations of frequency ω† are available, it is possible, with suitable apparatus, to produce two new oscillations of frequency $\omega+\rho$ and $\omega-\rho$ respectively, wherein ρ often bears a simple ratio to ω.

Two instances of this method of producing oscillations, the correlation of which is not immediately apparent, are the *frequency-doubler* and the *rectifier*. In each case $\rho=\omega$ and the frequencies resulting from ω are:—

$$\omega+\omega=2\omega$$

and

$$\omega-\omega=0$$

i.e., in addition to setting up an oscillation of double frequency 2ω an oscillation of zero frequency is generated, or in other words direct current or direct current magnetisation is produced. In the frequency-doubler the direct current component is ignored and the double frequency alternating current only is used, which is separated out by tuning. In the rectifier the double frequency current is neglected, use being made of the direct current only, which is separated out by means of choke coils and smoothing condensers, *i.e.*, a *circuit tuned to direct current* is used. A further example where $\rho=17/18\omega$ will be discussed in due course.

Section 2.

In order to render the methods of oscillation production more comprehensive, they were classed under three headings (A) (B) and (C); it can be shown however that (A) and (B) are merely variants of (C). For reverting to the general problem of transforming oscillations of frequency $\omega+\rho$ and

* This article was first published in the Dutch language in the *Polytechnisch Weekblad*, 19th November, 1925.

† [Throughout this article "frequency" is used for the angular velocity of the vector, *i.e.*, 2π times the number of cycles per second.—ED.]

$\omega-\rho$ from an oscillation of frequency ω, which may be more simply denoted by

$$\omega \begin{array}{l} \nearrow \omega+\rho \\ \searrow \omega-\rho \end{array} \quad \ldots \quad \ldots \quad (1)$$

the following problems may be more closely investigated :—

I. $\rho=0$ and therefore $\omega \begin{array}{l} \nearrow \omega \\ \searrow \omega \end{array}$

i.e., we obtain *forced oscillations* of identical frequency.

II. $\omega=0$ hence $0 \begin{array}{l} \nearrow \rho \\ \searrow -\rho \end{array}$

this denotes (seeing that an oscillation of $-\rho$ frequency simply means an oscillation of $+\rho$ with its phase shifted through 180°)* the *generation of an alternating current of frequency ρ from a direct current.*

III. $\omega=\rho$ hence $\omega \begin{array}{l} \nearrow 2\omega \\ \searrow 0 \end{array}$

this represents the *frequency-doubler* and *rectifier* mentioned above.

IV. $\rho=\frac{m}{n}\omega$, hence $\omega \begin{array}{l} \nearrow (1+\frac{m}{n})\ \omega \\ \searrow (1-\frac{m}{n})\ \omega \end{array}$

wherein m/n denotes a fraction reduced to its lowest terms.

Taking the special case where $\rho=\frac{1}{2}\omega$ the following notation is obtained

$$\omega \begin{array}{l} \nearrow 3/2\ \omega \\ \searrow 1/2\ \omega \end{array}$$

In this case the oscillation of frequency ω gives rise to two oscillations, one of which has a frequency of only half that of the original oscillation, an instance of *frequency division* to which further reference will be made subsequently.

From the examples given it will be seen that the problem of oscillation production is really identical with that of frequency transformation,* it being understood that a direct current can be considered as an alternating current of zero frequency.

Section 3.

We are next faced by the second problem, *i.e.*, that of ascertaining the conditions to which an electric system must comply in order to effect the described frequency transformations. Clearly such a system should conform to different requirements according as it is desired to produce transformation I., II., III. or IV. It is not intended to give a general answer to this question, but rather to investigate the problem of oscillation generation from another point of view, in which particular instances will be cited giving an automatic solution of the problem.

Going back to the now obsolete "spark transmitter" we find that this embodies an oscillating circuit (Fig. 1) consisting of a self-inductance L, a resistance r, and a capacity C, *i.e.*, a circuit complying with the conditions of the differential equation :—

$$L\frac{d^2i}{dt^2}+r\frac{di}{dt}+\frac{i}{C}=0 \quad \ldots \quad (2)$$

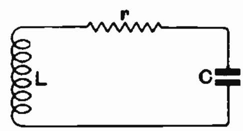

Fig. 1.

When a spark passes the gap a *damped oscillation* is set up. In the following considerations of the problem it is intended to revert to the above simple oscillatory circuit, but to vary the constants in the above equation one by one, and thus follow step by step the inventions and new methods introduced in recent years. In the simple spark transmitting circuits L, r and C are *constants*, *i.e.*, they are independent of the time and independent of the momentary current passing through the circuit.

Section 4.

However, before following up this idea we first consider a circuit consisting of a battery E and a variable resistance r in series with the fixed resistance R (see Fig. 2). If the rheostat (variable resistance) is now moved rapidly to and fro with a slight pause at the end of each move, the resistance of the circuit will vary between the limits $R+r$ and R (Fig. 2). The current in the circuit will consequently vary between

* This is clear from the fact that the vector rotates in the opposite direction.

* The general problem of frequency transforming represented as indicated above, was discussed by the author in a paper read before "Diligentia," and published in *Physical Science Lectures* (*Diligentia*), New Series, No. 2, p. 180, 1924.

$E/(R+r)$ and E/R, the P.D. V_r across the rheostat will vary between $rE/R+r$ and zero. Owing to the fact that the resistance of the circuit is varied the source of power E gives rise to a current which may be split up into a direct current i_0 where

$$i_0 = \frac{R+1/2\ r}{R\ (R+r)}\ E$$

and a peaked alternating current of amplitude i_1 in which

$$i_1 = \frac{r/2}{R(R+r)}\ E$$

By referring to Fig. 2 it will be seen that the potential drop over the variable resistance is at a maximum when the current is a minimum and *vice versa*, *i.e.*, as the P.D. rises the current falls off. This property of a conductor is generally called "negative resistance," the conductor in other words has a dropping characteristic, which is one of the conditions necessary to render it suitable for converting direct into alternating current.

Section 5.

We have just seen that when the resistance of a circuit is varied periodically by some external cause, alternating current may be generated. Going one step farther, if we can let the current in the circuit itself cause the resistance to vary, continuous oscillation would be set up in the system. What is meant, however, by letting the current cause the resistance to be varied? The answer to this simply means a divergence from Ohm's Law. The resistance is no longer constant, as is the case in ordinary metal conductors, but now becomes a function of the current passing through it. In order to set up spontaneous undamped oscillations in the circuit shown in Fig. 1 of frequency

$$\omega = \frac{1}{\sqrt{CL}}$$

the resistance r can no longer be considered constant but must now be expressed by

$$r = r(i) \quad \ldots \quad \ldots \quad (3)$$

in which $r(i)$ denotes that r is a function of the current i.

Only by adhering to these conditions is it possible to produce alternating current from a D.C. source. (Case II.)—equation (3)—may be satisfied by the introduction of an *arc-lamp*, a *triode* with reaction, a *dynatron*, etc., but it is not intended to go further into the deduction of the above equation. Put into words, equation (3) simply means that the characteristic curve must be bent.

It has been found that the oscillating circuit as shown in Fig. 1 can only generate

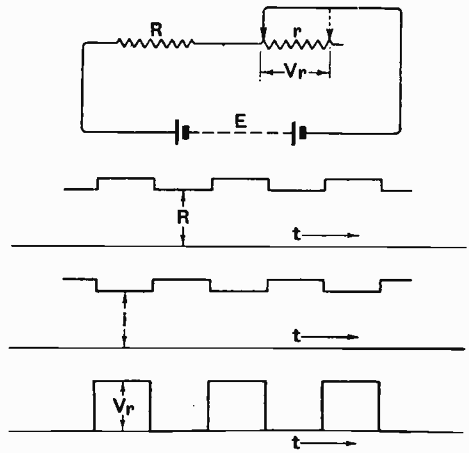

Fig. 2.

damped oscillations when L, r and C are constant as long as

$$r < 2\sqrt{\frac{L}{C}} \quad \ldots \quad \ldots \quad (4)$$

The oscillators just cited fully satisfy the conditions laid down in equation (4) for the range of amplitudes over which it is usual to work (r is obviously dependent on the oscillation amplitude seeing that it depends on the current in the circuit). The frequency of the oscillations generated is expressed by

$$\omega = \frac{1}{\sqrt{CL}}$$

The *Abraham-Bloch multi-vibrator** which consists essentially of a two-stage resistance-coupled retroactive amplifier, forms a triode system capable of generating oscillations rich in harmonics, which are so strongly represented that the 100th can be separated out. This circuit is a further example of that shown in Fig. 1 and, similarly to the the normal triode oscillator, the resistance is

* Abraham & Bloch, *Journ. de Phys.*, 1919.

again a function of the current, so that the condition of equation (3) is once more satisfied. However, for the multi-vibrator, equation (4) is changed to

$$r > 2\sqrt{\frac{L}{C}} \quad \ldots \quad \ldots \quad (5)$$

It is possible to maintain continuous oscillations conforming with the conditions laid down by (3) and (5) but such oscillations diverge considerably from the sine curve, being more peaked. The frequency is, moreover, no longer determined by the equation

$$\omega = \frac{1}{\sqrt{CL}}$$

but the time period is approximately given by the product of the resistance into the capacity, *i.e.*, a relaxation time. Such oscillations belong to a separate group and can conveniently be called *relaxation-oscillations*. These relaxation-oscillations may be produced in a circuit as shown in Fig. 3 in which a *Neon lamp* may be used at A.*

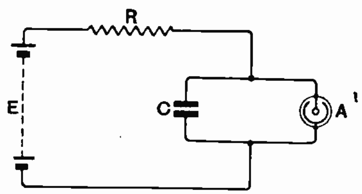

Fig. 3.

Thus, if R is 1 megohm and C a capacity of 1μF, the circuit would oscillate with a time period of the order

$$RC = 10^6 \times 10^{-6} = 1 \text{ second}$$

so that the lamp will light and extinguish once every second.

Mention has already been made of the diode or rectifier as an example of a frequency transformer, in which a direct current is produced from an alternating current of frequency ω (Case III.). In this instance again the operation depends on the bend of the characteristic so that the conditions of equation (3) are satisfied. The bend is therefore essential both for converting from D.C. to A.C. and *vice versa*.

* See Schallreuter, *Ueber Schwingungs Erscheinungen in Entladungsröhren.*

Section 6.

The various properties of the original circuit of Fig. 1, obtained by making r a function of the current, having been fully discussed, it is now proposed to investigate what will happen if the self induction L is made a *function of the current* such that

$$L = L(i) \quad \ldots \quad \ldots \quad (6)$$

An example of this is a coil with an iron core in which the permeability depends on the field strength. In this case the bend of the characteristic is again indicated, only the bends under discussion are now moved one term to the left in the differential equation (2). These bends are largely used in connection with the well-known frequency amplifiers such as are used, *e.g.*, at the Dutch transmitting station of *Kootwijk.* An example of considerable interest in this connection is the development made by Schmidt* who succeeded in bringing out the 47th harmonic in a single step, whilst at the same time maintaining a high efficiency. In passing reference should be made to the interesting investigations carried out by *Zenneck*† and *Heegner*‡ which deal with oscillation circuits in which iron-core self induction coils are inserted.

Heegner's circuit, as shown in Fig. 4, illustrates the principle of *frequency dividers* as opposed to frequency multipliers.

Circuit 1, which includes the alternator E, is tuned to the alternator frequency ω. The circuits 2 and 3, which are coupled to the first circuit as well as to each other by the iron ring transformer, are tuned respectively to frequencies $\omega+\rho$ and $\omega-\rho$. The sole function of the fourth circuit is to provide the D.C. magnetisation of the iron ring. By means of a suitable choice of the controlling factors, alternating currents are set up in circuits 2 and 3, the frequencies of which correspond with the respective tunings of these two circuits, viz., $\omega+\rho$ in circuit 2 and $\omega-\rho$ in circuit 3. *Heegner* was able to obtain $\rho = 17/18\ \omega$, such that an alternating current was produced in circuit 3 the frequency of which was 1/18 of that

* Schmidt, *E.T.Z.*, 40, 910, 1923.

† Zenneck and others in several articles in *Zts. für Hochfrequenztechnik*, 1924.

‡ Heegner, *Zts. für Physik* 29, 91, 1924 and 33, 95, 1925.

supplied by the generator E, a remarkably fine instance of frequency reduction.

Section 7.

Returning once again to the well-known circuit, shown in Fig. 1, the resistance r and the self induction L have successively been made a function of the current. The question now arises as to what will take place when the capacity C is made dependent on the current. Although this point could readily be discussed from a mathematical point of view, no practical object would be attained by further investigating this, in view of the fact that so far no material has been discovered, the dielectric constant of which varies with the field strength to any marked extent.

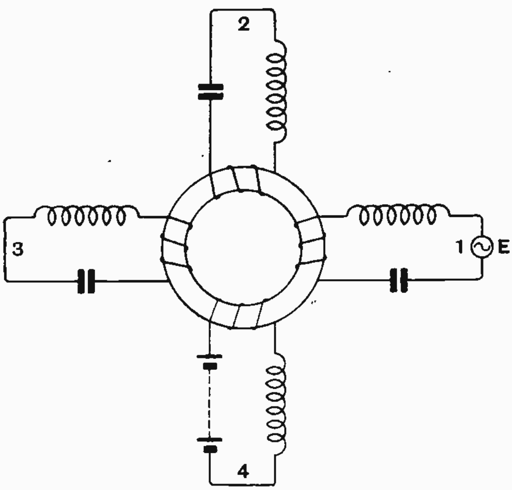

Fig. 4.

Section 8.

In the examples already discussed r and L were made to vary with the current. The momentary value of the latter, determines the momentary respective values of the resistance and inductance ; these in their turn react on the value of the current. This complicated interaction is consequently somewhat difficult to grasp in detail and the mathematical solution is rather involved. The problem is considerably simplified by making r, L and C in Fig. 1, *a definite function of the time, i.e.*, rigorously influenced by external means. In such a case the values of r, L and C would be independent of the current. It is of primary interest to investigate the effects obtained when r, L and C vary periodically, viz., when their values themselves oscillate.

Section 9.

Taking first the case in which the *resistance* of the circuit in Fig. 1 *is varied periodically* we have

$$r = r\,(t) = r_0 + r_1 \sin qt \;.\;.\;. \qquad (7)$$

in which q denotes the frequency of the oscillation of the resistance.

When q lies within the audible range of oscillations, but the resistance is varying slowly in comparison with the time of oscillation of the high-frequency oscillations, we obtain an example of the *Armstrong super regenerator*,* which is, in fact, an oscillation circuit having a periodically varying resistance. This variation in resistance can be obtained in practice by varying the grid— or anode potential of a retroactive triode system by means of a second triode oscillating circuit of frequency q.

The effective resistance of the former circuit is thereby caused to alternate between positive and negative values, thus rendering the system remarkably sensitive to forced oscillations. It is not intended further to investigate this point at present.

Section 10.

The next step is expressed by the equation

$$C = C(t) = C_0 + C_1 \sin qt \quad .. \quad (8)$$

This time the *capacity* C of the circuit in Fig. 1 becomes *a periodic function of the time*. If q is again an audible frequency we obtain an example of the *condenser microphone*, the theory of which has been investigated by *Carson*.†

The capacity of an oscillating circuit being thus varied at an "audio-frequency," the frequency of the transmitted oscillations also is varied periodically, which may or may not be regarded as a *frequency modulation* as opposed to *amplitude modulation* more commonly met with in wireless telephony.

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* Armstrong, *Proc. Inst. of Radio Eng.*, 10, 244, 1922.

† Carson, *Proc. Inst. of Radio Eng.*, 10, 57, 1922.

Section 11.

The final case to be investigated is expressed by

$$L = L(t) = L_0 + L_1 \sin qt \quad . \ . \ . \quad (9)$$

In this case the *inductance* L in the circuit shown in Fig. 1 *is varied periodically.* In the main, cases (8) and (9) are analogous; for example, if in case (9) the frequency q lies within the audible range, we obtain an instance of *magnetic telephonic modulation,* in which the iron-core self-inductance of a high-frequency system is altered to the rhythm of speech by means of an alternating current of audio-frequency.

Section 12.

Cases of considerable interest are obtained when the frequency q of the oscillation of L and C attains a value of the order of

$$\omega = \frac{1}{\sqrt{CL}}$$

with which the L, C, r circuit would oscillate freely itself. For example, in Fig. 1, if L and r are kept constant, but the capacity C is varied by a small amount with a rapid periodicity of frequency 2ω, *i.e.*, double the normal frequency of the system, we would have

$$C = C_0 + C_1 \sin 2\omega t$$

in which

$$\omega = \frac{1}{\sqrt{C_0 L}}$$

Without resorting to any external electromotive force, a continuously increasing current* would be generated spontaneously in the circuit. The energy for this current is derived from the work done by the force which draws the automatically charged plates of the condenser repeatedly apart. The condition for the occurrence of this phenomenon is, according to our calculations, expressed by

$$\delta < \frac{\pi}{2} \frac{C_1}{C_0}$$

i.e., the logarithmic decrement δ of the circuit must be less than $\pi/2$ times the maximum variation ratio of the capacity. Experiments to verify these theoretical deductions are at present being made.

Section 13.

The foregoing is intended to be a summary of the modern development of wireless telephony and telegraphy as viewed from one single point of view. It was not possible to make it complete, although it was found feasible to correlate several new inventions which at first sight appeared to stand quite apart. The generation of new oscillations from a given oscillation was principally discussed. The well-known combination tones, on which *heterodyne reception* depends, were not touched upon, though the application of these in *super-heterodyne*† work is daily becoming more prominent. These combination tones are produced from two given oscillations setting up two new oscillations made up of the sum and difference of the former.

* *I.e.*, a continuously increasing alternating current of frequency ω.

† Armstrong, *Proc. Inst. of Radio Eng.*, 12, 539, 1924.

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Alignment Charts for Selective Amplifiers.

By W. A. Barclay, M.A. [R082

In his article on "Selective Amplifiers" (*E.W. & W.E.*, October, 1925) Mr. P. K. Turner analysed the factors which make for "efficiency" as opposed to "selectivity" in tuned H.F. circuits, and described a practical method of amplifier design to suit given conditions of required signal strength and possible jamming. It will be remembered that he obtained the equation—

$$1/\eta^2 = \left(\frac{R_a}{R_e} + 1 + m\psi\right)^2 + m^2\left(\rho - \frac{1}{\rho}\right)^2 \quad .. \quad (1)$$

in which, for the working frequency, ψ represented the phase difference of the coil, *i.e.*, the ratio $R/\omega L$; m the ratio of the anode resistance, R_a, of the valve to the reactance; ωL of the coil; ρ the "tuning ratio" of any different frequency, *i.e.*, the ratio to the resonant frequency; and η the "efficiency," or E_g/E_a,

The equation (1) is of such fundamental importance in the theory of selective amplification that the writer here proposes to describe how, by means of the Alignment Principle, the numerical relations between its several variables may be conveniently and accurately exhibited. In general, the Alignment Principle admits of application to a greater number of variables than can be dealt with graphically. Though it is quite possible to design Alignment Charts which would deal simultaneously with the variations of all the above variables, the diagrams now to be described are, it is thought, sufficiently comprehensive in exhibiting the relations between four only.

The Chart (Fig. 1) is designed to illustrate equation (1), in which, following Mr. Turner, ψ is assumed to have the constant value .01. The ratio R_a/R_e is, however, now treated as variable, thus increasing the generality of the representation. It will be observed that the values of m are represented by a series of short vertical lines, which are intersected by four diagonal lines to which correspond the four values of R_a/R_e which have been selected for illustration, viz., 0, .1, .2, .3. The value R_a/R_e=0 corresponds, of course, to the ideal case in which the following grid circuit offers an infinite resistance as compared with the anode impedance of the valve, a condition of affairs which may often be approximately realised on the higher wavelengths. To employ the chart, a straight-edge or piece of thread is placed through the point situated at the intersection of the given m and R_a/R_e lines. If now it be rotated about this point until it meets the scale of ρ in its appropriate value, the required value of η can be read off in alignment on the η-scale. It will be seen that if any three of the four variables m, ρ, R_a and η be given, the fourth may thus be found. The convenience of this "inverse" use of the diagram will be appreciated when it is required, say, to find the value of m for which signals of "tuning ratio" ρ will be amplified with efficiency η. Again, the effect of varying R_a/R_e upon the other variables of the formula can be traced with ease; for example, if ρ=1.2 and m=7, when R_a/R_e = 0, η=.36; while if R_a/R_e=.2, η decreases to .35.

It will be observed that the "efficiency" here dealt with is defined as the ratio E_gE_a for signals of the detuned frequency. This ratio, it must be emphasised, does not become unity even when the frequency is actually that of the carrier wave to which the amplifier is tuned. That this is so may be seen by putting ρ= 1 in equation (1), which then becomes—

$$1/\eta = \frac{R_a}{R_e} + 1 + m\psi \quad .. \quad (2)$$

This equation, of course, gives the relations between m, R_a/R_e, ψ and the efficiency η or E_g/E_a with which the tuned signals are amplified. In this case η does not depend upon the tuning, except in so far as the constants of the equation are themselves modified by changes in frequency.

Chart II. (Fig. 2) has been designed to illustrate equation (2). It will be seen that ψ has been here included as an extra variable. The method of using the chart is similar to that for Chart I. Selecting that point on the network of lines representing R_a/R_e

and ψ which corresponds to given values of these variables, we join it to the given value of m, and read the required value of η in alignment upon the η-scale. As before, when any three are given, the fourth may be found. It is of interest to use Chart II. to exhibit the effect of changes in R_a/R_e and ψ upon the "efficiency" of tuned signals. Thus, for example, given $m = 60$ and $\psi = .01$, we find that when $R_aR_e = 0$, $\eta = .625$, while, when $R_a/R = \cdot 1$, $\eta = .588$.

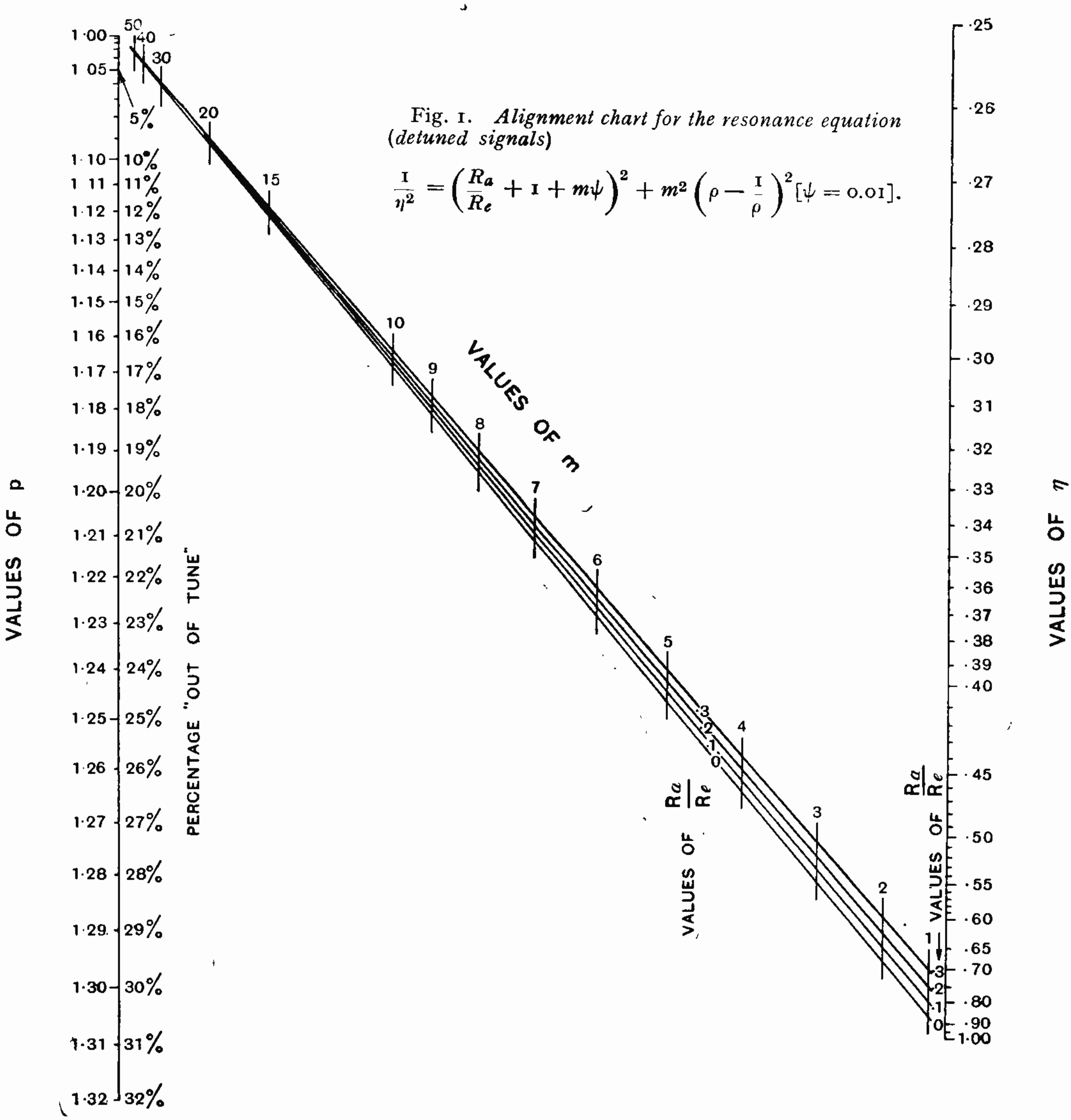


Fig. 1. *Alignment chart for the resonance equation (detuned signals)*

$$\frac{1}{\eta^2} = \left(\frac{R_a}{R_e} + 1 + m\psi\right)^2 + m^2\left(\rho - \frac{1}{\rho}\right)^2 [\psi = 0.01].$$

Charts I. and II. (Figs. 1 and 2) provide in compact and readily accessible form the numerical effect on η of changes in m and R_a/R_e, in the first case for signals detuned from the working frequency, and in the second for signals at the working frequency itself. Chart II. is, apart from the inclusion of ψ as variable, a particular case of Chart I., viz., that for which $\rho = 1$, the only value of ρ for which Chart I., being intended for detuned signals, does not cater. It is not necessary to stress the advantages of these diagrams in thus readily showing the effect which changes in the several variables have upon each other. Such features will be obvious to the reader. Mention should, however, be made of the values of η as found from Mr. Turner's graphs (see Fig. 2, p. 802) with the values as obtained from Charts I. and II., taking, of course, $R_a/R_e = .1$.

In order to compare the strength of detuned signals with that of the tuned carrier, Mr.

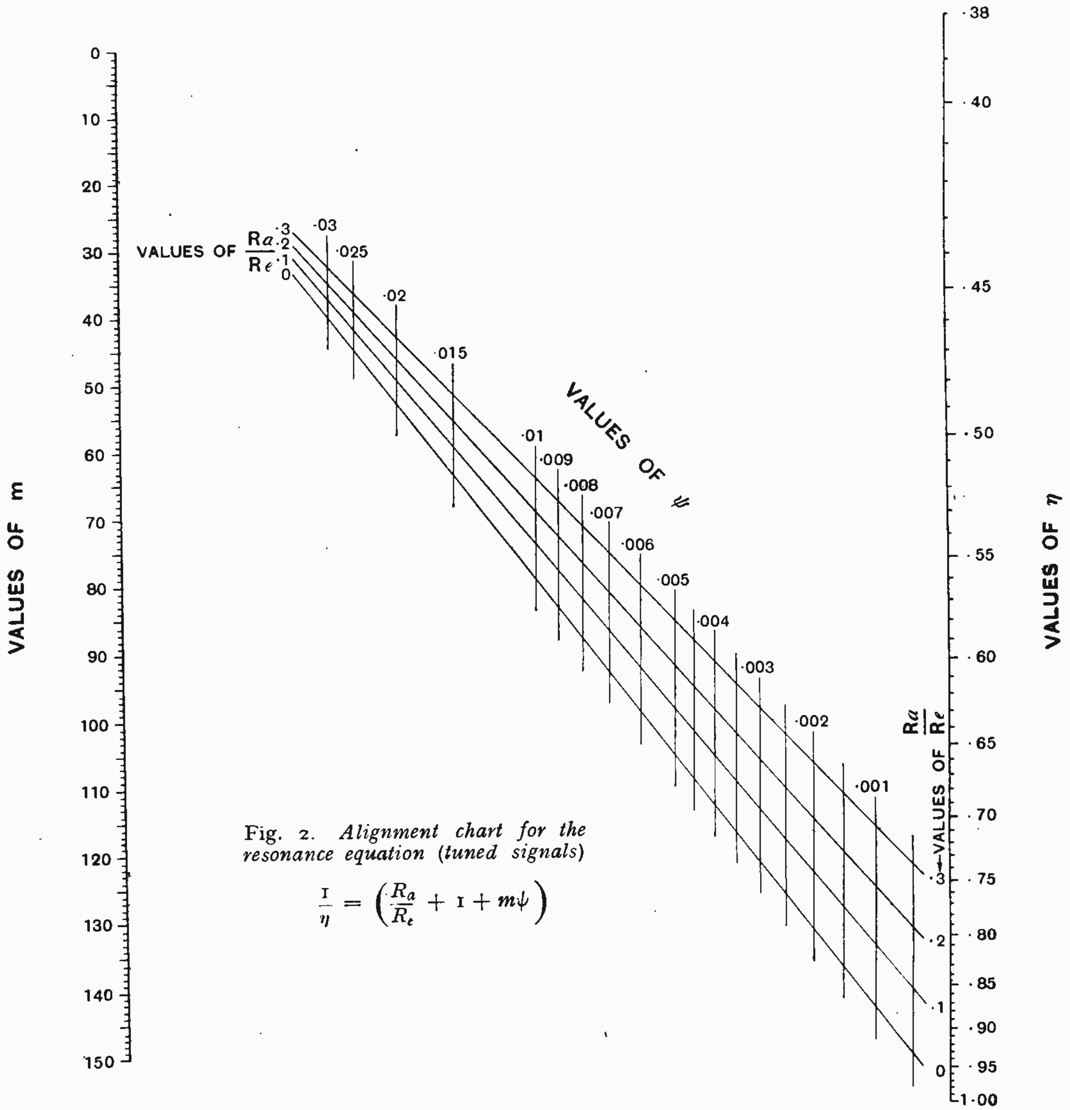


Fig. 2. *Alignment chart for the resonance equation (tuned signals)*

$$\frac{1}{\eta} = \left(\frac{R_a}{R_e} + 1 + m\psi\right)$$

extreme facility and rapidity with which resonance curves of the type given by Mr. Turner may be plotted out by means of these charts, and this, too, for the different values of R_a/R_e which are here included. It may be found interesting to compare the Turner now assumes the latter to be unity, and raises the value of the "efficiency" of the detuned signals in this proportion for all values of m and ρ. Calling now this new estimate of the strength of the detuned signals η', it will be seen that η' may be

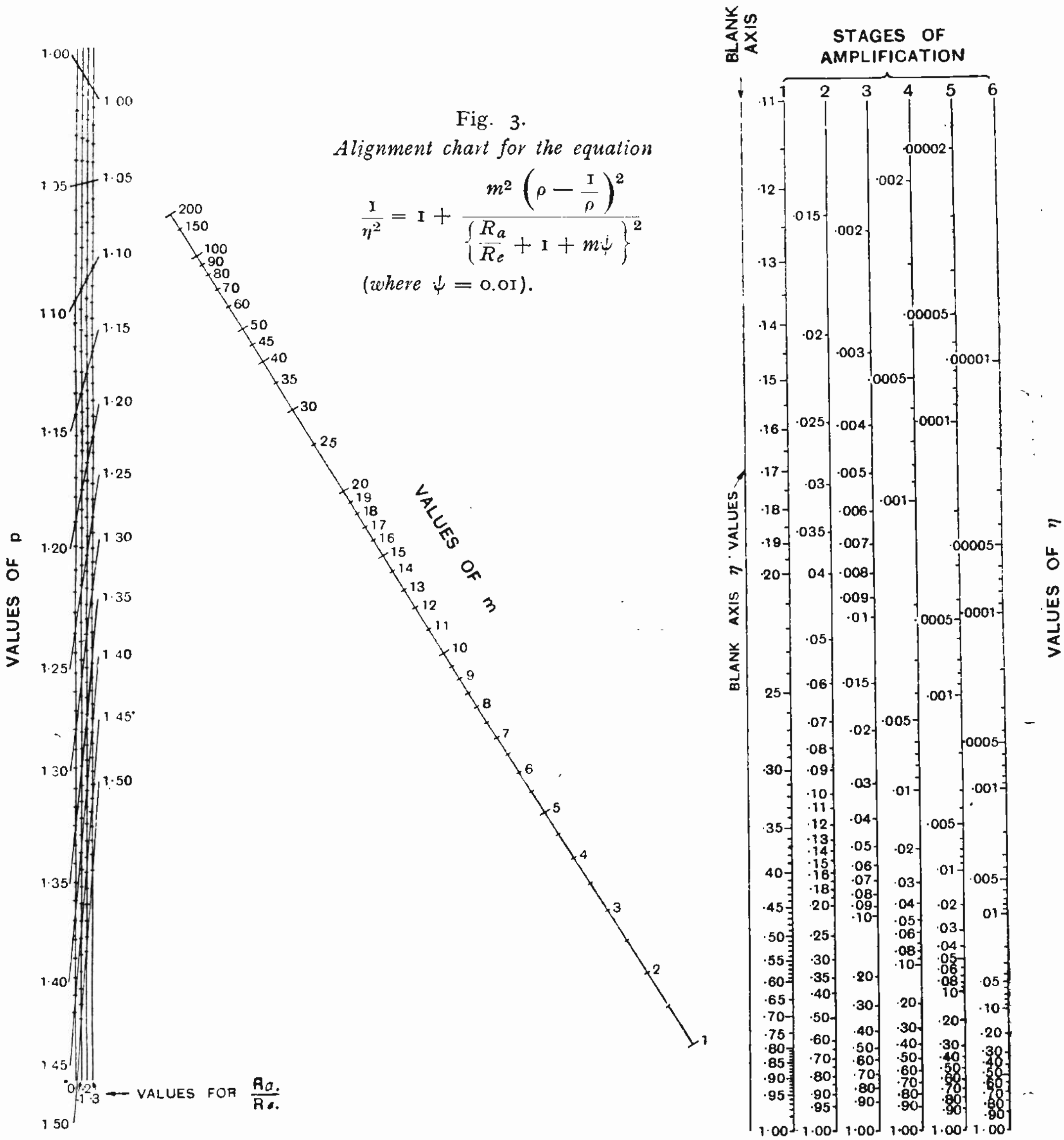


Fig. 3.
Alignment chart for the equation

$$\frac{1}{\eta^2} = 1 + \frac{m^2\left(\rho - \frac{1}{\rho}\right)^2}{\left\{\frac{R_a}{R_e} + 1 + m\psi\right\}^2}$$

(*where* $\psi = 0.01$).

obtained by dividing the efficiency given by equation (1) by that given by equation (2). In symbols,

$$\eta'^2 = \frac{\left(\frac{R_a}{R_e} + 1 + m\psi\right)^2}{\left(\frac{R_a}{R_e} + 1 + m\psi\right)^2 + m^2\left(\rho - \frac{1}{\rho}\right)^2}$$

$$i.e.,\quad 1/\eta'^2 = 1 + \frac{m^2\left(\rho - \frac{1}{\rho}\right)^2}{\left(\frac{R_a}{R_e} + 1 + m\psi\right)^2} \quad \ldots \quad (3)$$

Equation (3) forms the subject of Chart III. (Fig. 3) in which, as in the case of Chart I., ψ has been taken as having the value ·01. Since the ratio of strength of detuned to that of tuned signals decreases in a geometrical progression with successive stages of amplification, it is possible to include values of η for different stages. Chart III. contains first, on the left, a network of vertical and slanting lines corresponding to values of R_a/R_e and ρ respectively; second, a diagonal line inscribed with values of m; and third, on the right, a blank axis with six other parallel scales, each graduated with values of η for various stages of amplification. The method of use is as follows:—

Seeking upon the left-hand network the point corresponding to the selected values of R_a/R_e and ρ, we find that a line through it and the value of m taken on the diagonal scale will meet the blank axis in a point opposite which the required value of η will be found upon the scale representing the desired stage of amplification. Conversely, knowing the value of η and number of stages, the corresponding point on the blank axis may be joined to that point on the network appropriate to R_a/R_e and ρ, when the value of m is found in alignment. It will be seen that, equally with the other charts, the present diagram affords a means of estimating the value of any one variable in the formula when the others are known. It should be carefully noted that the working alignment point for the values of η is situated upon the blank axis, and that values of η are only to be read off *opposite* to this point. It is therefore important to align with points on this axis, and not directly on to the particular scales of η. To facilitate the reading of the values of η from the blank axis, a number of light horizontal lines have been drawn at intervals throughout its length.

The utility and convenience of Chart III. will readily be appreciated. Given η, the minimum permissible strength of side-bands of "tuning ratio" ρ, we can obtain the corresponding value of m for any desired number of stages of amplification. Thence, using this value of m we can derive corresponding values of η for signals of other detuned frequencies by altering the value of ρ in our alignment. In addition to the above, the effect of varying R_a/R_e can, of course, be taken into account by using the appropriate left-hand vertical scale on which to take the values of ρ.

The Permanency of Calibration of a Variable Condenser.

By E. Simeon. **[R220**

FOR many purposes it is obviously useful to have a variable condenser calibrated, so that the actual capacities may be recorded. It is proposed to deal with some defects which may cause undesired variation, thus rendering anything like permanent calibration impossible.

Fig. 1 shows the effect of slight up and down movement of the centre spindle with its vanes. The curve is drawn for a spacing of .04 in. on either side of the moving vanes. The capacity of the condenser as a whole for any given scale reading is, of course, a minimum when the moving vanes are midway between the fixed ones. It may appear at first sight that if the moving vanes were shifted up or down, that the loss in capacity on the one side would just negative the gain on the other, the total capacity being unaltered. Suppose, however, the vanes to

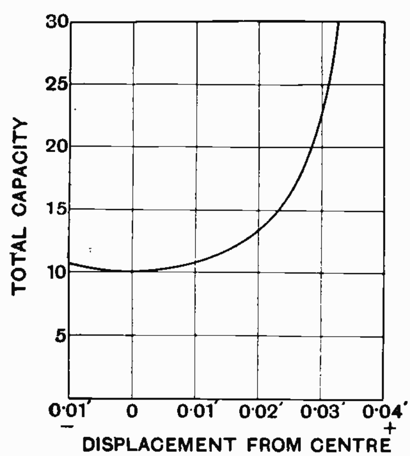


Fig. 1.

move axially so that the spacing on one side becomes halved, then the capacity on the other side which is left is clearly the increase in total capacity.

For small movements about the central position the change is seen to be very slight. Thus for the spacing of .04 in., which is quite a usual figure, a shift of .002 in. from the centre position will produce an increase of only 0.25 per cent. The same movement would, however, cause a 3 per cent. increase had the vanes been set in the first place .01 in. from the centre. It is therefore well worth while to set the moving blades carefully to the minimum position before sending the condenser for calibration. This may be done quite easily, the best way being to use the condenser in a heterodyning valve circuit, and adjust the bottom pivot while listening to the note.

To be worth calibration at all, a condenser should surely be reliable to 1 per cent. over at least a year. This means that endways spindle movement must not exceed .004 in. in that time. If the spacing can be doubled or trebled, the accuracy will be increased proportionally, but the bulk of a condenser for a given maximum increases rapidly with increase of spacing, since more pairs of plates are needed, each at an increased spacing.

One or two mechanical details may be useful. The diameter of the vanes should be kept down, even if a longish locking condenser results. A suitable thickness for the vanes is 18 S.W.G., and if of zinc they may readily be flattened with a hot flat iron on a flat surface, a method much less likely to leave strains than hammering. Zinc is, however, rather heavy, and the vanes may in time sag down slightly under their own weight, especially if the condenser is jarred often when being put down. This tendency can be got over by mounting the condenser with its spindle horizontal.

A mild steel shaft is recommended, so that the conical end may be case hardened. The shaft should have a shoulder, on which a spring bears, providing contact and keeping the pivot well home.

The end plate carrying the corresponding conical hole needs to be rigid, and should therefore be of metal, not ebonite. The insulating bush is best made of mica, which is not likely to yield under pressure to any extent. Finally, the condenser is enclosed in a metal case, connected to one set of vanes and earth.

It is possible to design a condenser where any amount of end movement will not produce change in capacity, the principle being shown in Fig. 2. It is not claimed as

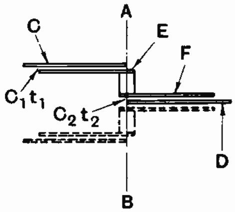


Fig. 2.

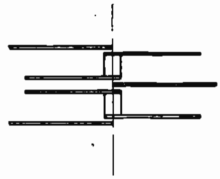


Fig. 3.

a complete solution to the problem, because it has the disadvantages of large bulk for capacity, and rather high minimum value. It is at any rate believed to be original. *AB* is the axis of the condenser, *C* and *D* being two fixed semi-circular electrodes, the terminals of the condenser being soldered to them. On the spindle is mounted an insulated pair of semi-circular vanes, *E* and *F*, connected by a distance piece. Other plates may, of course, be added below, all fixed plates under *C* being joined together, and similarly with those under *D*.

The areas of *E* and *F* are made equal, and the same dielectric exists between *C* and *E*, and between *F* and *D*. Hence any difference in capacity between C_1 and C_2 will be due to the spacing t_1 or t_2, *i.e.*,

$$C_1 = \frac{K}{t_1},$$

$$C_2 = \frac{K}{t_2}$$

C_0, the capacity between the plates *C* and *D*, will be equal to the product of these two divided by their sum, the two condensers being in series.

$$C_0 = \frac{\frac{K^2}{t_1 t_2}}{K\left(\frac{1}{t_1}+\frac{1}{t_2}\right)} = \frac{\frac{K}{t_1 t_2}}{\frac{t_2+t_1}{t_1 t_2}} = \frac{K}{t_2+t_1}$$

i.e., the capacity between *C* and *D* depends only on the sum of t_1 and t_2, which is not changed if the plates *E* and *F* move up or down.

In the minimum position, the plates are as in Fig. 3.

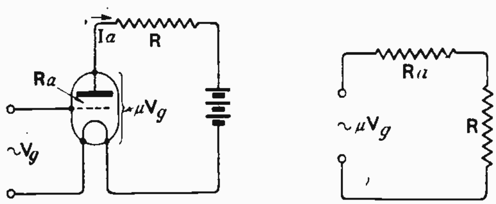
Some Notes on Intervalve Couplings.

A Lecture delivered by Mr. H. L. KIRKE, of the British Broadcasting Company, before the Radio Society of Great Britain, on 28th April, 1926.

[R132

WHEN I was asked by one of your members a little while ago to give a lecture here, at rather short notice, I had the same difficulty that I always have when I am asked to lecture, in deciding what to talk about. I always feel that other people have talked so much about the various subjects that it is very difficult to find something that is really interesting and useful and new to talk about. Therefore I thought that possibly the best thing to do would be to choose rather a wide subject and run through a number of notes of results and experiments that I have carried out rather than to give a definite lecture on one small subject. The subject I have chosen is intervalve coupling and I propose to run through the general principles of magnification and to discuss the odd things that occur in amplification rather than to deal with the things that everybody knows all about.

Magnification is generally accomplished by a valve having in its anode circuit some form of impedance, sometimes in the form



Figs. 1 and 1*a*. *The relation between the various quantities is* $Ia = \mu V_g/R + R_a$, *and the magnification is*

$$RI_a/V_g = \mu/1 + \frac{R_a}{R}.$$

of a plain resistance which acts as an ordinary resistance amplifier, and sometimes it is a choke with inductive impedance, and sometimes it is a resistance shunted by a capacity. Sometimes chokes are shunted by a capacity and in many cases the circuit is tuned to a frequency so that it amplifies at that frequency. In general, the magnification of a valve can be considered as the ratio of the amount of voltage developed across the impedance in the anode of the valve to the voltage which is put into the valve. From that point of view it follows that you can consider a valve as a generator having a

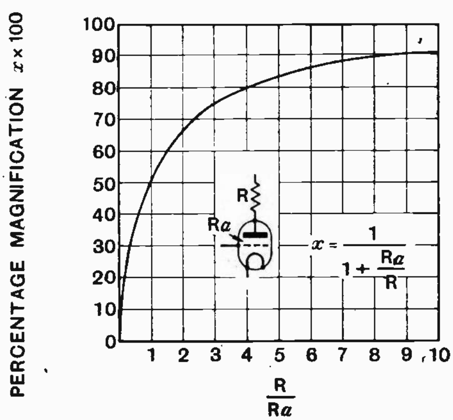


Fig. 2. *Curve showing per cent. magnification of a valve with a pure resistance load in the anode circuit.*

certain E.M.F. at its terminals and having a certain internal resistance, *i.e.*, when the grid is made alternately positive and negative, the anode current alternately increases and decreases, causing differences of potential across the output circuit. These differences of potential tend to reduce the rise and fall of the current and so to reduce magnification, which is exactly what happens in an A.C. generator, and if you put a high resistance in series with an A.C. supply it is obvious that you will not get very much current if you want to take a large load out of it, and you will not get very much potential difference.

At the top of Figs. 1 and 1*a* an ordinary plain resistance amplifier is shown in which the magnification is the ratio of the voltage developed across the resistance—which can be applied to any other stages which come after it—to the input voltage. I neglect all questions of plate, grid, etc. That ratio is represented by the formula given.

Fig. 2 is a curve showing the ratio of the maximum possible magnification which you get, for various ratios of the external impedance to the internal impedance of the valve, and for a ratio of $8\frac{1}{2}$ to 1, the magnification is 90 per cent. of the maximum, and it falls off in a fairly even curve.

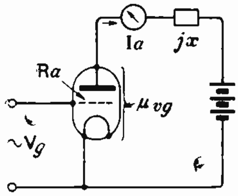


Fig. 3.
Here $I_a = \mu V_g/R_a + jx$ *and the magnification* = $\mu/1 + \frac{R_a}{jx} = \mu jx/R_a + jx$.

By *jx* in Fig. 3 I mean a pure negative or positive reactance in the plate circuit. This is a somewhat different case because you have the E.M.F. across *jx* 90° out of phase with the current flowing through it and consequently the magnification ratio will be reduced in a different way. The various formulæ which you will all recognise, are shown under the figure.

Fig. 4 shows a curve of relative magnification in percentage against the ratio of internal and external impedance, and you see that for 9 to 1, we get nearly 100 per cent. That is due to the fact that the back E.M.F. is 90° out of phase and does not reduce the current in the same way as an ordinary resistance does. For 90 per cent.

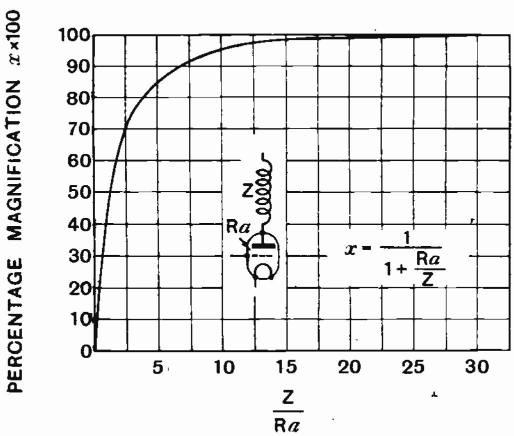


Fig. 4. *Curve showing per cent. magnification of a valve with pure inductance in the anode circuit.*

here, we only need a 3 to 1 ratio to get the same ratio of magnification to the maximum as we did with the resistance amplifier. This other scale is the inductance in henries required per thousand ohms of anode impedance at 50 cycles to give the various percentage magnification, as shown in the scale, so that if you have a 1,000-ohm valve and 20 henries you will get 98.7 per cent. magnification out of the valve, at 50 cycles, which is fairly good.

At relatively low frequencies, *i.e.*, audible frequency, there are various peculiar things which can happen to a valve.

The ordinary valve has an inter-electrode capacity which many people who have done short wave work hate like poison. Unfortunately, that capacity can come in at relatively low frequencies. If you have a circuit such as Fig. 5, and you apply an E.M.F. to the grid, it will cause a certain magnification and you will get a certain difference of potential across the anode. That will cause a current to flow back to the condenser through the resistance R_g, causing a potential difference the phase and magnitude of which will depend on the value of the condenser. If the condenser is infinitely large you will get the same potential across R_g that you do at the anode.

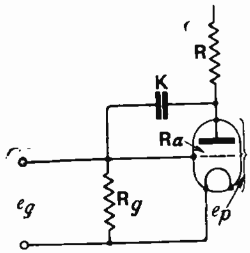


Fig. 5.
Circuit representing conditions in an amplifier.

When the grid is negative due to the incoming impulse, the anode will be positive and you will get back an amount of E.M.F. on the grid which is exactly 180° out of phase with the incoming E.M.F. That reduces the magnification to less than 1, the phase angle will change round to nearly 90° when the condenser impedance becomes very high in relation to R_g. R_g means the grid-leak of the valve, in parallel with the impedance of the valve before it, because if you have another valve you have *via* an intervalve condenser the impedance of the other valve to earth, so that the anode impedance of the valve before is really in shunt with R_g. We call X the ratio of the magnification, which you get when feed back is present, to the magnification which you would get if there were no feed back. We came across this anode reaction about 18 months ago in some work on power modulation systems in use at the time.

We had certain apparatus and were taking curves of the magnification right through the system and we found that the magnification at about 5,000 cycles was about one-tenth of what it ought to be and various experiments showed that it was due to this capacity feed back. Actually we had seven valves, which were fairly big, in parallel and we were working with about 10,000 volts on the anode, and that was the result we got. We could not reduce the capacity K because it was the capacity of the valve and we could not use a different type. We actually did reduce the M value of the valve a little bit by opening the grid, which reduced the effect slightly but the best effect was obtained by reducing R_g. We did not actually reduce the grid-leak resistance but we reduced the impedance of the valve before it. The reason we did not reduce the grid-leak resistance was because we had an intervalve condenser which we could not increase in capacity, so we actually changed the impedance of the valve, from one of 50,000 ohms to two in parallel of 5,000 ohms each, which reduced this value of R_g, which meant that the frequency at which we could get a definite cut-off, X, was very much higher. Thus we reduced R_g from 50,000 to 2,500, a matter of 20 to 1, so that the frequency at which we got a definite cut-off in magnification was increased by 20 times, and that was our saving grace on that particular job.

In H.F. amplification, it is generally assumed that it is not possible to amplify with resistance capacity at wavelengths below 1,000 metres, but actually I have used H.F. magnification, or I have seen it done, at 250 or 300 metres, fairly successfully. I do not say the magnification is efficient, but it is a definite magnification which is useful and that magnification was not obtained in the ordinary way. The reason I am talking about that, is this: most people consider that the loss in magnification is due to the valve capacity shunting the anode resistance. That is so to a certain extent, but intervalve feed back comes in considerably and in all cases we may have pure resistance in the grid and in the anode. The feed back due to this, results in a definite reduction because the E.M.F. across the grid due to feed back has got to be made up by the incoming signal which actually reduces the magnification, and I firmly believe that quite a lot of the loss of magnification in high frequency is due to that feed back and not purely to the fact that there is a shunt capacity across the resistance.

I show in Fig. 8 a circuit which I have tried. I have used it in other connections and find it useful and I think it may possibly neutralise the feed back effect and enable one to get a fairly good magnification. Part of the circuit is a pure capacity Wheatstone bridge and the two valve capacities are balanced so that any E.M.F. across one diagonal will not produce an E.M.F. across the other. I have not tried that circuit for the particular purpose of neutralising the feed back in resistance amplifiers, but only in transmitting sets, but I think it is worth considering.

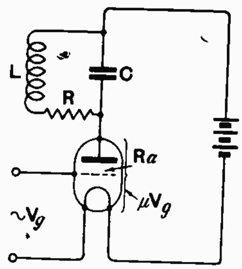


Fig. 6.

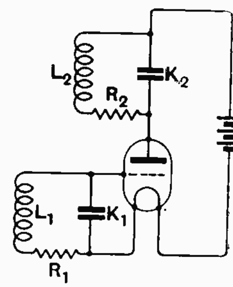


Fig. 7.

Fig. 6. *Tuned anode circuit. When there is no reaction and the circuit* LRC *is in resonance, the phase angle of this anode circuit load is zero and* LCR *acts as a pure resistance. The magnification is* $\mu/1 + R_aRC/L$.

Fig. 7. *Tuned anode circuit with tuned input to valve.*

Fig. 6 shows an ordinary tuned anode circuit, neglecting what is put on to the grid in an ordinary circuit of this kind and it is generally assumed that the circuit CLR has tuned resonance. When the circuit has zero phase angle, it acts as a resistance and therefore that circuit can be assumed to have the same effect as a resistance amplifier. The capacity across the electrodes is neglected and therefore we should be able to consider an ordinary tuned anode circuit as a pure resistance amplifier having a magnification given by

$$M = \mu/1 + \frac{R_a R}{L}.$$

If that is the case, *i.e.*, if it is pure resistance, then everything that happens in your resistance amplifier must happen in the tuned anode. Therefore, with a circuit like this, we shall have a feed back effect which will give anti-reaction—not ordinary reaction — due to the phenomena shown in Fig. 5. From that it would appear that with an ordinary tuned anode you will get anti-reaction so that it will not oscillate. The average tuned anode, if you adjust it by twiddling the knobs, oscillates—much to the annoyance of your neighbours—and the reason is this: If you mistune the anode circuit very slightly one way you will alter the phase angle in one direction; if you mistune the grid circuit slightly in the opposite direction you alter the phase angle in the opposite direction and the result is that you so juggle the phases of the two sets that the conditions of anti-reaction,

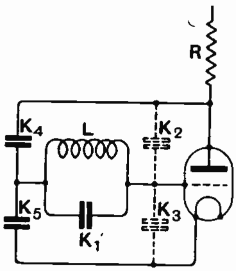


Fig. 8. *For balance* $K_4/K_5 = K_2/K_3$.

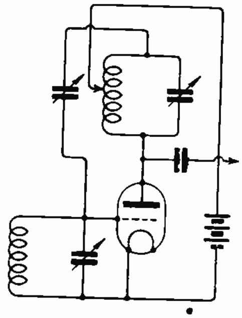


Fig. 9*a*. *The ordinary neutrodyne circuit.*

shown in Fig. 5, change and you turn what was an anti-reaction into a reaction by mistuning the circuits; therefore you will not be getting maximum efficiency. Actually, you always tune in to the maximum signal and therefore it can be assumed that you tune in to the point where you have maximum reaction, because the magnification of an ordinary valve is no more than about 6, where as the magnification or increase of signal due to reaction is of the order of 20 to 40 times, according to the stability of the circuit and the resistance of the various coils.

There are one or two possible methods of overcoming this anti-reaction and so enabling you to tune dead on to the radio frequency and get the advantage of the full magnification of the valve and the full effects of resonant circuits as well as reaction (Figs. 9*a*, 9*b*, 9*c*). Circuit Fig. 9*a* is the ordinary well-known neutrodyne circuit, but the balancing condenser is increased beyond

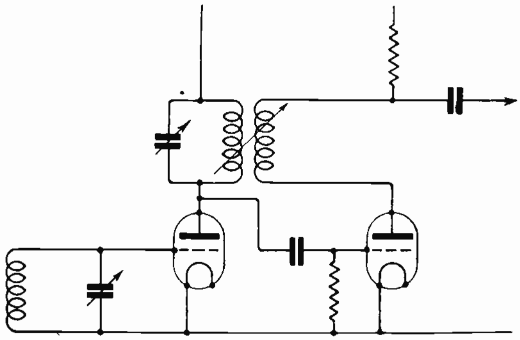


Fig. 9*b*. *Tuned anode circuit with reaction.*

the neutrodyne point, *i.e.*, the point where its capacity is equal to the intervalve capacity, to bring up the reaction and I have found that such a circuit does give better results than the ordinary tuned anode circuit which is left to oscillate and is damped in some way.

Fig. 9*b* is an ordinary tuned anode with reaction from the detector valve on to the anode circuit, and that is considerably better than an ordinary circuit for reacting.

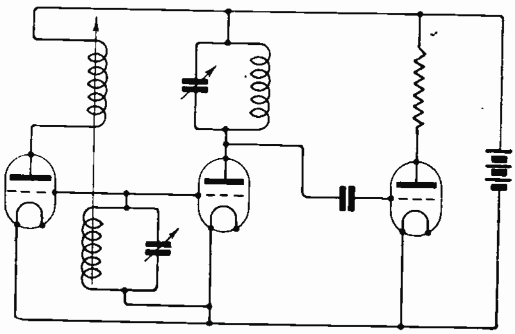


Fig. 9*c*. *Circuit using an extra valve to give stable reaction control.*

Fig. 9*c* is a commercial circuit which a friend of mine got out some years ago and it is used considerably. The left-hand tuned circuit is the aerial coil or closed circuit coil and the circuit generally is fairly simple for reacting. You get pure reaction without mistuning the circuit and that is a very good thing to use, particularly in resistance amplifiers where you have no other means of getting reaction. Reaction from the ordinary resistance amplifier is, to put it mildly, rotten, because you get all sorts of phase changes, whereas in this it knows what it is doing. It may be argued that it is not worth having the extra valve because you do not get the extra gain, but it is much better than using the valve as another tuned anode, because if you put in another tuned anode you have more instability and three handles to tune plus the reaction controls, whereas in this case you have only two handles and one reaction which is very, very stable.

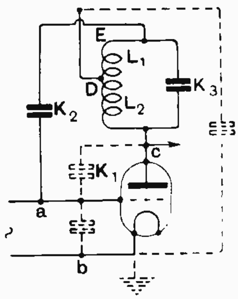


Fig. 10a. *Showing where the stray capacities occur in a tuned anode circuit.*

The next point in connection with high frequency is the balancing of the neutrodyne circuits. Everybody has more or less gone in for neutrodyning at the present moment,

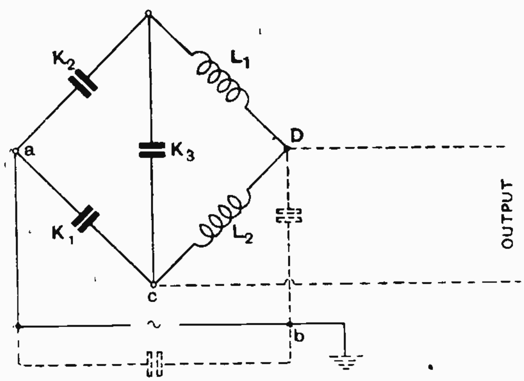


Fig. 10b. *Theoretical circuit of neutrodyned tuned anode.*

except those with the supersonic tendencies, and I thought a few comments on neutrodyne balancing, particularly where a large number of stages have to be used, would be useful. An ordinary simple neutrodyne circuit with a split anode coil (Fig. 10*a*) is one of the simplest things possible to rig up. What happens is that when you get a signal in the anode circuit you get a circulating current in the anode coil, and when the anode end is positive, the opposite end will be negative and *vice versa*, and you put back on to the grid the same amount of E.M.F. but in the opposite phase from the E.M.F. put back through the intervalve capacity. If we draw that in another way (Fig. 10*b*) it looks like a Wheatstone bridge, the lettering give the clues for tracing the set, but the only snag is this, in a Wheatstone bridge you put in E.M.F. across *A* to *D* and take it out from *C* to *E*. In a tuned anode such as this, you take it out across the anode and the filament, because the H.T. usually goes through the condenser to earth, so that you take the output only across half the coil. In the

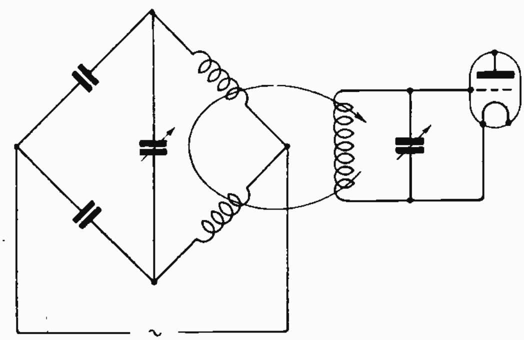


Fig. 10c. *Theoretical circuit of neutrodyne transformer.*

average neutrodyne receiver there are four valves and you balance by turning out the filament and adjusting the neutrodyne condenser until you get silence, and when you have done that you light all your filaments again and the thing begins to oscillate (laughter). The reason is, I believe, that you do not get a true balance.

Fig. 10*c* shows a form of neutrodyne circuit in which you can definitely get a balance.

Figs. 11*a*, 11*b* and 11*c* show circuits in which the anode tuning condenser or a part is split.

Figs. 12 and 12*b* give another circuit in which the grid coil is neutrodyned instead of the anode coil. In the ordinary course of events the anode coil or condenser is split, but in this case a pure Wheatstone bridge is constructed. There is capacity between the grid and plate, balanced by a condenser, and another capacity between grid and filament which is balanced by a condenser. Therefore a coil is connected across *C D* (Fig. 12*b*) which is not affected by potential across the anode coil. A grid-leak is used in order to allow the grid current to get to earth somewhere and another gridleak should be connected across the opposite arm (*a d*) to balance properly. It may be necessary, if ever you use such a circuit as that, to put a small resistance in series with the condensers in order to get a perfect balance. The great advantage of this circuit is that you do not lose half the impedance of the anode circuit as in a split coil, as it is sometimes an advantage to have a high impedance in the anode circuit.

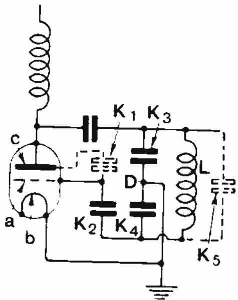


Fig. 11*a*. *Neutrodyning with a split tuning condenser.*

Fig. 13*a* is another type of circuit which has been used. Essentially it is a tightly coupled transformer with tuned secondary.

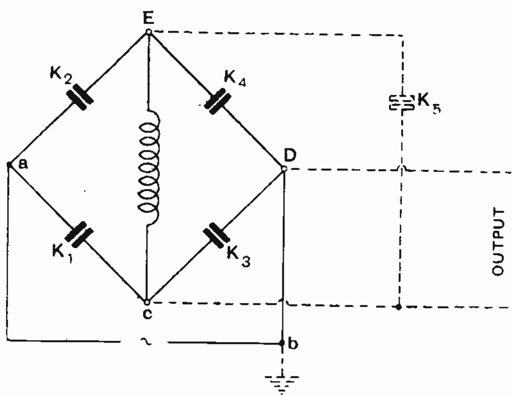


Fig. 11*b*. *Theoretical circuit of Fig. 11a.*

The primary has a centre tap. The end remote from the anode has an equal and opposite potential induced which is used to balance.

Fig. 13*b* is a system of neutrodyning used in America and consists of a reversed winding transformer tightly coupled, a portion of the secondary being connected through a condenser to the grid. I have used that circuit lately with four and five stage magnification and it has the disadvantage that it tends to get out of balance for different frequencies rather quicker than most circuits, because the coupling is not 100 per cent. and also because there is a considerable amount of electrostatic capacity between the two coils which puts the circuit out of balance. That could be got over by copper

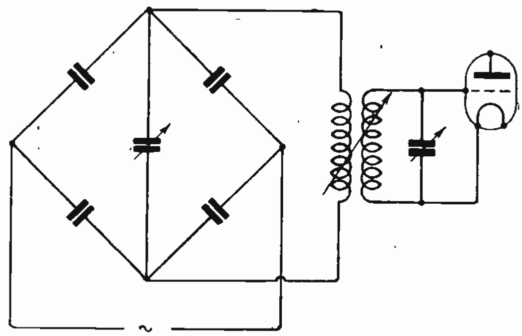


Fig. 11*c*. *Theoretical circuit of neutrodyned transformer using a split tuning condenser.*

screening between the coils, but that would at the same time probably decrease the efficiency somewhere else, and I do not think it would be worth it, unless very carefully designed.

In Fig. 14 we have an ordinary low frequency choke-coupled amplifier, of which you have seen the curves before. Various people have asked me what sort of choke to use and I have shown in Fig. 4 a simple formula for estimating the choke value.

There is just one point in connection with the choke-coupled amplifier which is worth while bringing out. If you use this circuit and your loud-speaker does not bring out anything below 300 cycles, it is no use giving magnification below that, and you probably put in a smaller choke. If you happen to be using a valve with large inputs, you will get distortion because the choke does not act in the same way to the

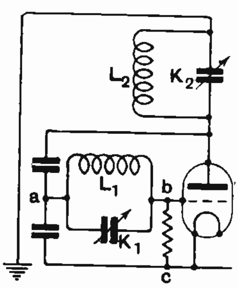


Fig. 12*a*. *Showing how the grid coil may be neutrodyned.*

frequency for which it is designed as for the low frequency. It takes more current at low frequency and it alters the dynamic characteristic of the valve and you get base blasting, since all forms of blasting

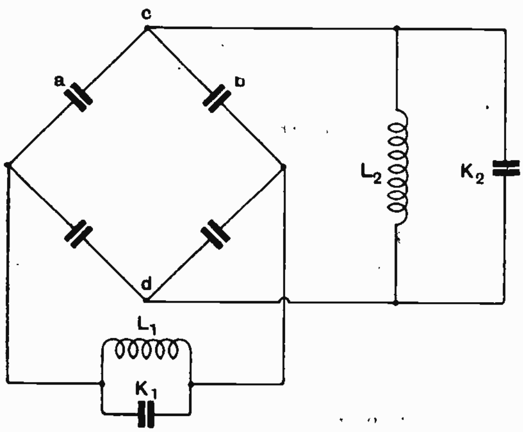


Fig. 12*b*. *Theoretical circuit of Fig.* 12*a*.

produce harmonics and all harmonics will be heard in the loud-speaker although the fundamental is audible.

I do not think there is any necessity to say anything more about ordinary resistance low frequency amplifiers and the curve I showed at first is quite obvious. The minimum value for an intervalve condenser in any low frequency amplifier must be borne in mind. Incidentally, it is considered in best circles that it is necessary to get reproduction down as far as 50 cycles

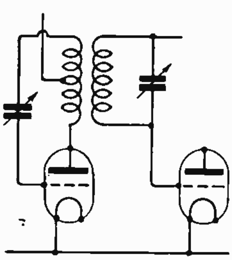


Fig. 13*a*. *Transformer circuit with primary neutrodyned.*

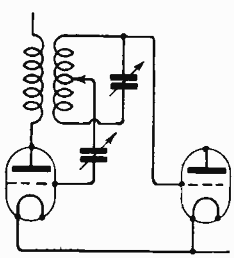


Fig. 13*b*. *Tuned transformer circuit with secondary neutrodyned.*

for the reproduction of music and, that you must have fairly big condensers. The value of an intervalve condenser depends solely on the lowest frequency you want to transmit, and on the value of the grid-leak, because all the grid condenser has to do is to pass current through it to the grid-leak. If you increase the value of the grid-leak you can decrease the value of the condenser and *vice versa*.

The next thing we come to is low frequency transformer amplification, which is a subject in which I dare say everybody is interested. A transformer which has no shunt across the secondary can be regarded at low frequencies as a pure choke-coupled amplifier, and the total magnification of such a transformer is the magnification of the primary considered as a choke-coupled amplifier, multiplied by the step-up ratio. The trouble is how to design the secondary, because it has self-capacity and magnetic leakage.

A representative diagram of any transformer is shown in Fig. 15. We are considering here (R_a) the internal resistance, which may be a valve or anything else; the same law holds. R_2 is the primary resistance; R_3 is the secondary resistance; L_3 and L_4 are the choke inductances of the two windings; K_1 is the capacity of the secondary. L_1 and L_2 represent the magnetic leakage of the transformer; it has been found that in most cases the magnetic leakage of a transformer can be represented by series inductances in the primary. And for the secondary, R_1 represents the hysteresis and eddy current loss. In the diagram we have the primary consisting of inductance and resistance and the secondary is, in effect, a resonant circuit. If we had no any leakage, and had just a resistance across this circuit between *PY* and *SY*, looking at it from the primary—I do not know whether you can follow the method—but I mean what would you feel like if you had a transformer like that stuck on to you. What current would you produce and what would its phase angle be? If we had a resistance shunted across the secondary what would it look like viewed

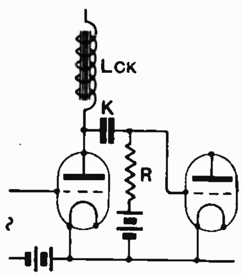


Fig. 14. *A low frequency choke coupled amplifier, which gives a magnification curve similar to Fig.* 4.

from the primary? Normally, if we had no losses in the transformer and an infinitely large inductance, we have a resistance across the secondary which takes current and allows the primary to take current in order that the lines of force in the core shall cancel out, but if you have a 2 to 1 step up transformer the secondary volts are double the primary volts, the secondary current half the primary current. The impedance of any circuit is the voltage divided by the

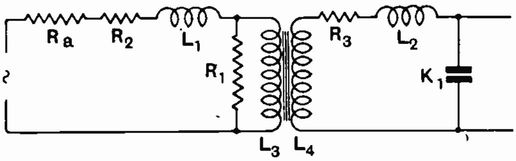


Fig. 15. *Equivalent intervalve transformer circuit.*

Here R_a *Anode impedance.*
R_1 *Eddy current and hysteresis loss.*
L_1, L_2 *Leakage inductances.*
L_3, L_4 *Primary and secondary inductances.*
R_2, R_3 *Primary and secondary resistances.*
K_1 *Secondary self capacity.*

current; therefore, the impedance of the secondary circuit can be said to be four times the impedance of the primary circuit. In other words, the impedance of a transformer, as shown on the primary or the secondary, varies as the square of the transformer ratio—that is absolutely fundamental, and it must be remembered that it is so. Therefore, we can ascertain the primary impedance by taking all the impedances in the secondary and dividing them by the square of the transformer ratio. If we have a resistance of 100,000 ohms and a 2 to 1 transformer, there would be 25,000 ohms as the effective primary impedance and if we have half a henry as L_2 it would be one-eighth henry as L_1 on the primary. If we have 1μF as K_1 it would be equal to 4μF across the primary.

Fig. 16 shows a transformer laid out as looked at from the primary. R_1 is a fairly high resistance; L_3 is a very high choke value; L_1 is a small inductance; R_2 is a small resistance and R_a represents the impedance of the valve. Therefore we see that at high frequencies L_3 will pass but little current and the resistance R_1 is high, so the thing approximates to an ordinary series resonating circuit. With such a circuit we are tending to get more and more voltage developed across K_2 as the frequency goes up. Then, at a certain point, magnification will drop off again, the amount of increase at the resonant frequency (R_a) will depend on the resistance. The lower we make R_a, the more will be the resonance, and the higher the resistance the less will be the resonance.

Now we come to an interesting point. As we increase L_3 to bring up our low frequencies (the inductance of the primary is the thing that matters), we have to increase the primary turns and increase the inductance. As we increase the turns we decrease the ratio and, at the same time, decrease the ratio of L_5 to K_2 because L_5 is inversely proportional to the square of the ratio and K_2 is proportional to the square of the ratio. By altering the number of turns we increase the magnitude of the resonance peak, due to resonance circuit, L_1 L_5 K_2 R_a considerably, and that is a point which must be taken great care of. The only way of getting over that is either by decreasing the leakage, by increasing the capacity, or by putting a shunt across the secondary.

Three transformer curves are shown in Fig. 17: (A) is a typical good commercial

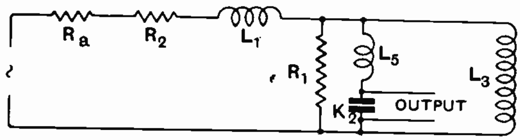


Fig. 16. *Equivalent intervalve transformer circuit as regarded from the primary side.*
Here X = *Transformer ratio.*
$L_5 = L_2/X^2$ ($L_2 \times K$ *as in* Fig. 15.)
$K_2 = KX^2$.

transformer which starts cut-off up at about 650 or 700 cycles and is down to about .7 at 500 cycles and it goes up to a slight peak at 5,000 cycles, dropping off again. That peak is what is left of the resonance peak after the losses in the transformer. If we try more turns on the primary of the transformer to get up to low frequencies, we get the curve (B), and that actually happens in practice. We had enormous difficulty to get over that but we did so by damping the secondary with resistance and the resultant curve is shown in (c). It is interesting in this connection to note that for an ordinary valve, like the LS5, PM6 or DE5, if you want to get an intervalve transformer which drops not more than 10 per cent. at 50 cycles and not more than 10 per cent. at 10,000 cycles—which is the ideal transformer, although I do not know of one being in existence (commercially) at present—you will not get a step up of more than 2.25 to 1. For a 10 per cent. drop at 300 and 5,000 cycles, you may have a 6 to 1 ratio transformer and that explains when you see on the market 8 to 1, 6 to 1, 4 to 1 transformers, etc. You are always told there is no distortion, in fact, none of the transformers ever distort officially, but what actually happens is that they have got different ratios and different turns and they have got different characteristics. The ones which have a high step up ratio have not got enough turns on the primary.

With regard to the use of stalloy iron, which is used so largely on transformers, there is the question of the flux density at very low intensities and I think it would be interesting to endeavour to plot a curve showing the value of inductance for various magnetising forces expressed in ampere turns.

Fig. 18 represents *log* ampere turns against inductance. I think this figure rather destroys the idea that iron does not do anything at low intensities; that idea

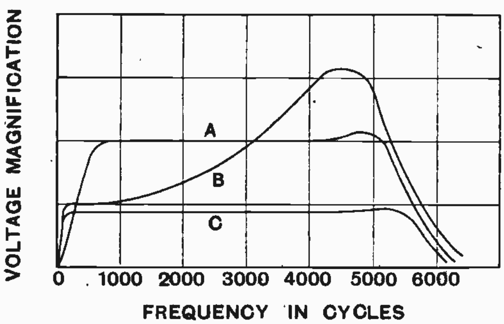


Fig. 17. *Amplification/Frequency curves for various transformers.*

has been put forward and has misled people considerably.

The curve was taken by an inductance bridge and amplifier, the current in the coil being measured at one value and adjusted by the insertion of resistance networks between the supply and the input terminals of the bridge, great care being taken to avoid any cross talk or induction troubles.

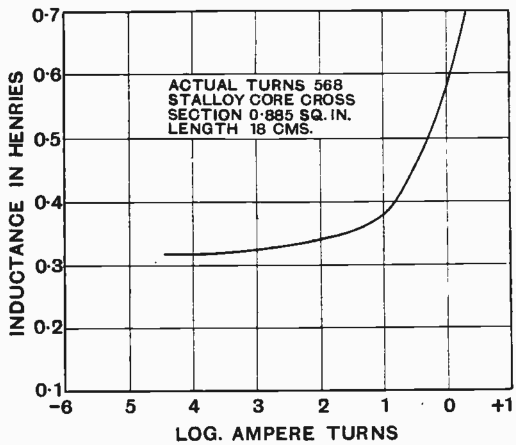


Fig. 18.

DISCUSSION.

Mr. R. E. H. Carpenter: I should like to thank Mr. Kirke for one of the most interesting lectures to which I have listened for a long time. Mr. Kirke has shown himself a master of his subject, and there are one or two points on which I should like his views. The first is this. Van der Bijl was, I think, the first to point out that if you have a reactance in the anode circuit of a triode, the characteristic—which before you put the reactance in might have been a straight line—opens out into an ellipse. If that is the fact, it would seem that it would be impossible to avoid a certain amount of rectification in a triode which has reactance in its anode circuit.

I am very glad that the lecturer has nailed down once for all the extraordinary story that was started a little while ago that iron does not respond to very small magneto motive forces. I think his results are in substantial agreement as to shape—I do not know how they agree quantitatively—with the generally accepted statement that stalloy has an initial permeability of about 300, and I should be interested to know how Mr. Kirke's results compare quantitatively with that figure.

With regard to one of the earlier slides showing a retroaction circuit in which you used potential from the remote end of the anode coil in order to get the retroaction effects—I think it was slide No. 9—one is, of course, familiar with the fact that over-neutrodyning will bring you into the oscillating condition again, and I have tried to make a rough comparison between the signal obtained when getting critical retroaction by under-neutrodyning and over-neutrodyning. I do not think it makes much difference whether you approach your critical retroaction by under or over-compensation. I should like to finish by again thanking Mr. Kirke very much indeed for his lecture. I am looking forward with great pleasure to seeing the thing in print when I can perhaps digest some points I have not been able to to-night.

Lieut. H. S. Walker : I hardly know what to say about this lecture by Mr. Kirke. Mr. Carpenter has covered several points which I wanted to bring out, and he has left me very little to say beyond the fact that this lecture obviously wants a lot of consideration and digesting. One cannot grasp it all at once because it covers such a wide field. I think, however, it may be interesting to ask Mr. Kirke, if he has a few moments left at the end of this discussion, to say a little more on the subject of the general design of neutrodynes, particularly with regard to getting perfect balance. I feel that with most neutrodynes—or, rather, the neutrodyne circuits one meets with—one cannot get perfect balance no matter how one may screen the coils, for the reason which he mentioned—namely, that the perfect Wheatstone bridge effect is not usually obtainable. I think it could be obtained, and, if it could, I think one might use a much larger number of stages in cascade. The other point I want to ask the author for further explanation about is the use of resistance capacity for high frequency work. Obviously it always possesses the disadvantage that there will be a drop of potential on to the anode so that extra high tension voltage must be used, but probably in these days that is not so serious as it might have been 12 months ago, and therefore it has occurred to me that a field is opened for perhaps more use to be made of resistance capacity for high frequency work, because, after all, it does away with the necessity for an extra control, such as a tuning condenser, which one has to use for a tuned anode or tuned grid, and, for that matter, also transformer coupling. Mr. Kirke did not deal with a subject which interests me very much, and that is the question of the intervalve coupling for the intermediate frequency stages in the superheterodyne receiver. I think most of the points which he talked about covered that field, but it does possess one or two special points, particularly, I think, the question of whether it is worth while to neutrodyne intermediate frequencies or to use some apparatus other than a transformer for the coupling. I know transformers are chiefly used for the intermediate frequency coupling, but I am not at all sure in my own mind whether they are the best method of coupling. If Mr. Kirke has a few moments to spare I should be very grateful if some remarks could be made, especially on the latter point.

Mr. Ashbridge : I also should like to express my appreciation of Mr. Kirke's most excellent lecture. He has dealt with the thing in a highly scientific way, and after listening to his lecture there is very little more to say on the subject, although it is such a large one. There are, however, two points I wish to mention. The first one is whether he has any experience of neutrodyning a high frequency resistance capacity amplifier. Of course, we all know, without going into details, the shortcomings of such amplifiers, but they are a certain amount of use after all, although when used with several stages they become unstable. I should like to know whether Mr. Kirke can suggest a method of neutrodyning, and whether it has ever actually been done. The other point is not a technical one exactly. I believe it is a fact that the principle of neutrodyning has been known for several years. In fact, I think I heard something about it in a quiet sort of way about four years ago. For some reason or other it never became used here until comparatively recently, and it would be interesting to know whether this is due to the fact that it was not realised that intervalve capacity was the trouble or whether people started on the right idea and got into trouble with magnetic coupling and abandoned the scheme because they did not think it would work. Generally speaking, the lecture has been so comprehensive that it almost prevents discussion.

Mr. F. L. Hogg : I should like, with other speakers, to thank Mr. Kirke for his most excellent lecture which will be of great value to me. I should like to know if he could help me to solve a difficulty. We have all had trouble when using separate resistance amplifiers at low frequency, when one tries to introduce reaction on the detector valve, particularly in cases where one is using an extremely bad aerial, and it is necessary to use reaction to get any sort of results at all. One gets into great difficulties due to the fact that when you get near the oscillation point it is difficult to keep there and prevent oscillation at a frequency of about 10 or 20 per second or even less than that, perhaps four or five per second. I have been endeavouring for some time past to produce a receiver to conform to certain ideals using a varying number of stages of high frequency and anode rectification for receiving long distance transmission of the greatest possible purity, and I have had tremendous difficulty in eliminating this oscillation trouble, without sacrificing in some way the quality. It seems usually necessary to get over the trouble by using the most horrible method of shunting the resistance in the plate circuit of the detector valve with a condenser or using a shunt reaction coil, which amounts to exactly the same thing. I have tried numerous schemes which various people have suggested, but have not found any satisfactory way of getting over that trouble without having to use a shunt condenser or some equally bad scheme in which one loses a great deal of the quality which one has taken a great deal of trouble to get. I should be glad, therefore, if Mr. Kirke can give me some assistance on that point and the best way of doing it in order to get the absolute maximum possible purity.

Mr. A. E. Bawtree : I should like to ask Mr. Kirke's opinion on one point which is troubling me. I have three stages of low frequency amplification with LS5 valves and resistance capacity, and by mistake, in the first instance, the condensers which were put in were only one-fiftieth of the capacity which they should have been, but I seem to be getting perfect results. When I was advised that the condensers were too small, I did not replace them with proper ones, but I added one of larger capacity to each of the condensers in turn, but the final result on the loud speaker appears to be absolutely nil, and it certainly does not give the great increase in strength of the lower notes which

I was told I should get. I cannot account for it, and I wonder if Mr. Kirke can give any explanation which will help on that point. I should like to express my extreme appreciation of the lecture, and anticipate with other speakers that we shall benefit very considerably when we have an opportunity of studying it in detail.

Mr. Maurice Child : There are one or two remarks I should like to make. In the first place, I think it would be of interest to many here if Mr. Kirke would give us some idea as to how he actually arranges his main anode coils in a multi-valve neutrodyne system. It is a little practical point which might be of some assistance to those who have not yet attempted to do it. I have tried many times to arrange coils, but I have found it is not an easy matter, apart from the neutrodyning, to arrange the actual setting of the coils to avoid absolutely any interaction. I have found it a very complicated and difficult job. I was particularly struck with the very pretty way in which Mr. Kirke analysed the transformer action, and I think he is very much to be congratulated on having brought the thing down to such a very picturesque and nice way of looking at it. I was unfortunately not able to follow at the moment what Mr. Kirke said with regard to stalloy, but it was a point which I had intended to raise if the opportunity occurred. I have never been able to understand why stalloy steel has been used for so many years by the manufacturers of intervalve transformers. When one comes to think of it, the actual amount of change of current in the primary of an intervalve transformer is very small, unless one is dealing with fairly high power amplification, and such change of current—and therefore the change of the magnetic state of the iron—being exceedingly small, it is surely necessary to use a material for your core having the highest possible permeability. I understand that stalloy is not of that class of material. Stalloy, I believe, is mainly used for transformers on account of its very special qualities of high resistance to eddy currents, amongst other things, but I do not think in the ordinary intervalve or telephone transformer we are very much concerned with eddy currents. No doubt there is, theoretically, some small loss due to them, but I do not think it is very material. I have made up many telephone and intervalve transformers, and my last experiment was with a transformer in which I did not take the slightest trouble to insulate the various sections of iron at all. I left the iron surface perfectly bare, and relied on the slight oxide to do the work. I find I cannot detect any appreciable difference in the results given by this transformer over those given by a transformer with varnish or paper insulation between the laminations. I have given up the use of stalloy altogether now, and use the softest possible iron I can get. There is another point in connection with transformers, and that is on the question of the losses due to hysteresis in iron. Very frequently in certain types of commercial transformers it is quite possible to show that the iron is working at a very considerable magnetic density due to the strong anode currents relatively going through it, and I should like to know whether Mr. Kirke thinks that is of consequence, or that we may get a rectification effect due to the transformer itself. I may be talking nonsense here, but I should very much like to know whether he can confirm or completely upset my ideas with regard to this last point.

Mr. H. L. Kirke, replying to the discussion, said : With regard to what Mr. Carpenter said about the effect of reactance in the anode circuit of a triode, I should say that he is right. I understand that if the back E.M.F. is out of phase with the current, the resultant dynamic curve will be an ellipse, and the width of the ellipse will depend on the ratio of the impedance in the anode circuit to the resistance of the valve itself. I have used choke-coupled amplifiers of various sorts considerably and have not found any distortion due to doing it. I have two methods of detecting distortion. One is to listen through the piece of apparatus under test, before and after, making suitable arrangements for the signals to be of the same strength and then balance out the fundamental. After the current has gone through the apparatus, any distortion in any piece of apparatus will introduce harmonics. Therefore, if you are listening and a current after going through the apparatus has its fundamental balanced out, if there is any distortion you will get more harmonics or different harmonics. I tested various forms of coupling, and found that within reason, provided normal precautions are taken, there is no distortion. The other method is to use the cathode ray oscillograph. I have done considerable experimental work in that direction, and there is no essential distortion. The whole thing is that it does not matter if the shape of the dynamic curve is an ellipse provided the ellipse does not, anywhere in its excursions, run through any of the non-linear parts of the static characteristic curve, but once it does run into the non-linear part, then it has that effect which Mr. Carpenter has referred to. There was one instance in which I definitely found distortion due to that, and I did not quite understand it. It was only a few days ago, and I was doing some tests on various methods of rectification and trying to find out what is the distortion due to rectification. One of the methods of rectification was with a special two-electrode type of valve which had a very perfect static characteristic. When you put the negative on to the anode, you got no current, but when you put the positive on you got current which was proportional to the voltage. We found that when we used a low frequency choke in the output of this circuit, we definitely got distortion, because apparently the output of the low frequency E.M.F. was out of phase with the low frequency current, and the efficiency of rectification depended largely upon the amount of back E.M.F. ; until we shunted the choke with relatively low resistance to neutralise the phase angle and bring it nearly to zero, we did get definite distortion coming in with this and various other types of rectification ; I think that all rectification will depend partly on the back E.M.F. and as to how that varies according to the impedance in the anode circuit. I am carrying these tests further, and if I have anything of interest to communicate I hope to be able to give you a short account of it. With regard to the initial permeability, the figure of 300, as mentioned on the curve, is what I have obtained, and it may be plus or minus 20 per cent. With reference to neutrodynes, I am afraid I have not done very much work on the point which Mr. Carpenter has brought up. The only thing I can say is this—in fact, I can say nothing exactly on the point he has brought forward because I have never actually done a test on it—but with regard to whether this is scientific or not, I really think that experimental tests are very, very useful and very often disprove certain scientific theories, and therefore are probably more useful than science in some ways. There is no doubt that using reaction from the detector valve or a separate reaction valve, you definitely benefit, particularly if you do not wish to put reaction near the point of instability.

With regard to Mr. Walker's point as to neutrodyning and perfect balance, one point is that you seldom get perfect screening between coils, and the other point is that you do not use neutrodyning as a perfect balance, and therefore you cannot expect to get perfect balance. A third point in this connection is that possibly, due to small phase differences and small electrostatic couplings which are not suspected, you are not getting a true phase balance. You probably get a true balance with regard to amplitude, but the phases are not in the right relationship and the introduction of a small resistance in series, or a shunt with the neutrodyne condenser, might improve the balance. I do not know whether that is true, but it might be.

Mr. R. E. H. Carpenter : It does.

Mr. Kirke : I believe it is used in some forms of transmitter work. The point with regard to resistance capacity high frequency amplification is, I think, as Mr. Walker rightly said, that although magnification is small, it is fairly stable, and there is only one handle. To borrow a phrase from Mr. Carpenter, it provides something for Grandmother Jones—it is ideal. With regard to superheterodyne, I have had no actual experience of the superheterodyne transformer of the iron core variety. I have used the resistance method—the resistance transformer coupling—but I have no doubt that, provided the various details are taken account of, the main points to bear in mind with regard to design are very much the same as for the low frequency transformer. There is one point to bear in mind in superheterodyning and things of that description, and that is the more you step up the less will be the back E.M.F. of the primary winding, because its impedance will be lower; therefore, the less will be the back E.M.F. and the tendency for reaction.

With regard to Mr. Ashbridge's point about neutrodyning and high frequency resistance capacity amplifiers, the only way in which I have had anything to do with this is low frequency. That is rather Irish. Actually, I was thinking about the question of feeding back in connection with resistance capacity amplifiers, and we got over it by reducing the impedance of the valve before and so bringing the resistance of the grid down. What we did was to introduce a reaction condenser in the manner in Fig. 19.

Actually, we used the grid filament of an ordinary power valve, and that was all right except that there was a tendency to howl at high frequencies. We took some curves, and one particular curve was like Fig. 20a, without the condenser, whilst with the condenser the curve was something like Fig. 20b. The measurement was actually at about 6,000 cycles, and we immediately came to the conclusion that the phase angle of the circuit changed over at 6,000 cycles, which was the natural frequency, and became the opposite phase angle and so gave us a reaction in the reverse direction. We put a high resistance in series *R* (Fig. 19) with the neutrodyne condenser in order to overcome that, and that was nice because we could alter our ratio of resistance to capacity and so alter the phase angle. In the end, we got a curve like Fig. 20c, and we raised the natural frequency of the transformer, and got nearly a straight line, up to 10,000 cycles, which was fairly suitable for the job in hand. It was not quite good enough, however, and we went to the other method, *i.e.*, using a low impedance valve. It is, however, a possible method of neutralising the capacity effect at high frequency of a resistance amplifier. At one time I was doing some short wave work—100 metres—and we got out an amplifier, using a V24 type of valve, of

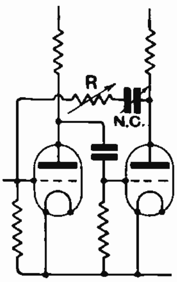


Fig. 19.

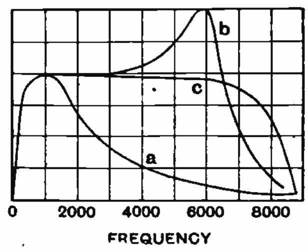


Fig. 20.

low capacity and a special intervalve transformer. It was an ordinary wire-wound transformer wound with resistance wire, and we used various forms of reaction to stabilise this thing, which used to oscillate. I used eventually a trick coupling consisting of a small condenser connected to two grids in front of it. In that way we got a special arrangement and excellent reaction. We reduced the anti-reaction and put in reaction. With regard to the growth of the craze, if I may so call it, for neutrodyning, my opinion is this: In the old days everybody just used to oscillate and undoubtedly, provided nobody else minded, it was an excellent way to get a distant station. Since broadcasting started, however, oscillating has been rather unpopular in certain circles, and now we have a lot of people using sets who have very little skill and who would not use wireless at all but for broadcast. That started the craze for getting a receiver which was fairly stable over a big wave range and at the same time give long distance reception.

With regard to Mr. Hogg's point that when he used bottom bend rectification with a resistance in the anode circuit for low frequency and long distance reception he got trouble with oscillation, I am not sure whether he used a small condenser across the resistance or not. I always use a condenser of the order of .0002μF when using high frequency, and it not only improves the detector efficiency but it also prevents the high frequency getting past to the resistance amplifier. Although the resistance amplifier is not much good at 300 metres it does amplify perhaps 1½, 2 or 3 times, but at high frequency, unless you take steps to stop it, you will get what I call a squiggering effect. The other possibility is that as soon as you oscillate your feed tends to rise due to the curvature of the valve characteristic, particularly if you are using the bottom bend of the valve. Then the voltage drops, and directly the voltage drops the reaction becomes less and it stops oscillating, and it is a question of how quickly the H.T. can rise in the plate circuit, and that is what we call the squiggering effect. I think that is probably the trouble. It might also be due to the fact that he has not got condensers across the H.T. battery, although I should think he has.

Mr. Bawtree brought forward the point of cut down at low frequency due to intervalve condensers. That is very much the same in effect as the cut-down due to lack of inductance in a choke amplifier. The only reason that it cuts down is that if the condenser is small it has a fairly high impedance, and there is a certain amount of potential difference drop across it. That p.d. is 90 deg. out of phase with the main p.d., and has not as much effect as it would if it were not 90 deg. out of phase, with the result that you can have a smaller condenser than you think. It is quite possible for a loud speaker to cut off at frequencies below 300 cycles. Therefore it is possible that you would not feel the benefit of using larger condensers.

With regard to Mr. Child's remarks as to the placing of the main anode coil in multi-valve systems when neutrodyning, I have not done much with that myself, but on each occasion recently when I had to build a high frequency amplifier, I was so dead keen on getting the thing thoroughly efficient that I took enormous precautions and screened every coil completely. I have found binocular coils extremely efficient because you localise the feed. These coils have two long solenoids in the same direction connected in series. If the fields are in opposite directions the tendency will be for the fields to be neutralised outside, and that is quite a useful thing for balancing with neutrodynes. Beyond that, I am afraid I have had no experience. In regard to the actual placing of the coils, I have always taken the precaution of screening everything. The other point was with regard to losses with stalloy in transformers. I have done a certain amount of measurement of hysteresis and eddy current losses, and there is definitely a sign that there is a considerable eddy current and hystersis loss in stalloy. In my measurements on transformers, the phase angle is of the order of 60 deg., but it varies according to the amount of flux density in the iron at the time, and it varies with all sorts of things, according to how much D.C. you put through the transformer yesterday or the day before, for instance. That is an actual fact. I have given a transformer to somebody to test with an ordinary D.C. galvo test, and the inductance has changed about 10 per cent. afterwards. With regard to eddy current and hysteresis loss, I have never worried where the soft iron is good, but for experimental purposes when a man builds his own transformer he can afford to take certain risks and build certain things in a circuit where a commercial man might fear to take them. On the question of distortion due to iron, what I do is to get a cathode ray oscillograph and put a sine wave into the iron and look at the wave form. Distortion did not occur up to a density of 5,000 lines per sq. cm., after which distortion started and increased. That was with no D.C. through the transformer. I have done very few experiments of this kind, but I did find in one experiment about a year ago that the D.C. does not matter very much provided you do not put too much A.C. through. In that case, at low frequencies the variation of flux density is not high. If, however, the change of flux density was likely to be high, then it would be a bad thing to put D.C. through because you will definitely get distortion. For that reason, in my amplifiers I always avoid having D.C. through the transformers by feeding through a choke and through a condenser.

Inductance Coils Quantitatively Compared.

By A. L. M. Sowerby, B.A., M.Sc.

Part II.

[R240

THE measurements embodied in Part I. of this article may be taken as a general survey of all types of inductance coil; and if solenoids are the only coils seriously considered, this is so merely because they alone are efficient enough to repay the work of investigation.

There are four independent variables involved in designing a solenoid coil to a definite inductance-value—they are as follows:

1. The amount and kind of dielectric to be used in the construction of the former, and as covering to the wire itself;
2. The shape, or ratio of diameter to length (D/l ratio);
3. The gauge of wire; and
4. The spacing between turns.

Of these, the effects of 1, 2, and 4 are the subject of direct measurements in the present article, and although it is not pretended that a full examination of any of these points has been made, yet sufficient information has been obtained to be of material assistance to those who wish to design coils of high efficiency and reasonable compactness.

1. Effect of Dielectric.

The figures on this point were obtained by Mr. Vaughan-Spencer, and are included here by his permission. The writer takes this opportunity of acknowledging Mr. Vaughan-Spencer's very valuable assistance in most of the remaining measurements.

A comparison was made in the manner described in Part I., between two coils carefully adjusted to the same inductance, and as nearly identical as possible in shape, size, wire-gauge, and spacing, the one being wound with bare wire on a skeleton former, in approved "low-loss" style, and the other wound with heavily-covered bell wire, turns touching, on a waxed cardboard tube. Any increase in the H.F. resistance caused solely by dielectric losses should be clearly shown by this comparison.

The results were as follows:—

(A) *Description of Coils.*

1. "Low-loss Coil," 4.4 in. diameter hexagonal skeleton former lightly constructed of wood and ebonite. Wound with 60 turns of 20 S.W.G. bare tinned copper wire, 14 turns per inch. Length 4.3 ins.

2. "Bell-wire Coil," 4.5 in. diameter waxed cardboard former. Wound with 59 turns of 20 S.W.G. tinned copper wire, covered with rubber and a very thick cotton covering, heavily impregnated with wax, 14 turns per inch approximately. Length 4.1 ins.

(B) *Voltmeter Readings.*

Coil.	Tuning. Condenser. (degrees)	Deflection.
"Low-loss" ...	139	1,270
"Bell wire" ...	139½	1,240

Frequency of measurements about 800kC or 375 metres.

Mr. Vaughan-Spencer was sufficiently surprised by this result, which is in direct opposition to the current belief on the point, to confirm it by measurements of several other "bell-wire coils" of different shapes. These other measurements confirmed that given above, the figures obtained being almost the same. Those given are chosen for inclusion here because they refer to two coils deliberately constructed to be identical in all respects save that of dielectric.

Since the increase in effective H.F. resistance due to the presence of this unnecessarily large amount of dry dielectric amounts to less than 2.5 per cent., the effect of dielectric losses in single-layer coils designed for the broadcast wavelength may safely be neglected in all but the most critical work. In multilayer coils, where turns at greater potential difference are in juxtaposition, the effect may probably be larger. The writer hopes later to perform similar comparisons at much higher frequencies (6,000 to 10,000kC) at which dielectric losses may reasonably be expected to become serious.

In all work done after the above result was obtained, no attention was paid to the absence or presence of wax, cotton, silk or cardboard as dielectric.

Effect of Moisture.

As already remarked in Part I., moisture largely increases the H.F. resistance of a coil close-wound with cotton-covered wire; the writer is of opinion, in the temporary absence of experimental data on the point, that this is due to *insulation* losses rather than to dielectric losses. To rule out irregularities due to the moisture, all formers, though bought as "waxed," and all covered wire, were well boiled in wax before winding the coils used in the remaining measurements described below.

2. Effect of Shape of Coil (D/l ratio).

A number of coils, of D/l ratio varying from 0.75 to 8.6, were made up and measured in the usual manner. In order to attain so wide a range of D/l ratios, it was found advisable to use two gauges of wire, the windings being chosen so that there was a large overlap of D/l ratio between the two series.

TABLE I.

Coil No.	D/l.	Diam. ins.	Length ins.	Wire. S.W.G.	Turns.	D.C. resistance (apprx.) ohms.
1	0.75	2½	3.35	22	85	0.725
2	1.12	3	2.68	22	67	0.685
2A	1.09	3	2.75	22	67	0.685
3	1.55	3½	2.25	22	53	0.632
4	2.17	4	1.84	22	47	0.640
5	2.73	4½	1.65	22	42	0.644
6	3.56	5¼	1.47	22	37	0.661
7	1.36	2	1.47	36	77	7.1
8	2.05	2½	1.22	36	61	7.05
9	2.82	3	1.06	36	52	7.21
10	4.15	3½	0.845	36	43	6.95
11	5.35	4	0.75	36	39	7.21
12	6.25	4½	0.72	36	35	7.25
13	8.6	5¼	0.61	36	31	7.51

All coils are close-wound, and cardboard tubes and wire both boiled in wax in all cases except 2A, which was left unwaxed for comparison.

The figures for D.C. resistance are calculated from wire tables, and are not the result of measurements.

Table I. gives particulars of the coils, and Table IA. the results obtained on measurements.

TABLE IA.

Coil No.	C. (degrees)	Deflection at resonance (microamps)	Low-loss Coil Deflection.
1	29.2	1340	1400
2	28.5	1340	1400
2A	29	1345	1400
3	28.5	1340	1400
4	29.1	1320	1395
5	28.5	1335	1395
6	28.5	1325	1400
7	29.0	1130	1400
8	29.3	1150	1400
9	28.5	1130	1400
10	29.1	1145	1400
11	29.5	1130	1400
12	29.0	1110	1400
13	28.1	1105	1400

The reading for the low-loss coil was checked immediately *after* each measurement in order to make certain that the oscillator output was reasonably constant. The figures for coils 4 and 5 are plotted as 1325 and 1340 respectively.

The figures of Table IA. are plotted in Fig. 1, the diameter-length ratios as abscissæ, and the deflections in microamps as ordinates. It will be seen at once that both lines are substantially horizontal, though both show a tendency to fall at high values of D/l.

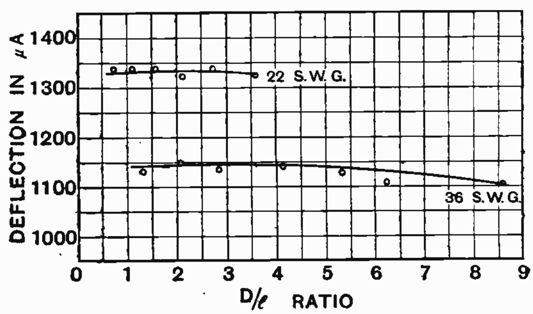


Fig. 1.

There is thus no indication of any optimum value for the D/l ratio, so that all solenoid coils of the same inductance, wound with the same gauge of wire and with the same spacing between turns, may be taken as identical, whatever their shape. The fall in efficiency at high D/l values appears to be a secondary effect, and will be referred to again in the section dealing with spacing.

Incidentally, the popular prejudice against waxing coils is shown, by comparison of Coils 2 and 2A, to be unfounded; the difference is within the limit of variation of coils nominally identical.

3. Effect of Spacing.

To investigate the effect of spacing between turns, two sets of coils, one wound with 22-gauge wire and the other with 28-gauge, were prepared. Acting on the results of previous experiments, the influence of dielectric was ignored to the extent of obtaining the first three spacings for each gauge by winding coils, turns touching, with enamel, double silk, and double cotton covered wire respectively. Further coils were obtained by "double-winding," putting on two wires simultaneously and removing, after winding, the wire not required.

TABLE II.

Coil No.	Condenser. (degrees)	Deflection on resonance. (microamps)
1	105	810
2	106	875
3	106	955
4	106	985
5	106	950
6	107	750
7	106½	830
8	106	895
9	105½	935
10	106½	910
11	106	905

The coils were measured twice, each time going through the whole series in the order given above, and no variations greater than 5 microamps (the smallest variation observable on the 0-1.5 milliammeter used) were observed.

Table II. shows the results of the measurements, and Table IIA. gives a full description of the coils.

Curves are shown in Fig. 2 of these results, "surface-spacing in diameters" being plotted as abscissæ, with deflections in microamps, as ordinates.

Both for 22 and 28-gauge wire there is an optimum spacing, the maximum of the curve being more sharply defined for the thinner wire, as might be expected. For the two cases examined, this optimum spacing is more nearly the same when expressed in wire-diameters than when expressed in mm. —hence the scale chosen for plotting. The maxima come as follows:—

For 22-gauge wire at 1.4 diameters, or 0.875 mm. between surfaces;

For 28-gauge wire at 1.2 diameters, or 0.5 mm. of adjacent turns.

These maxima will appear at slightly different spacings, in all probability, on formers of different diameters—the writer would anticipate that slightly wider spacing would be required on a former of larger

TABLE IIA.

Coil No.	Wire.	Length. (cms.)	Turns.	Approx. D.C. Resistance. (ohms.)	Centre-Spacing. (mm.)	Surface-Spacing. (mm.)	Surface-Spacing. (diameters).
1	22 ENAM.	3.5	56	0.574	0.625	0	0
2	22 D.S.C.	5.0	62	0.635	0.806	0.185	0.296
3	22 D.C.C.	8.1	72	0.736	1.12	0.507	0.811
4	22 D.C.C.	11.7	83	0.850	1.41	0.795	1.27
5	22 D.C.C.	18.9	99	1.011	1.91	1.30	2.08
6	28 ENAM.	2.0	48	1.76	0.417	0	0
7	28 D.S.C.	2.45	51	1.87	0.48	0.065	0.156
8	28 D.C.C.	3.58	56	2.05	0.64	0.226	0.542
9	28 ENAM.	5.4	63	2.31	0.86	0.448	1.07
10	28 ENAM.	6.05	66	2.42	0.916	0.508	1.22
11	28 ENAM.	0.8	72	2.64	1.11	0.705	1.69

All coils wound on 3 in. waxed card formers.

"Centre-spacing" means distance between centres of successive turns.

"Surface-spacing" means distance between surfaces of successive turns, measured in mm. (Col. 7) or in terms of the diameter of the wire with which the coil is wound (Col. 8).

The diameter of the wire, being less in each case than the published figure for the gauge, is taken as the diameter of enamelled wire; *i.e.*, 0.625 mm. and 0.417 mm. respectively.

diameter, owing to the greater potential difference between turns. It is to this effect that he attributes the slight falling off in efficiency shown by the coils of high *D/l* ratio in Table I.; the spacing was certainly closer than the optimum on the 3 in. former, and still further removed, on this assumption, from the optimum value for the larger formers. Even in the case of the 36 D.C.C. wire, where small variations in spacing may be expected to make large changes in the efficiency, the falling off is small, showing that the change in "effective spacing" is likewise small. Thus only small divergences in optimum spacing-values are to be expected in consequence of changes in the diameter of the coil.

4. Effect of Gauge of Wire.

On this point the writer has no new facts to offer; it is already well known that, up to 22 gauge at least, the thicker the wire the better the coil. But it is of some interest to note that before a fair comparison of the relative merits of different wire can be made, the optimum spacing for each gauge must be found; 22 D.S.C. wire, for example, if close-wound, makes a coil less efficient than the optimum of 28-gauge wire.

Further, provided that the best spacing is used, the gauge of wire makes less difference than is popularly supposed; 22 gauge is less than 6 per cent. better than 28. (Fig. 2.)

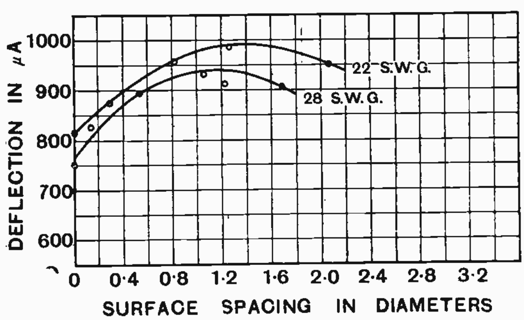


Fig. 2.

In practice, a limit to the thickness of the wire is soon reached, on account of the rapidly increasing bulk of the coil. Not only is the wire itself thicker, but a greater space has to be left between turns, this space increasing even more rapidly than the wire-diameter itself. Since, further, this wider spacing necessitates an increase in the number of turns to reach the same inductance, the bulk of the coil speedily becomes impossibly great.

The writer has not investigated coils wound with wire thicker than 22 gauge, chiefly on account of the difficulty in obtaining even spacing with stiffer wire.

5. The Practical Design of Coils.

The measurements here given show that the task of designing a single-layer coil for the broadcast wavelengths is less involved than is normally supposed. Since neither dielectric losses nor shape need be seriously considered as factors in efficiency, it only remains to choose a moderately stout gauge of wire, and wind it, at somewhere near the optimum spacing, to the required inductance, using any reasonable former. Further, since the spacing-efficiency curve is very flat-topped for the thicker wires, the natural spacing afforded by close-winding double cotton covered wire is near enough for most purposes, giving actually about 95 per cent. of the efficiency, if 22-gauge wire is chosen, of the "low-loss" coil taken as standard.

It should not be forgotten, in this connection, that the anode-rectifier used for measuring, even with the addition of six or eight feet of aerial, probably introduces less damping than almost any apparatus connected to a coil in an ordinary receiver, so that any small differences shown by these measurements would be suppressed in practical use.

On balance then, the old-fashioned solenoid, well waxed, holds the field for efficiency combined with convenience; the multilayer coil is hopelessly inefficient, even when turns and layers are well spaced, while the extra efficiency of the "low-loss" coil is minute, and, owing to the trouble of making, absurdly dearly bought.

The Cause and Elimination of Night Errors in Radio Direction Finding. [R510

Paper read by R. L. SMITH ROSE, Ph.D., M.Sc., and R. H. BARFIELD, M.Sc. before the Wireless Section, I.E.E., on 5th May, 1926.

Abstract.

THE paper is communicated by permission of the Radio Research Board, and describes experiments carried out with a view to obtaining more conclusive evidence as to the causes of apparent variations of bearings observed under certain conditions with wireless direction-finders.

Much of the authors' work in the past few years has been the investigation of "night effect" in direction-finding, and methods have been developed to distinguish between the electric and magnetic components, with separate measurements of their intensity and direction. It is now evident that the variations are caused by the action of the horizontal components of the electric force in the downcoming waves on the horizontal parts of the D.F. loops. Another portion of the work has been to ascertain whether the downcoming waves have been laterally deviated from the great circle plane through transmitter and receiver. This matter is one of practical interest, for apparatus which shows the absence of lateral deviation provides a direction-finding system free from variable night errors.

The problem involves the production of apparatus which will measure the horizontal component of the direction of arrival of wireless waves, irrespective of their angle of incidence at the earth's surface or their state of polarisation.

Several methods which have been suggested for tackling this problem are then described, and early experiments on the subject at the Radio Board's Station at Ditton Park, near Slough, are discussed.

The arrangements finally described in the paper are a modification of a system patented in 1919 by F. Adcock, in which the aerials are mounted and connected so as to ensure that only the vertical parts are acted upon by the arriving waves. The simplest form which the system can take is probably that of Fig. 2*.

The connections shown should have the effect of rendering any E.M.Fs. set up in the horizontal parts of the system equal and opposite with regard to the "aerial—field-coil—earth," so that the net voltage induced in the circuit is that due to the phase difference of the voltages in the two vertical limbs (of Fig. 2*b*, which shows one of the pair of aerials). Since the E.M.F. follows a cosine law, the pairs of aerials may be used with a radiogoniometer and search coil, as in the Bellini Tosi system. The arrange-

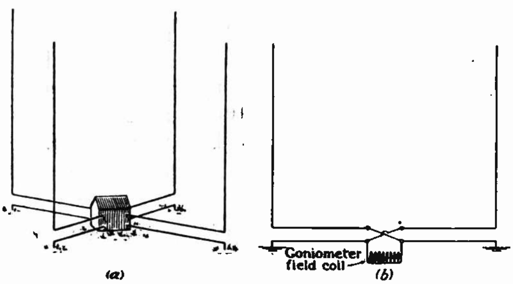


Fig. 2. (*a*) *Sketch of the system.* (*b*) *Elevation of single pair of aerials.*

ment of Fig. 2 was found to be unsatisfactory. The horizontal E.M.Fs. were not balanced out—probably due to stray capacities—and gave rise to serious errors. By way of improvement an attempt was made to screen the whole of the horizontal portion by means of a screening trunk formed of a number of parallel wires, the whole screen projecting a considerable length beyond the aerial, while at their inner ends the wires were joined to the metallic lining of a screened

* The authors' original figure numbers are adhered to throughout this abstract.

operating hut. This arrangement was also unsuccessful, for although the screen effectively shielded the horizontal portion, the secondary field due to the screen itself set up E.M.Fs. in the vertical limbs of the aerials.

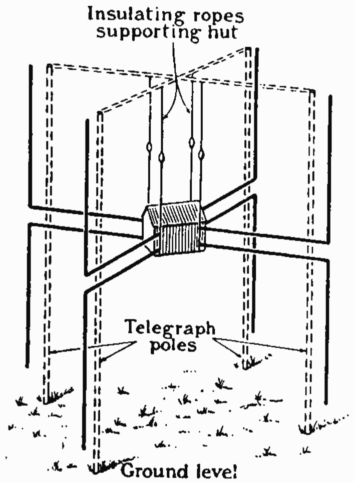


Fig. 4.

The alternative arrangement described by Adcock was therefore adopted. In this case the vertical aerials are comprised of complete Hertzian oscillators with leads taken horizontally from their mid-points to the apparatus in the screened hut. To maintain symmetry the hut with the apparatus and operator was raised to the level

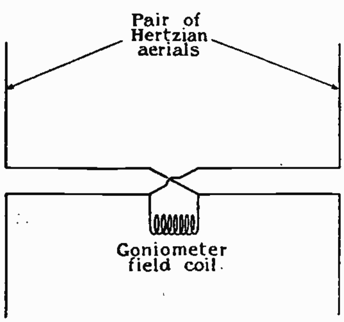


Fig. 5.

of the centre of the system, about 20 feet above the ground. The aerials were supported on poles 44 feet high placed at the corners of a 20-foot square. The receiving hut was suspended from cross beams on the poles by insulated steel ropes to minimise its capacity to earth. The arrangement is shown schematically in Fig. 4, while the connections of one pair of the Hertzian oscillators is shown in Fig. 5.

The balancing out of the effects in the horizontal limbs was verified first by measuring the directional properties of the individual aerials and secondly by comparing the induced currents in the upper and lower halves of the same aerial. The latter test revealed a superiority of 2 or 3 per cent. of the lower half over the upper, due probably to different capacities to earth. This

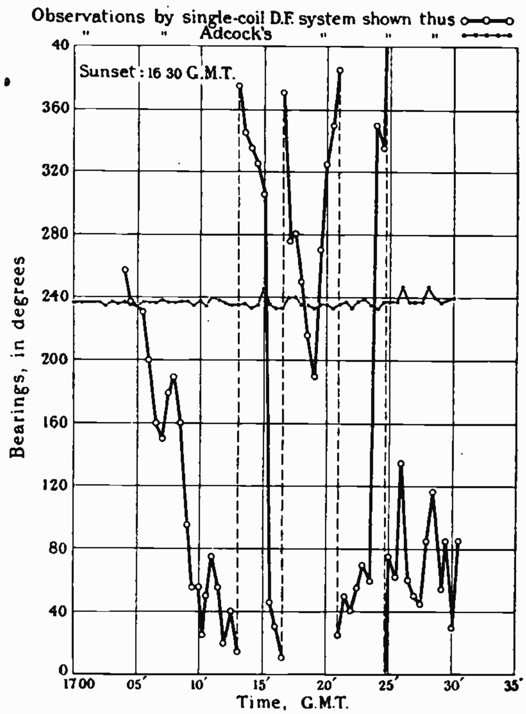


Fig. 6. *Observations of bearings on Bournemouth on 8th November, 1925 (wavelength 386 metres).*

could probably have been eliminated by a slight shortening of the lower half to secure electrical equality. Other tests showed that the receiving properties of the aerials were not materially influenced by slight irregularities or differences in the neighbouring supporting structures. Tested under conditions giving freedom from night errors the apparatus was found to be subject to a permanent error of the same order as that experienced on closed coil systems in use in the same field, due to the local surroundings.

In order to investigate lateral deviation, observations were made on certain transmissions which were known to give rise to night errors. The apparent bearings were observed simultaneously on the apparatus described and on an ordinary single coil direction-finder in another hut 100 yards away. The most serious night variations were obtained on Bournemouth and Cardiff. The results of two sets of simultaneous observations are shown in Figs. 6 and 8.

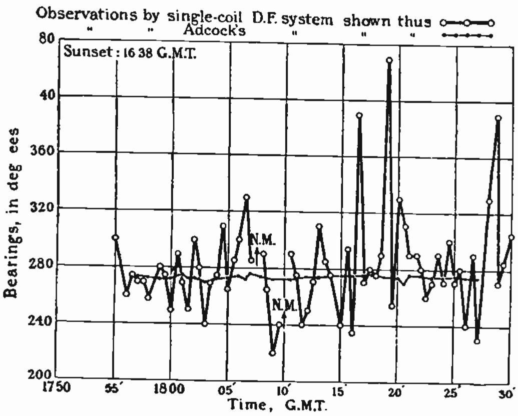


Fig. 8. *Observations of bearings on Cardiff on 26th January,* 1926 (*wavelength* 353 *metres*).

In Fig. 6 it is seen that the single coil system showed a rotation of apparent bearing through more than 360°, while on the Adcock system the extreme variation was 14°. The results on Cardiff in Fig. 8 show the same effect, although the variations are less violent.

From these results it is to be concluded that lateral deviation plays a negligible part in producing large and variable night errors, as are obtained on single coils, and that these errors are entirely due to the arrival of downcoming waves polarised with the electric force horizontal. The slight residual errors shown for the Adcock system (up to ± 7°) may be caused by a slight imperfection of balance, or it may actually be a residual amount of lateral deviation. It may be shown that if two waves are arriving with varying phases and direction of travel, in vertical planes separated by an angle ψ, the total apparent variation in the resultant direction will greatly exceed ψ. The apparent variations of ± 7° is probably an indication of a much smaller real lateral deviation. A slight lateral difference of path is almost certain to exist, as the horizontal wave on land is nearly always slightly deviated by local irregularities (trees, etc.). The investigations described in the paper form a useful confirmation of the magneto-ionic theory recently introduced (by Appleton and Barnett in England and by Nicholls and Schelling in America) in which rotation of the plane of polarisation of the downcoming wave is ascribed to the influence of the earth's magnetic field on the motions of ions in the upper atmosphere.

From the results shown, it is concluded that Adcock's four-aerial system may be used as a direction-finder giving the true direction of the great-circle plane of arrival of waves whatever their state of polarisation or angle of incidence relative to the earth.

It should have important applications as an accurate direction finder under night conditions or for observing signals from aircraft at high angles of elevation, when the ordinary closed loop is subject to large errors. It would, in practice, be preferable to have the receiving gear and operator located on or near the ground, and several methods of securing this are in view for test as soon as possible. An appendix by Mr. F. Adcock, M.B.E., B.Sc., deals with "Some Early Observations on Aircraft with the Four-Aerial Direction-Finder."

In the tests described an aeroplane flew at a moderate altitude and at distances of 3 to 8 miles from the direction-finding station, where observations were made on an ordinary loop and on the four-aerial system. Errors of up to 40° are shown in a table for the closed loop, while the maximum error for the four-aerial system is 6°. The errors of the loop were reversed when the direction of flight of the transmitting aeroplane was reversed.

Audio-Frequency Measurements.

Extracts from a Paper read before the Institute of Electrical Engineers on 29th April, 1926.

[R290

An interesting and informative paper on "The Frequency Characteristics of Telephone Systems and Audio-Frequency Apparatus, and their Measurement," was read before the I.E.E. on 29th April, by Messrs. B. S. Cohen, A. J. Aldridge and W. West, of the G.P.O. Research Department at Dollis Hill.

Much of the paper is concerned with line-telephone practice, but a large part is of considerable wireless interest, dealing with loud-speakers and low-frequency intervalve transformers.

Various methods are described for the direct and indirect production of constant acoustic output over the audio range.

Of the indirect methods, *i.e.*, those consisting of the electrical generation of the requisite frequency, the use of an unusual form of valve generator is discussed. The requirements are a constant output over a continuously variable frequency from, say, 0 to 5,000 cycles. This is secured by means of two radio frequency oscillators arranged to beat with each other, the beating output being used for the required audio frequency. The circuit diagram is shown in Fig. 7,* which also shows the method of taking photographic records. Each oscillator circuit comprises a grid coil L_2 of 50,000μH, coupled to an anode coil of 20,000μH, tuned by C_1 of about 0.001μF. A variable condenser C_2 of 0.0005μF maximum is in parallel with one of the condensers C_1 to cover the beat range of about 50,000 cycles. Output coils of L_3 of 10,000μH introduce the radio frequencies in the amplifying valves V_2, which serve to prevent, as far as possible, interaction between the oscillators.

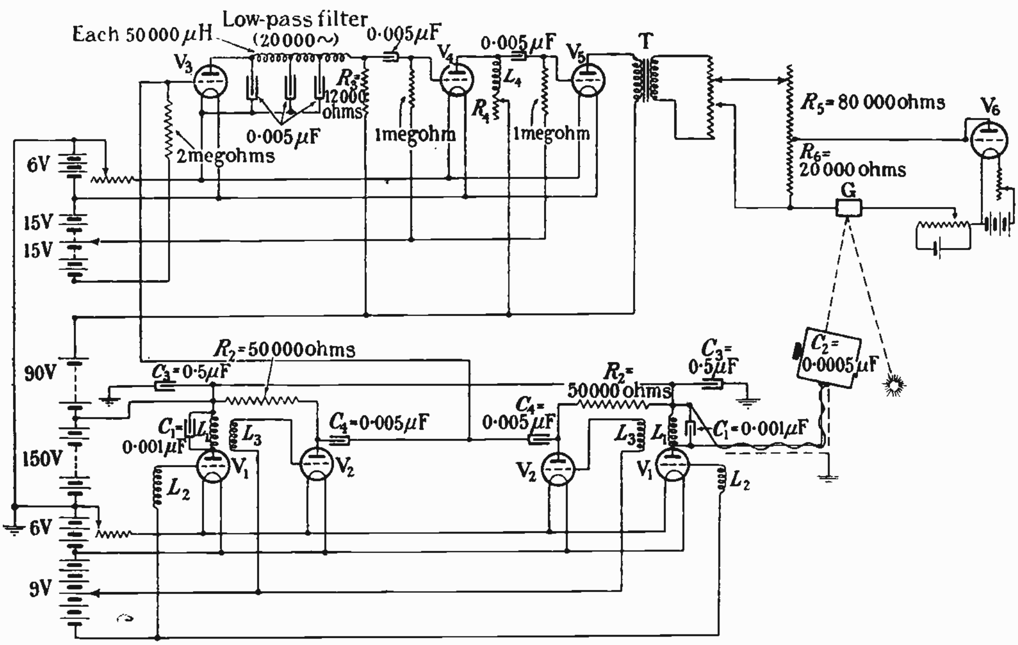


Fig. 7. *Diagram of the circuit used.*

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

Each oscillator and its amplifier is also enclosed in an iron box. The high frequencies are taken by resistance capacity coupling and a common input lead to the grid of the detector V_3 operating on anode bend rectification. A low-pass filter in the anode circuit, with a cut-off at about 20,000 cycles, serves to reduce to negligibility the high frequencies in the L.F. output, which is brought by two stages of resistance capacity coupling to the output transformer T. This consists of interleaved wave-wound slab coils built on 1-inch square cores of stalloy stampings, the secondary terminating on a non-reactive load of 800 ohms. There still being a tendency for the output to fall off at higher frequencies, which is remedied by the 0.2H air-cored coil L_4, which is in

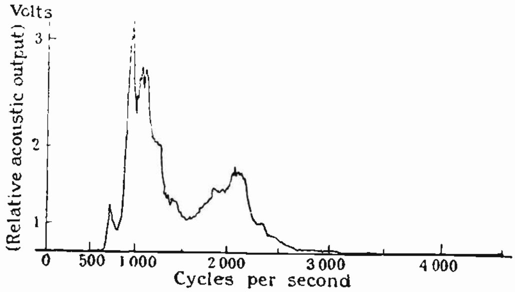


Fig. 21.

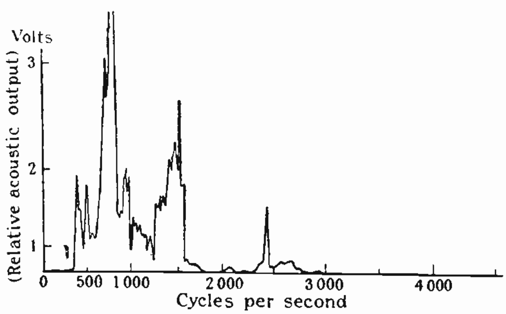


Fig. 22.

series with R_4, gives the circuit impedance a rising characteristic with frequency. The output (f) frequency of the oscillator is shown in a curve to be practically entirely constant over the specified range.

Extensive results are described and illustrated, those of wireless interest concerning loud-speakers and intervalve transformers.

Fig. 21 is the frequency characteristic of a horn-type loud-speaker having a circumferentially corrugated diaphragm, with its centre connected to an armature. The horn expanded from an internal cross sectional area of 0.32 sq. in. to one of 0.5 sq. ft., the axial length being about 20 in. This was

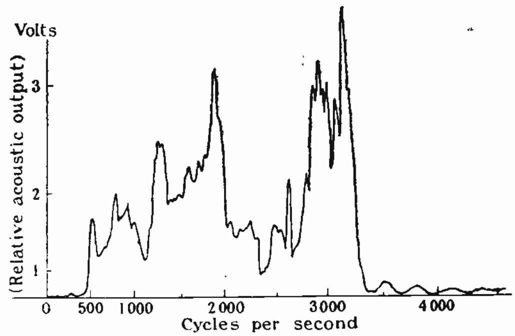


Fig. 23.

taken in the open air at some distance from buildings.

Fig. 22 is also of a horn type, with stalloy disc diaphragm. The horn was of metal, the extreme cross-sections being 0·25 sq. in. and 1 sq. ft., and axial length of about 28 in.

Fig. 23 is of a telephone headgear receiver used as a loud-speaker, with an exceptionally well-designed horn, which expanded, according to an exponential law, from a cross-

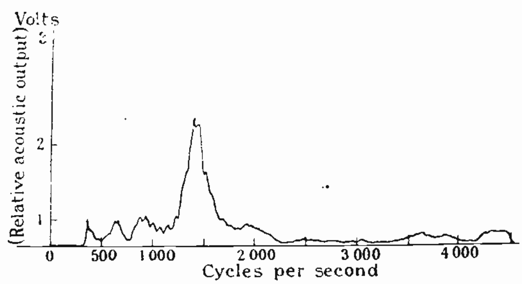


Fig. 24.

section of 0·2 sq. in. to one of 1 sq. ft.; the axis was straight and 3 ft. in length.

Figs. 24 and 25 are for hornless patterns. That of Fig. 24 was of pleated diaphragm type with a diameter of about 1 ft. That of Fig. 25 was umbrella-shaped and very light. In both cases the centre of the diaphragm is connected by a pin to the armature of the electro-magnet system.

Figs. 22, 23 and 24 were taken in a cabinet which had been draped to minimise sound reflections. Fig. 25 was taken in a large room without any reflection precautions, which may have modified the characteristics.

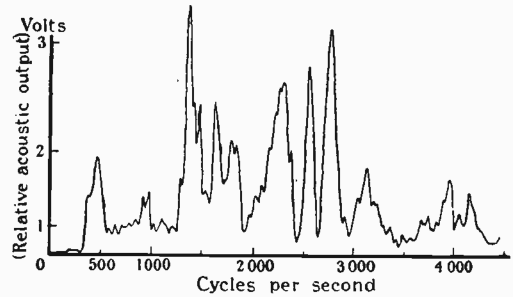


Fig. 25.

As regards L.F. amplifiers and intervalve transformers, results are given of measurements with the transformers in circuit with a valve, and also for a test circuit in which the anode impedance of the valve is replaced by a non-inductive resistance. It is pointed out that the performance of the transformer depends on the circuits with which it is used. The especial points are (*a*) the impedance of the valve in its primary circuit; (*b*) the capacity load on the secondary; (*c*) the presence of grid current in the secondary.

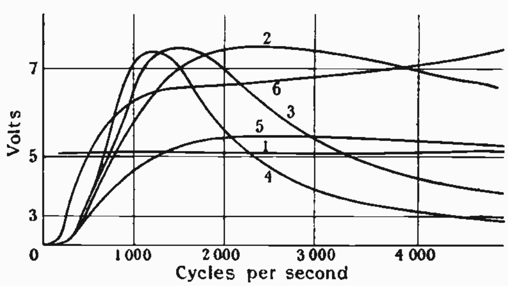


Fig. 37.

The anode impedance of the second valve may also exert an influence, which has not been investigated.

Fig. 37 shows the performance under different conditions of transformer *A*, of the ordinary type and commercial manufacture, with 4 to 1 turn ratio. Curve 1 is the oscillator output, curve 2 the performance of the transformer normally connected (*IP* to anode, *OS* to grid). Curves 3 and 4 were with loads of 100 and 200$\mu\mu$F respectively on the secondary, and curve 5 with 50,000 ohms on the primary. A valve of 20,000 ohms impedance was used in the primary; this being replaced for curve 6 by one of 6,000 ohms, with normal connections.

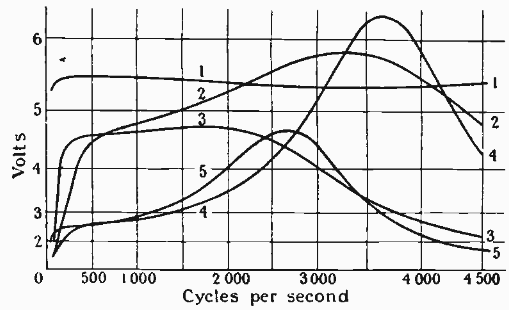


Fig. 38.

Fig. 38 is for transformer *B*, also of commercial manufacture with 4 to 1 ratio. It was of slab coils round a heavy closed iron core, and from its construction exceptionally high magnetic leakage was to be expected. Curve 1 is oscillator characteristic; curves 2 and 3 the performance with normal connections and with reversed secondary respectively, with a 20,000-ohm valve. For 4 and 5 a 6,000-ohm valve was used, curve 4 with normal connections, and 5 with reversed secondary. Capacitative load on the secondary is illustrated in Fig. 39, where curves 1 and 2 are as for those of Fig. 38. Curve 3 was taken with a capacity load of 50$\mu\mu$F on the secondary, and curve 4 with a load of 1,000$\mu\mu$F on the primary.

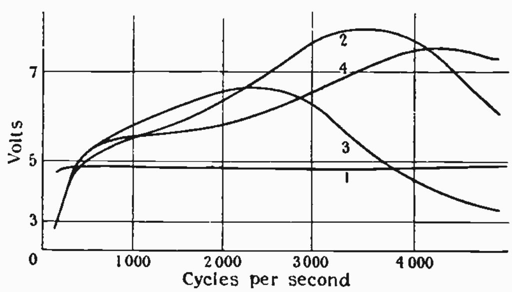


Fig. 39.

A mathematical appendix deals with the equivalent circuits of intervalve transformers.

Mathematics for Wireless Amateurs.

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

(*Continued from page 287 of May issue.*)

BEFORE going on to consider the combination of positive and negative numbers in general, it will be convenient to learn a little more shorthand (for that is what the use of mathematical signs really amounts to).

(i.) $a > b$

means that the number a is greater than the number b. Notice that the thin edge of the wedge points to b, which is, so to speak, the thinner of the two numbers.

(ii.) $a < b$

means that the number a is smaller than the number b. The same mnemonic* will serve.

There are some variations of these signs which are useful for numbers which can vary in size under given conditions.

(iii.) $a \ngtr b$

means that a is *not greater than* b, *i.e.*, a can be any number equal to or less than b. Notice that the "not" is suggested by the crossing out of the "greater than" sign.

(iv.) Similarly $a \nless b$

means that a is *not less than* b, *i.e.*, can be any number equal to or greater than b.

(v.) In the same way $a \neq b$

means that a is not equal to b.

(vi.) Finally, it is necessary to define a new idea, or a new word, which comes to the same thing. *The difference between two numbers is that number which must be added to the smaller of the two to make it equal to the larger.* Thus the difference between two and five is three, three being the number which must be added to the smaller, two, to make it equal to the larger, five. We are not here concerned with sign at all, nor with the combination of positive and negative numbers. Difference expresses a simple arithmetical relation between the sizes of numbers, regardless of sign. In symbols the difference between a and b is written

$$a - b.$$

* Mnemonic means "assistance to memory."

The general case of the combination of positive and negative numbers can now be considered, and with the help of the ideas already acquired it should not prove difficult.

The combination of the positive number a and the negative number $-b$ can be written

$$+a-b$$

or more shortly still,

$$a-b.$$

In terms of our journey units this means a journey of a inches to the right followed by a journey of b inches to the left. This is illustrated in Fig. 4 (a) for the case $a>b$. The length of the resulting journey will obviously be the difference between a and b, *i.e.* $(a-b)$,

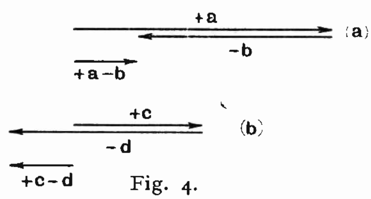


Fig. 4.

and its direction, *i.e.* sign, will depend on whether we go more to the right than to the left or *vice versa*. In other words, the sign of the resulting journey will be the sign of the greater of the two numbers, a and b, just as in a human partnership the stronger of the two partners will get things his own way. In the case illustrated in Fig. 4 (a), a wins, *i.e.*, the sign of the resultant journey is positive. In symbols,

$$a-b=+(a-b).$$

On the other hand, for two other numbers c and d, such that $c<d$ (Fig. 4 (b)) :

$$c-d=-(d-c)$$

or the resultant journey is to the left or negative.

In words, *the combination of a positive and a negative number is another number the size of which is the difference of the two numbers, and the sign of which is the sign of the greater of the two numbers.*

A further thing to notice is that it does not matter which of the two journeys is made first. The result will be the same. If this is not immediately obvious it can be made

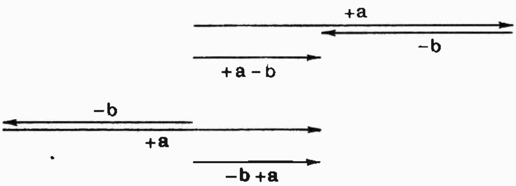


Fig. 5.

a fact of experience by actually drawing out and measuring several such cases, as in Fig. 5. This conclusion can be stated

$$+a-b=-b+a.$$

Further, in the case of several journeys such as

$$+a-b-c+d-e+f, \text{ etc.,}$$

any arrangement of these can be got by changing round two at a time, and since changing round two at a time does not affect the result, any arrangement of these journeys will have the same result. Finally, as these journey units satisfy the fundamental rule about addition (being things all of the same kind) the above statement may be completely generalised as follows :—

The result of adding any number of positive and negative numbers is not affected by the order in which the various positive and negative numbers are added.

First, therefore, the journey will be arranged in the form

$$+a+d+f-b-c-e.$$

Now all the positive journeys or journeys to the right can be combined together and considered as the single journey to the right, $+(a+d+f)$.

Similarly all the negative journeys or journeys to the left can be combined together. The result will be a single negative journey the length of which is equal to that of all the separate journeys put together, *i.e.*, the sum of the separate negative journeys. This single negative journey is therefore

$$-(b+c+e).$$

The total journey can now be expressed as the combination of these groups, *i.e.*,

$$\begin{aligned} &+a-b-c+d-e+f \\ &\quad=+a+d+f-b-c-e \\ &\quad=(a+d+f)-(b+c+e) \end{aligned}$$

and the rule of sign can be applied to the two separate groups. Thus if $(a+d+f)$ is greater than $(b+c+e)$ the sign of the total combination will be positive, and *vice versa.*

(B.I,) *Brackets and the Negative Sign.*

It was shown in the preceding section that the three negative journeys $-b$, $-c$, and $-e$ could be combined together into the single negative journey represented by $-(b+c+e)$ and since $(b+c+e)$ is the same as $(+b+c+e)$, then this grouping process is represented by

$$-b-c-e=-(+b+c+e)$$

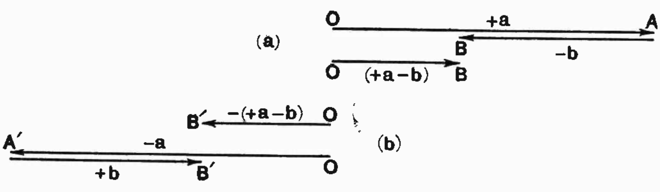


Fig. 6.

This is known as the Law of Commutation (*cf.* Section 3 (a)).

How is the rule of signs to be applied to a rather complicated group of journeys (or numbers) like the one just considered ? The easiest way is to take all the positive journeys together and all the negative journeys together, just as in making up accounts one adds up all the credits together and then all the debits together.

and since there is no reason why this process should not be reversed

$$-(+b+c+e)=-b-c-e.$$

This shows that if there is a negative sign in front of a bracketed expression and the brackets are taken away then all the positive signs inside the brackets must be changed to negative signs.

Consider now the combination of journeys $+a-b$ shown in Fig. 6 (a). This means the journey O to A and then A to B. Considered as a single journey it is the journey $(+a-b)$, *i.e.*, the journey O to B. Applying the negative sign to this journey reverses its direction and makes it the journey O to B' shown in Fig. 6(b), *i.e.*,

$$OB=(+a-b)$$
$$OB'=-(+a-b).$$

If now it is wished to dissociate the journey OB' into two parts one of which shall be of length a and the other of length b, there is only one way to do it. The journey a, the longer of the two, must be made to the left and the journey b to the right. That is,

$$OB'=-a+b.$$

This shows that

$$-(+a-b)=-a+b.$$

The same argument can be applied if a is less than b.

If the bracket contains a number of positive and negative numbers these can be grouped together in the manner shown in the preceding section. For instance,

$$a-b-c+d+e-f=a+d+e-b-c-f$$
$$=(a+d+e)-(b+c+f) \text{ by Section 3 (d).}$$

Now representing the group $(a+d+e)$ by the single number or journey p and the group $(b+c+f)$ by the single number or journey q, then

$$a-b-c+d+e-f=p-q$$

and

$$-(a-b-c+d+e-f)=-(p-q)$$
$$=-p+q \text{ as already shown.}$$
$$=-(a+d+e)+(b+c+f)$$
$$=-a-d-e+b+c+f$$
$$=-a+b+c-d-e+f$$

The general rule should now be clear. *If a negative sign is in front of a bracketed group of numbers and the brackets are taken away, then all the positive signs inside the brackets must be changed into negative signs, and all the negative signs must be changed into positive signs.*

It should already be obvious that if there is a plus sign in front of the brackets, then the brackets can be taken away without altering the signs inside the brackets at all. This only expresses the idea that a combination of positive and negative numbers can be considered as a single number, *i.e.*, for instance,

$$a-b-c+d=(a-b-c+d)$$
$$=+(a-b-c+d)$$

or reversing the process,

$$+(a-b-c+d)=a-b-c+d.$$

(c) *Repeated Combination.*

Just as a number of parcels can be wrapped up into a larger parcel, and a number of these larger parcels can be wrapped up together into a still larger parcel, so a number of combined numbers can be grouped together into a combination of combined numbers, and these again can be further grouped together indefinitely. For distinctness, each degree of combining or wrapping up is shown by a different sort of bracket. To take an example—combining the numbers

$$(a-b)$$

and $$-(c+d)$$

gives $$[(a-b)-(c+d)]$$

Combining this with a similarly combined negative number

$$-[(e+f)+(g-h)]$$

gives

$$\{[(a-b)-(c+d)]-[(e+f)+(g-h)]\}$$

and combining this with another simple number k

$$k+\{[(a-b)-(c+d)]-[(e+f)+(g-h)]\}$$

In carrying out the reverse process, one would, in dealing with a parcel of parcels, remove one wrapper at a time, starting with the outside one. Dealing with the above combination of combinations in the same way, and remembering that every sub-combination is to be regarded as a separate single thing, the process becomes

$$k+\{[(a-b)-(c+d)]-[(e+f)+(g-h)]\}$$
$$=k+[(a-b)-(c+d)]-](e+f)+(g-h)]$$
$$=k+(a-b)-(c+d)-(e+f)-(g-h)$$
$$=k+a-b-c-d-e-f-g+h$$

which reveals the fact that k, a, and h are the only positive numbers in the whole group, a point which was not at all obvious in the combined form.

Actually the parcel analogy is not quite complete, because in a case like the one above there is nothing to prevent one from unwrapping some of the inside parcels first without disturbing the outer wrapping.

Thus

$$k+\{[(a-b)-(c+d)]-[(e+f)+g-h)]\}$$
$$=k+\{[a-b-c-d]-[e+f+g-h]\}$$

One can even rearrange the separate numbers into different inside parcels again thus

$$k+\{[(a-d)-(c+b)]-[(e-h)+(g+f)]\}$$

Another inside rearrangement is

$$k+\{[a-(b+c+d)]-[(e+f+g)-h]\}$$

or

$$k+\{[a-(b+c+d)]+[h-(e+f+g)]\}$$

which exhibits the number in a more symmetrical form.

The following is left as a simple exercise for the reader. Show that

$$[(a+b+c)-\{(a-b)-[(c-b)+(a-c)]\}$$
$$-[(a+b-c)+(a+b+c)+(c-a-b)]=0$$

(C.I.) *Extended Meaning of the Letter Symbols.*

Up to this point it has been assumed that the letter symbols used in algebra represent positive whole numbers, and negative numbers have been represented by prefixing the negative sign to the letter symbol. This was done in order that the laws about association and commutation and the rules relating to the negative sign might be explained as clearly as possible. But now that these things have been explained, there is no reason why the meaning of a letter symbol should be restricted in this way,* and in practice it would be rather inconvenient. In later applications it will be found that the number represented by a given symbol may vary over very wide ranges in accordance with the conditions of the problem, and may be negative for one set of conditions and positive for another. It will be found on examination that the rules developed for the combining of the numbers a, b, c, d, etc., in accordance with the signs written in front of them, will be equally valid whether the actual numbers represented by the letters are taken as positive or negative. For example, on the understanding that the letters mean positive numbers, it was shown that

$$a-(b-c)=a-b+c$$

and this can be confirmed by putting

$$a=1$$
$$b=2$$
$$c=3$$

Then $(b-c)=2-3=-1$

and $a-(b-c)=1--1=1+1=2$.

Also $a-b+c=1-2+3=2$

which confirms the statement.

Now suppose instead that

$$a=1$$
$$b=2$$
$$c=-3$$

Then $(b-c)=2--3=2+3=5$

and $a-(b-c)=1-5=-4$

Also $a-b+c=1-2+-3=1-2-3=-4$

and again the statement is confirmed. As an example of a case in which a single symbol can assume a wide range of values, positive or negative, take

$$a=b-c$$

where b can be any number from 0 to 100 and where c can be the same or any other number from 0 to 100. Here a can be any number from -100 to $+100$.

On the basis of this wider interpretation of the letter symbols, it will be necessary to reconsider the meaning of the "greater than" and "less than" signs. (Section 3 (B), i, ii, iii, iv.) When a and b are positive numbers, say $a=1{,}000$ and $b=1$, then the statement $a>b$ is quite unambiguous. But suppose $a=-1{,}000$ and $b=1$. What is meant by "greater than" in a case like this? It is, of course, only a matter of definition and agreement, and it is generally agreed that the "greater than" sign shall mean "more positive than" so that now $b>a$ for the given values. Remember that the wealth of a man who has one pound is greater than that of a man who has a debt of a thousand pounds. That is the sense in which the "greater than" sign is used algebraically. The other signs are similarly interpreted and need not be considered in detail. If in any case it is desired to indicate the relation between the actual numerical magnitudes of the two numbers without regard to sign, then this must be specifically stated, *e.g.*, "$a>b$ numerically." Some writers use for the same purpose the notation

$$|a|>|b|$$

i.e., the symbol is enclosed between strokes to indicate that its numerical magnitude only is being considered.

For the present, therefore, the letter

* According to Chrystal this important fact was not generally realised until about 1640.

symbols can be taken to mean positive or negative whole numbers. Further extensions of their possible meaning will come in their own time.

(C.2.) *A Physical Example of the Combination of Positive and Negative Numbers.*

The general meaning of algebraic addition will perhaps be made clearer by a physical example. A man starts from a point 100 feet above sea level and goes for a long walk up hill and down dale, eventually coming back to where he started from. Dividing up his walk into parts where he is either keeping on the same level, going up, or going down, let c_1, c_2, c_3, c_4, etc., completely represent the separate changes of level that he encounters. Then since his total change of level is nothing from start to finish

$$c_1+c_2+c_3+c_4+c_5+\text{etc.}=0.$$

It is clear that some of these numbers must be positive and some negative, and this is what is implied by the words "completely represent." If an ascent is represented by a positive number, then the algebraic statement is sound if a descent is represented by a negative number. If a_1, a_2, a_3, etc., and d_1, d_2, d_3, etc., be *positive* numbers which represent the actual amounts of the various ascents and descents, then the statement can be put in the form

$$a_1+a_2+a_3+\text{etc.}-d_1-d_2-d_3-\text{etc.}=0.$$

It is just a matter of definition and agreement which form is used. If the first, which is in a sense more general, then it must be remembered that when actual numbers are put in place of the letters, the numbers must have their proper sign attached to them, according to whether they stand for uphill or downhill journeys.

The discovery of a scientific law is often, perhaps always, the recognition of an analogy, or an essential similarity between two sets of ideas. If in the above example the idea of potential difference is substituted for "change of level" and the journey round and back to the starting point is thought of as going round a closed circuit of electric conductors, then readers will recognise in the example a statement of Kirchoff's Law about the sum of the potential differences in a closed circuit, an ascent representing a forward electro-motive force, and a descent representing a fall of potential or a back electro-motive force.

(C.3.) *Understanding or "Rule of Thumb"?*

Before going on to the last of the fundamental rules of arithmetic, *i.e.*, those concerned with multiplication and division, it will do no harm to take a short rest and a look round.

So far the ascent has not been very difficult, though the writer will not flatter himself that it has been really easy. There is no system of "mathematics without tears." As the learned Greek replied to the king many centuries ago, "There is no royal road."

This raises a question which some readers may already have asked themselves. Assuming that one learns the rules and abides by them, how far is it necessary to really understand them? (The infinitive is deliberately split, for emphasis.)

Let us think of a housemaid using a vacuum cleaner. She knows that if this thing is put into that and this other thing is pressed down until it clicks, a humming noise follows and the mouth end of the long stick will now pick up dust from the carpet. She does not know what makes the humming noise, and even if she did she would not know why the motor goes round; nevertheless, she can still use the long stick to pick up dust from the carpet. True enough, but think of the suppressed fear that persists even when familiarity has dulled the fine edge of her sensibilities, and think also of her helplessness when something goes wrong.

There are of course two sides to the question. It is not suggested that only qualified engineer maids should be allowed to use vacuum cleaners. Translating the analogy, the reader need not wait until he completely understands the rules before making use of them. (If he does he will wait for ever. Does the engineer really know why the motor goes round?) But there are several reasons why he should try to understand them as fully as possible, understanding being taken to mean the reduction of a mystery to its lowest terms.

In the first place, understanding deepens the original impression and so gives the memory a firmer foothold. Again, understanding gives confidence, real confidence, and not merely the absence of fear that follows on familiarity. Finally, using rules without understanding them is not treating the mind with proper respect. It is asking it to be satisfied with the position and capabilities of a tram driver, without aspiring to those of the engineer who knows how to lay down fresh tracks and design better machines to run on them.

There is one other thing to be said about this question of understanding the rules, and this introduces what has always seemed to the writer to be one of the most fascinating aspects of mathematics. Borrowing a phrase from the racing stables, the Rules of Mathematics are by Intuition out of Experience. In other words, they result from the mating of certain inborn habits of mind or " modes of perception " with sensory impressions of the outside world. Now many cases will arise where adherence to these rules will take the mind into a region where understanding breaks down, in the sense that no kind of sensory impressions can be found to correspond to the processes of thought. Nevertheless, it will be found that the rules remain valid in passing through this region of darkness, for the processes can be carried still further until they re-emerge into daylight, so to speak, and sensory impressions can again be found to correspond to them. To take an example, which the more advanced readers at least will be able to follow, it is possible by blindly following the rules to calculate where the tangents to a circle from a point inside the circle will make contact with the circle. Such tangents cannot be drawn in the ordinary sense of the word, and the points of contact will be " imaginary." However, continuing the process, the line that passes through these points can also be calculated, still by blindly following the rules, and it will be found that this is a real line, possessing certain useful properties with respect to the point inside the circle. It is difficult to realise the full implications of this process. It suggests that by means of its intuitions the mind can transcend the limitations of its environment. It is only in this sense that the mind should be allowed to be satisfied in using rules without understanding them.

(To be continued.)

Wire Anode Resistances.

Practical Details of Construction. [R383

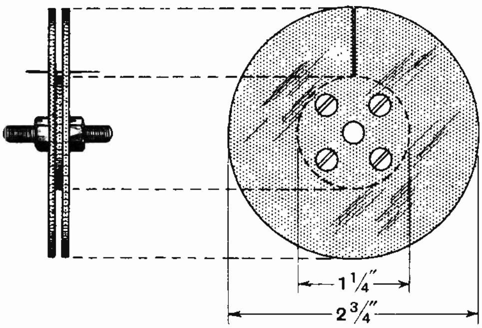
THE writer has recently had occasion to construct a number of non-inductive resistances of low self-capacity and about 50,000 ohms in magnitude suitable for use in the anode or grid circuit of a receiving valve. Since the method of construction adopted has proved very simple to carry out and gives a resistance of good electrical properties, it has been thought worth while to publish the following brief description.

First the requisite number of discs are cut from $\frac{1}{16}$ in. ebonite sheet, the dimensions being as shown in the figure. A number of these can be conveniently turned up together from square or octagonal pieces held together between two 2 B.A. nuts on a short length of 2 B.A. studding as a spindle. All the discs are then drilled with just clearing 6 B.A. holes and on half of the larger discs the holes are countersunk on one side so as to bring the head of a 6 B.A. countersunk screw just flush with the surface of the ebonite. It is preferable to use a jig for the drilling and a small register mark can be made on each disc in case the jig is not quite accurate. The larger discs are then clamped together in a vice (care being taken to register the holes) and a narrow saw-cut is put in radially as shown in the diagram.

The formers can now be assembled by putting 6 B.A. counter-sunk brass screws through the clearing holes, cutting them off short and just burring the ends with a light hammer.

Apart from the present application, formers made as above are very suitable for the construction of radio-frequency transformers or chokes of low self-capacity.

For the winding of the resistances No. 47 gauge D.S.C. Eureka wire should be used. This can be obtained from the London Electric Wire Company and is quite easy to handle, being surprisingly robust. It has a resistance of about 200 ohms per metre.



Details of bobbin construction.

One end of the winding is soldered on to the head of one of the 6 B.A. fixing screws and the disc is then mounted in the lathe on a length of 2 B.A. studding as spindle. Fifty turns are wound on in a forward direction, then a fine needle is put through the slots across the winding, as can be seen in the figure, and fifty more turns put on in the reverse direction, the needle serving to hold the loop in place. By the time the second fifty turns are on, the loop due to the reverse of direction is securely locked in place and the needle can be withdrawn, re-inserted in the slots on top of the winding and fifty more forward turns put on. This process is continued until the desired resistance is obtained. The actual number of turns will, of course, depend on the exact thickness of the ebonite sheet and to some extent on the tightness of the winding. Probably about 1,600 turns will be required for a resistance of 50,000 ohms, leaving about ¼ in. clear space inside the former. The winding should not be put on very tightly.

If a revolution counter is not available a thin thread carrying a little weight can be wound and unwound on the 2 B.A. studding spindle on which the bobbin is mounted.

The end of the winding is taken out through the slot and can be soldered on to the head of another of the 6 B.A. fixing screws. Thin copper leads can be soldered to the ends of the screws to the heads of which the winding has been connected.

For the measurement of the electrical constants of the finished resistances the writer is indebted to the courtesy of Mr. L. F. Hartshorn, of the National Physical Laboratory. The self-capacity was found to be between 6 and $7 \mu\mu F$ for resistances of just over 50,000 ohms. Such units will therefore be very satisfactory either for low-frequency amplification or for high-frequency amplification on the longer wavelengths.

Resistances of about 50,000 ohms were required for the writer's particular purpose, but anything up to about 100,000 ohms can be carried in these formers. F. M. C.

Long-Distance Work.

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

AT the time of writing, on account of industrial troubles now happily terminated, amateur radio work, in common with much other work, is somewhat curtailed, and reports of even such work as is in progress are not obtainable as readily as usual. However, quite a number of reports are to hand, and these, together with observations " on the air " itself, will form this month's article, which will necessarily be a short one.

DX conditions generally are about the same as those prevailing at the time of last month's report. Work with the U.S., though generally easy, is somewhat spasmodic, and nights when their stations are not to be heard are fairly frequent. Work with Australia continues to be easier than that with New Zealand, while South America, and particularly Brazil, still provides the easiest field for DX.

2SZ has not been doing a great deal of actual DX work recently, but has been chiefly occupied with experiments on aerial systems, and further work on quartz oscillators.

5BV is now in fairly regular, though not very frequent, operation again on 45 metres, with rather less power than that previously used. Like 5LF, he has not caught the prevailing " phone fever," which seems to have bitten most of the higher-powered stations.

6VP is still confining himself to 10 watts input, and has recently had a run of bad luck with valves, but has nevertheless got through to New Zealand.

Messrs. Studley, of Harrow, who have for a long time been well known for their work in DX reception, have now a transmitting station, with the call 5TD. At present they are using very low power, but have a useful range of over a thousand miles.

6CI, of Coventry, has been continuing the tests on very low power, which I have previously reported, and his results suggest that the present low-power record-holders (whose name, in my experience, is Legion) must look to their laurels. 6CI's power varies now between 0.5 and 0.75 watt, and his signals are regularly heard in all parts of Europe up to 1,000 miles. These results compare very favourably with those isolated cases of freak reception which are so often claimed as records.

2KK continues to work U.S.A. regularly with 10 watts and a Hertz.

5KO, though limited to a power which certainly does not recall the days when he was one of our very " biggest noises " on the air, is obtaining results which in their turn make the old high-power stations' work seem small. He has worked the Antipodes with a maximum of 30 watts from violently fluctuating mains.

There would appear to be no country in which 2CC has not been heard, and very few with which he has not worked. He puts out a very strong and pleasant note, whose only fault is an occasional instability in QRH, which would be worth curing.

Two Scottish stations, 5YG and 2VX, have worked Brazilian 6QA with 9 and 12 watts respectively. (6QA, by the way, is the new call of bz7AA.)

Belgian J2 and W2 are now working under the single call 2SM, and should soon be heard with a crystal-controlled set which, to judge from its description, should be very good indeed.

Reports for next month should be sent as early as possible, marked " DX work " and addressed care of the Editor.

Abstracts and References.

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

R000.—WIRELESS IN GENERAL.

R008.—DIGESTS OF UNITED STATES PATENTS RELATING TO RADIO TELEGRAPHY AND TELEPHONY. Issued 5th January, 1926, to 2nd March, 1926.—J. Brady. (*Proc. I.R.E.*, April, 1926, pp. 263—270.)

R010.—RUSSIA—SHORT WAVE RESEARCH. (*Electrical Review*, 9th April, 1926, p. 585.)

For some time past experiments with short waves have been in progress at the Russian Soviet Government Laboratory at Nishni-Novgorod, and it is reported that by the use of a 1,520-watt transmitter, devised in the laboratory, messages have been successfully transmitted to Chile and Porto Rico on wavelengths of 83, 102 and 104 metres. The object of the experiments is to provide a practicable form of communication with remote parts of Soviet Russia.

R030.—A QUESTION OF NOMENCLATURE.—W. Williams. (*Wireless World*, 17th March, 1926, p. 430.)

A letter drawing attention to an error of nomenclature in Dr. Smith Rose's article on " Polarisation of Wireless Waves " (*Wireless World*, 16th December, 1925, p. 159), where the plane of polarisation of a plane polarised beam is made to coincide with the plane of the electric vector, whilst hitherto, throughout the field of optics and electromagnetism, it has been taken to coincide with that of the magnetic vector.

Dr. Smith-Rose, in reply, admits his error according to the definition of the term " plane of polarisation " as derived from the history of physical optics, but points out that his use of the term is customary in the wireless profession. In anticipation of reaching some international agreement on the matter, as suggested by Mr. Williams, he desires to put forward two proposals for discussion :—

1. That the plane of polarisation should be referred to the electric instead of the magnetic vector ; and
2. That the definition of the plane of polarisation should be altered to be the plane containing the electric vector.

Reasons are given justifying these changes.

The question is also discussed in *E.W. & W.E.* for April, 1926, pp. 201—202.

R060.—CO-OPERATIVE RESEARCH IN THE UNITED STATES. (Circular of the *Bureau of Standards*, No. 296.)

Details are given of an admirably conceived plan, adopted by the Bureau, to provide a steady stream of trained research workers, familiar with the methods and resources of the Bureau, supplying the needs both of the Bureau and of industry.

R091.—BEVOR DER DREHKONDENSATOR KAM (Before the rotary condenser came).—O. Scheller. (*Zeitschrift f. Hochfrequenz.*, 27, 3, pp. 63—66.)

The technique of practical measurement and its significance in the first years of wireless telegraphy.

R100.—GENERAL PRINCIPLES AND THEORY.

R112.—DISTRIBUTION OF WIRELESS WAVES.—Dr. Smith-Rose. (*Wireless World*, 17th March, 1926, pp. 401—405.)

A popular article showing the dependence of reception upon ground conditions, and how blind spots in broadcast transmission are produced.

R113.—UBER DIE FORTPFLANZUNG ELEKTROMAGNETISCHEN WELLEN (Concerning the propagation of electromagnetic waves).—G. Elias. (*Zeitschr. f. Hochfrequenz.*, 27, 3, pp. 66—73.)

A theory is worked out to account for the ionisation of the upper atmosphere. It supposes a certain permanent ionisation produced by rays emitted by the sun, in addition to a temporary ionisation by day due to solar wave radiation. Simplifying these assumptions the number of ions is calculated. From the calculation there results a height of about 80 km. for the permanently ionised layer and 50—60 km. for the daytime layer—the former being far more sharply defined than the latter.

Further, the electrical constants of the upper atmosphere are calculated and represented graphically.

The behaviour of the different wavelengths, by day as well as by night, is explained on the basis of these calculations, also several of the facts found experimentally can be accounted for.

R113.—DIAGRAMMES DES CHAMPS ELECTRIQUES MESURÉS À MEUDON PENDANT LE TROISIÈME TRIMESTRE 1925 (Graphs of the electric fields measured at Meudon during the third quarter of 1925). (*L'Onde Electrique*, April, 1926, pp. 186—187.)

Graphs are shown of the electric field, in microvolts per metre, of Bordeaux, Nantes, Rocky Point, Rome and Leafield, measured at Meudon by the method described in No. 1 of *L'Onde Electrique*, January, 1922.

R113.1.—THE MYSTERY OF FADING.—Dr. Hall. (*E.W. & W.E.*, April, 1926, pp. 211—214.)

R113.4.—THE POLARIZATION OF RADIO WAVES.—G. Pickard. (*Proc. I.R.E.*, April, 1926, pp. 205—212.)

Prior measurements of wave polarisation made at the lower transmission frequencies have uniformly shown vertical electric force at all distances from the transmitter. The present work extends such measurements to the higher frequencies, where it is found that the electric force at any considerable distance from the transmitter is no longer vertical, but predominantly horizontal. Comparative measurements of radiation polarised alternately horizontally and vertically are also made, which indicate that the ratio of horizontal to vertical electric field depend only upon the frequency, distance and time of day, and are substantially independent of the plane of polarisation at the transmitter.

R113.3.—New Method Pertaining to the Reception of Interference in the Reception of Wireless Telegraphy and Telephony.—H. de Bellescize. (*Proc.I.R.E.*, April, 1926, pp. 249—262.)

The usefulness of directional reception and resonant circuit selectivity in reducing the effect of atmospheric disturbances is discussed.

Assuming that sinusoidal forces co-exist in a system with much larger impulses, it is shown that the sinusoidal forces will not pass through systems having internal frictional losses under certain definite conditions. The analogy between mechanical frictional systems and magnetic hysteretic systems is utilised in devising differential circuit arrangements whereby strong impulses, passing through two opposing circuits of controllable hysteretic damping, are nltimately balanced out, whereas smaller sinusoidal currents are delivered at the output of the system. The application to radio reception is described in detail.

R113.4.—Ozone and the Upper Atmosphere.—Prof. Armstrong. (*Nature*, 27th March, 1926, p. 452.)

A letter, referring to the discussion on the electrical state of the upper atmosphere at the Royal Society on 4th March, suggesting a way in which the ozone present might serve as an "accumulator."

R113.4.—The Electrical State of the Upper Atmosphere. (*Nature*, 27th March, 1926, pp. 454—456.)

A report of the contributions by Sir Henry Jackson, Prof. Chapman and Dr. Eccles to the discussion on the upper atmosphere at the Royal Society on 4th March.

R113.4.—Some Recent Advances in Atmospheric Physics.—Prof. S. Chapman. (*Nature*, 10th April, 1926, p. 537.)

Abstract of lecture given to Royal Meteorological Society on 17th March.

R113.5.—Perturbation Magnétique du 5 Mars 1926 et Perturbations des Premiers Mois de l'Année (Magnetic disturbance of 5th March, 1926, and the disturbances of the first months of the year). — H. Deslandres. (*Comptes Rendus*, 22nd March, 1926, pp. 733—735.)

R113.6.—Polarisation of Radiation scattered by an Electronic System to a Magnetic Field.—G. Breit. (*Journ. Optical Soc. of America* and *R.S.I.*, March, 1926, pp. 195—205.)

R113.6.—The Refractive Index of Gases and Vapours in a Magnetic Field.—R. Fraser. (*Philosophical Mag.*, April, 1926, pp. 885—890.)

R113.8.—Sur l'Orage Magnétique du 26 Janvier, 1926 (The Magnetic Storm of 26th January, 1926).—C. Maurain and L. Eblé. (*Comptes Rendus*, 1st February, 1926, p. 328.)

Account of the variations of the magnetic elements recorded at Val-Joyeux Observatory on 26th January.

R.113.8.—Atmospheric Ozone and Terrestrial Magnetism.—Dr. Chree. (*Proc. Roy. Soc.*. April, 1926, pp. 693—699.)

R113.8.—Measurements of the Amount of Ozone in the Earth's Atmosphere and its Relation to other Geophysical Conditions.—Dr. Dobson and Dr. Harrison. (*Proc. Roy. Soc.*, April, 1926, pp. 660—693.)

R114.—The Directional Recording of Atmospherics.—R. A. Watson Watt. (*E.W.&W.E.*, April, 1926, pp. 234—238.)

R114.—Lightning.—Dr. Dorsey. (*Journ. Franklin Inst.*, April, 1926, pp. 485—496.)

As here pictured, a lightning stroke starts with the initiation of a powerful electronic dart, and has a definite direction, that of the advance of the dart, and involves three distinct phenomena :—

1. Flying electrons ionise the air and produce certain characteristic effects where they strike.
2. Laggard electrons combine with the positive residues, giving rise to the flash.
3. A current results from the migration of the ions under the action of the field.

This current may be very great, but it is merely an incident of the flight of the electronic dart, is subsequent to that, and, relatively to the dart, is exceedingly sluggish. Whatever its direction, the stroke is not a result of the cloud discharging to earth ; the charge of the cloud does not pour into and along the flash, although ultimately the cloud does become partially discharged by the electrons or ions which have been freed by the dart. This discharge may involve relatively little motion of the charged particles initially resident in the cloud.

R120.—Space Characteristics of Antennæ.—W. Murphy. (*Journ. Franklin Institute*, April, 1926, pp. 411—429.)

A study is made of the actual radiated fields in space at unit distance by resolving the true fields into three imaginary components: A vertical component, a horizontal component in the directional plane of wave propagation, and a horizontal component perpendicular to this plane of propagation. This is done for special cases, such as for vertical and horizontal loops and antennæ, and from these cases general formulæ are evolved for inclined loops and antennæ. In addition to this, the component fields due to loops and antennae are added and resultant formulæ derived therefrom. The method of expressing the angle of the fields with respect to certain axes of reference, in other words, the polarisation of the field at any point in space is discussed, and formulæ derived for certain specific antennæ.

R127.—PRAKTISCHE BERECHNUNGSMETHODEN VON ANTENNENKAPAZITÄTEN (Practical methods of calculating antenna capacity).—J. Pusch. (*Zeitschr. f. Hochfrequenz.*, 27, 2, pp. 47—50).

The capacity of all forms of antenna, not too complicated in their composition, can be calculated to a good degree of accuracy by the method given by Howe (*Wireless World*, Dec., 1914, Jan., 1915, Sept., 1918, etc.). For many cases in practice, however, such a calculation is too intricate and would take too long. Accordingly, formulæ and methods of calculation are given here, making it possible to reckon antenna capacity simply and rapidly, with sufficient accuracy for many purposes.

The article is arranged in five sections :—

1. Calculation from the capacity of one wire and the number of wires.
2. Calculation from the antenna surface.
3. Calculation from the apparent surface of the antenna.
4. Increasing the capacity due to use of iron masts.
5. Choice of the number of wires.

R130.—EXPERIMENTAL STUDY OF INPUT ADMITTANCE OF TRIODE VALVE AT RADIO FREQUENCY AND THE METHOD OF RADIO - FREQUENCY VALVE CONSTANTS MEASUREMENT.—Yasusi Watanabe. (*Journ. Inst. Elect. Engineers of Japan*, March, 1926, pp. 299—310.)

This method, which claims to be new, consists in determining the variation of input admittance, which depends upon the valve constants.

In a previous paper by the author, *Input Admittance of Triode Valve*, the conclusion is drawn that the circle diagram of the input admittance depends upon the circuital constants as well as the valve constants. Consequently the valve constants can be determined from any measured results corresponding to the circle diagram. Some examples of determinations made at a frequency of 100,000 cycles per second are given, and it is concluded that the valve constants are literally constant and independent of the frequency, within the range of the author's experiments.

Some experimental results are also given with respect to the input admittance at radio-frequency.

A simple bridge method of determining the constants at radio-frequency was treated in the journal *Denki-Hyoron*, January, 1926.

R132.—AMPLIFIER PERFORMANCES.—H. Thomas. (*Electrician*, 9th April, 1926, pp. 410, 411 and 415.)

Abstract of a paper read before the Institution of Electrical Engineers.

A method of determining voltage amplification is given in detail and the effect of the amplifier on input circuits is analysed. Among the conclusions drawn from the experiments described are :—

1. The effect of increasing output is to modify the wave-form seriously. In general, the harmonics increase in magnitude far more rapidly than the fundamental.
2. As the frequency is lowered, the distortion becomes much more pronounced.
3. The effect of negative grid bias is to reduce the magnitude of the second and third harmonics and to introduce small harmonics of a higher order.
4. The form factor remains sensibly constant under most conditions.

R132.—UBER DIE KONSTRUKTION VON ARBEITSKENNLINIEN BEI VERSTÄRKERN MIT WIDERSTANDSKOPPLUNG (The construction of working characteristics in the case of Amplifiers with Resistance coupling).—M. von Ardenne. (*Zeitschrift f. Hochfrequenz.*, 27, 2, pp. 50—51.)

In supplement to the paper on resistance amplifiers (M. von Ardenne and H. Heinert, *Zeitschrift f. Hochfrequenz.*, 26, 52, 1925) data are given for the construction of working characteristics from a characteristic with constant anode voltage.

R133.—OSCILLATION WITHOUT REACTION.—Dr. Kröncke. (*Wireless World*, 24th March, 1926, pp. 467—468.)

Account of an effect produced by the emission of secondary electrons in the valve.

R135.—LE RADIOMODULATEUR BIGRILLE (The four-electrode valve as a modulator).—J. de Mare. (*L'Onde Electrique*, April, 1926 pp. 150—180.)

Lecture given before the Société des Amis de la T.S.F. on 12th November, 1925.

After considering generally reception by change of frequency, the characteristics of the four-electrode valve and its employment to produce a frequency changer by modulation are described.

Following the lecture there was a long discussion in which MM. Lévy, Barthélemy, and de Bellescize took part.

M. Lévy considered that the four-electrode modulator contains no new principle and the frequency change effected is brought about in exactly the same way as in the superheterodyne. He observed that this circuit arrangement has already been described some time ago—in June, 1924—in *E.W. & W.E.*, by M. Williams, and that this latter gave it the name of superheterodyne.

M. Barthélemy, on the contrary, is of the opinion that an essential difference exists between the working of the four-electrode valve and that of the superheterodyne ; the second grid should play a modulating part very different from that of detection which, according to him, would be one of the characteristics of the superheterodyne.

R135.009.—Die Gittergleichstrom-Modulation des Selbstemgten Rohrensenders (Grid current modulation of the self-excited valve transmitter).—G. Lubszynski. (*Zeitschr. f. Hochfrequenz.*, 27, 2, pp. 33—46.)

A detailed description of experimental investigations carried out in the Telefunken firm's physical laboratory during 1924.

The great number of ways of modulating the oscillations of a valve transmitter can be divided into two principal groups—those in which the high-frequency is modulated before amplification (at the grid), and those where modulation takes place after amplification (at the anode). Since the tendency always is towards controlling the transmitter with the least possible energy, grid methods have claimed increasing attention. It has been found, however, that when the low frequency is brought through a transformer directly to the grid of the transmitting valve, the oscillations completely break down as soon as the low frequency control exceeds a certain value (this phenomenon is described by Manz and Zenneck in the *Jahrbuck*, 19, p. 262, 1922). This instability of the oscillation conditions, caused by the oscillations ceasing below a certain amplitude, has been overcome by a combination of resistance and capacity in the grid circuit. Here the actual modulation is produced by altering the direct current grid resistance—which is then replaced by a valve. The phenomena occurring in this circuit are investigated in this article, the results being represented by means of curves.

R138.—Über die Bestimmung der Glühfaden-temperatur in Elektronenröhren (The determination of the temperature of the incandescent filament in valves).—H. G. Möller and F. Detels. (*Zeitschrift f. Hochfrequenz.*, 27, 3, pp. 74—81.)

Four methods for determining the temperature are available :—

1. By optical means, using a pyrometer or by photograph.
2. By means of a thermo-couple.
3. Finding the resistance increase of the filament.
4. A new method consisting in measuring the Maxwellian distribution of velocity of the electrons leaving the filament.

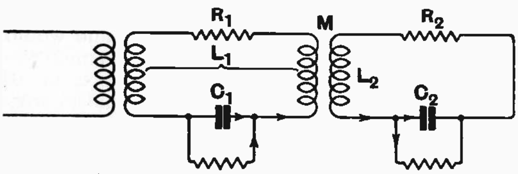
So long as Maxwell's law of distribution can be taken to hold good for electrons close to the filament surface, this method must yield exact values. In this article the sources of error of this new method are discussed and the working conditions deduced for obtaining reliable temperature determinations.

R140.—Entretien d'une Oscillation Libre non Sinusoïdale par Résonance de l'un de ses Harmoniques (Maintenance of a free non-sinusoidal oscillation by resonance with one of its harmonics).—J. Fallon and A. Manduit. (*Comptes Rendus*, 1st February, 1926, pp. 312—313.)

An experiment is described which shows how the transitory voltage across the condenser of a circuit, containing resistance, self-inductance, capacity and alternating supply, when the circuit is closed (due to the free oscillation of the system with pulsation equalling approx. $\frac{1}{\sqrt{LC}}$ and which ordinarily becomes negligible at the end of a certain time determined by the exponential factor) can be wholly maintained if the pulsation of one of its harmonics coincides with that of the source.

It is also shown how the principle can be utilised to obtain a ferromagnetic frequency demultiplier.

R142.3.—Bedingung für Maximale Energieubertragung in Induktiv Gekoppelten Kreisen (The condition for maximum transference of energy in inductively coupled circuits).—J. Kammerloher. (*Zeitschrift f. Hochfrequenz.*, 27th March, 1926, pp. 81—86.)



In this article the required condition for maximum transference of energy for the two oscillatory circuits, represented above, tuned to the same frequency, is found to be—

$$M = 1/\omega \sqrt{R_1' . R_2'}$$

where R_1', the resistance of circuit I,

$$= R_1 + \frac{L_1}{\zeta_1 . C_1}$$

and R_2', the resistance of circuit II.,

$$= R_2 + \frac{L_2}{\zeta_2 . C_2}$$

A similar condition also results for the coupling factor x for which the energy of circuit II. becomes a maximum, namely—

$$x = 1/\pi \sqrt{\delta_1' . \delta_2'}$$

where

$$\delta_1' = \left(\frac{R_1}{\omega L_1} + \frac{1}{\omega \zeta_1 C_1}\right)\pi$$

represents the damping decrement of circuit I. and

$$\delta_2' = \left(\frac{R_2}{\omega L_2} + \frac{1}{\omega \zeta_2 C_2}\right)\pi$$

that of circuit II.

The damping resistance in circuit I. always increases under the preceding condition to the double value. For the case when circuit I. is not tuned, the apparent resistance of circuit I. must be substituted for the damping resistance in the equation for M.

R144.—Effective Resistance of Inductance Coils at Radio Frequency. Part I.—S. Butterworth. (*E.W. & W.E.*). April, 1926, pp. 203—210.)

R.145.—On the Action of Parallel Plate Condensers under Exceedingly High Frequency.—T. Hoashi. (*Journ. Inst. Elect. Engineers of Japan*, March, 1926, pp. 311—318.)

A mathematical investigation from which the conclusion is drawn that the equivalent capacitance at exceedingly high frequencies is independent of its specific capacitance at low frequencies and inversely proportional to the specific resistance of the condenser plates and the impressed frequency.

For ordinary condensers there is no need to consider such a frequency effect on the capacitance unless the frequency is as high as some hundred million cycles per second.

R145.5.—Power Loss in Condensers.—L. Hartshorn. (*E.W. & W.E.*, April, 1926, pp. 225—233.)

R148.—Schnelltelegraphie mit Steuerdrossel (High-speed telegraphy with choke control). —W. Fischer and L. Pungs. (*Zeitschrift f. Hochfrequenz.*, 27, 2, 1926, pp. 51—54.)

Choke coils magnetised by direct current are frequently used to-day to modulate high-frequency currents. For a high-frequency circuit, a choke coil with an iron core represents a high ohmic resistance, owing to the large hysteresis and eddy current losses, as well as inductive resistance. If,

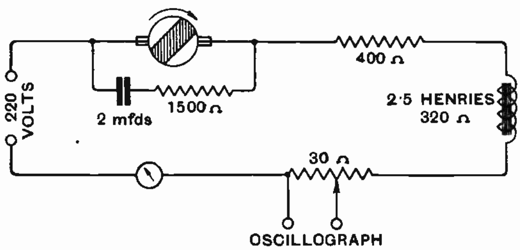


Fig. 2*a*.

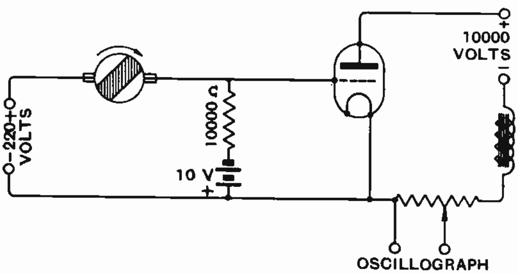
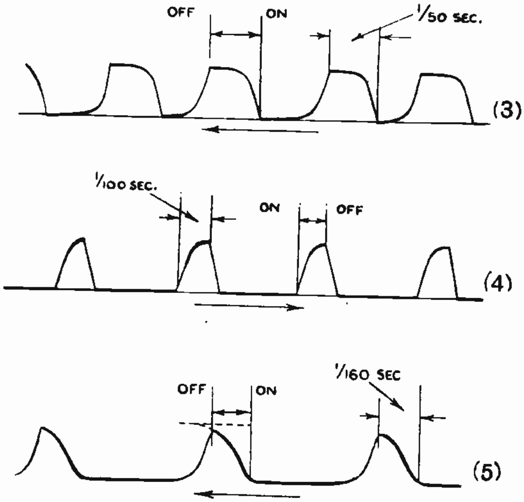


Fig. 2*b*.

by means of an auxiliary winding carrying direct current, the iron core is previously strongly magnetised, so that the induction comes far over the bend of the curve of magnetisation of the iron, no substantial variation of current occurs when a high-frequency magnetisation, whose amplitude remains considerably smaller than the direct current magnetisation, is superimposed. Consequently the inductive resistance of the choke is scarcely larger than would be that of the coil without the iron core, *i.e.*, through previous magnetisation the iron is made magnetically ineffective. At the same time the hysteresis and eddy current losses of the iron drop to a small fraction of the unsaturated values, so that when the coil has been previously magnetised, it no longer represents any considerable loss resistance for the high-frequency circuit. This



Figs. 3, 4 and 5.

fact is utilised to control the high-frequency current in such a manner that the coil is provided with a modulating winding separate from the high-frequency winding, the direct current supply of this control winding is keyed in the usual way, and thus the resistance of the choke, which is thereby altered, modulates the current in the high-frequency circuit. On closing the key the current does not reach its final value at once ,but only gradually, after an interval of time depending upon the time constant. Similarly when the circuit is broken, the current does not stop immediately, but there is a transient arc. Thus both beginning and end of the signs are distorted, while the form of the signs should be as rectangular as possible if the receiving apparatus is to work properly. To suppress the arc at break, a quenching circuit can be inserted to ensure that the current decreases according to a definite time function, as seen in Fig. 2*a**, where the H.F. circuit and choke winding are omitted for the sake of clearness. This circuit, however, has a time constant large compared with the duration of contact, so that it distorts the rectangular form, as shown by oscillograms obtained in a laboratory experiment which are produced in Figs. 3, 4 and 5.

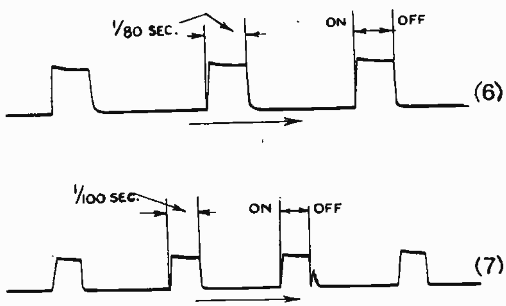
In Fig. 4 the quenching circuit is omitted. The only way of improving the shape of the wave form is to diminish the time constant (L/R). To decrease L by reducing the number of turns the current must increase beyond an admissible amount

* Note the authors' figure numbers are retained unchanged.

to keep the requisite number of ampere-turns. Accordingly, therefore, R must be increased. This is attained by means of the circuit arrangement shown in Fig. 2*b*.

Here the grid bias of a valve whose anode circuit contains the modulating winding is keyed. With the key open there is a small negative voltage on the grid completely suppressing the anode current. If now through the key a positive voltage is applied to the grid, an anode current flows whose value is determined by the resistances of the anode circuit, *i.e.*, the internal resistance of the valve, and the ohmic and inductive resistance of the control winding.

From a consideration of the valve characteristics it is shown that the time constant is nearly 20 times smaller than previously, and sufficiently small compared with the duration of the signal for all practical purposes. Figs. 6 and 7 show oscillograms taken with the circuit arrangement 2*b*—and corresponding to a telegraphic speed of 960—1,200 letters per minute.



Figs. 6 and 7.

There is a further advantage in this shortening of the period of make and break. The characteristic of the control coil, *i.e.*, the value of the H.F. current plotted as a function of the modulating current, no longer plays any practical part and can have any shape. The modulation of the high-frequency current will still be approximately rectangular, since the time occupied by make and break, in which this dependence of the one current upon the other alone appears, has become imperceptibly short. During the whole time that the sign lasts, the full H.F. current is flowing so that advantage is taken of the entire energy during the sign period.

As regards the practical applications of the device, it is mentioned, for example, that it solves the problem of high-speed telegraphy with the Poulson transmitter without employing a tuning wave, *i.e.*, keying up to the zero value of the aerial current, so that with Siemens' rapid telegraphing a speed of 800 letters can be reached.

R160.—Notes on Wireless Matters.—L. B. Turner. (*Electrician*, 9th April, 1926, pp. 408—409).

A review of the conditions which must obtain within the broadcast receiver for good quality reception, with particular reference to the high-frequency and rectifier circuits.

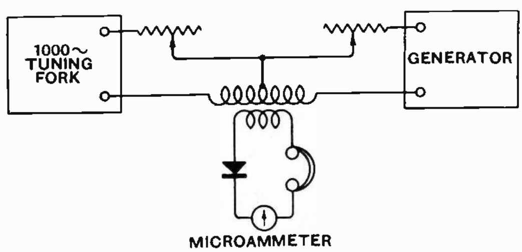
R160.—Sur la Détection (Concerning detection).—H. Pélabon. (*L'Onde Electrique*, April, 1926, pp. 141—149.)

The works of Mlle. Collet and M. Cayrel point to the conclusion that, in galena detection, the sulphur situated at the surface of the substance must play the fundamental part. The author effects detection by directly depositing some sulphur upon the metals, and then shows that all metalloids behave like sulphur, and finally that all insulating dielectrics can be employed. He is led to show that detection is produced in reality by the atmosphere and that the non-conducting granules play the double part of keeping constant the distance separating the two conductors and of decoherers.

R200.—MEASUREMENTS AND STANDARDS.

R210.—A Method of Calibrating a Low-frequency Generator with a One-Frequency Source.—S. Harris. (*Proc. I.R.E.*, April, 1926, pp. 213—216.)

Description of a simple method of calibrating an audio-frequency generator, a standard single-frequency source of oscillation being employed. The method makes use of the harmonics of the standard source and of the generator being calibrated. A diagram of the circuit arrangement is shown below.



The outputs of the generator and tuning-fork are combined in the transformer indicated, the secondary of which forms part of a circuit indicating the presence of beats.

R223.—The So-called Dielectric Constant.—S. W. Richardson. (*Nature*, 10th April, 1926, p. 515.)

R230.—Inductance Coils Quantitatively Compared.—A. Sowerby. (*E.W. & W.E.*, April, 1926, pp. 220—222.)

R240.—Detection of Small Changes in Resistance, Inductance and Capacity by means of an Oscillating Circuit.—L. Taylor. (*Journ. Optical Soc. of America & R.S.I.*, February, 1926, pp. 149—158.)

Discussion of a device consisting essentially of a Colpitt's oscillating circuit of carefully selected constants.

R251.2.—A Reliable Thermo-Converter.—Dr. Moll. (*Journ. Scien. Instruments*, April, 1926, pp. 209—210.)

Description of apparatus for transforming alternating into direct current by means of the thermo electric effect. In combination with a good milli-voltmeter it forms an instrument of high precision for alternating current measurements.

R260.—Messungen des Spannungsabfalles au Hochspannungs-elektronen-Röhren sowie au einer Einrichtung zur Beeinflussing Desselben (Measurements of the voltage drop in extra-high voltage valves and a means of influencing the same).—Max Wellauer. (*Archiv. f. Elektrotechnik*, 6th April, 1926, pp. 13—27.)

The voltage drop in high-frequency valves is generally taken to be small in comparison with the rectified voltage and not dependent upon it. Likewise it can be considered as independent of the value of the anode current so long as this remains below the saturation value. In this article an account is given of abnormal behaviour of the voltage drop, observed during experiments on insulating materials with valve rectified current, and the attempts made to investigate it. The experiments were carried out in the physical laboratory of the Verlikon machine factory and the principal conclusion drawn from the experiments is that under certain circumstances screening the valves electrostatically improves the efficiency.

R261.—A Valve Voltmeter with Self-contained Batteries.—C. R. Cosens. (*Journ. Scien. Instruments*, March, 1926, pp. 181—187.)

Description of a grid-type of triode voltmeter, with self-contained batteries, so that it is easily portable.

R281.—Isolantite.—A. Lescarboura and R. Kruse. (*Q.S.T.*, April, 1926, pp. 14—16.)

An account of this insulating material, which is said to be twice as hard as glass, tougher than cast iron, completely moisture proof, electrically excellent, and capable of being machined accurately.

R283.—Legierungen mit Besenderen Magnetischen Eigenschaften (Alloys with particular magnetic properties).—H. Freese. (*Zeitschrift f. Hochfrequenz.*, 27, 3, pp. 86—97.)

The employment of ferromagnetic material for frequency changers and control and modulation chokes has directed the attention of high-frequency technique to the metal alloys, with special magnetic properties, which have become known in recent years. Since the literature on these alloys is very scattered and often difficult of access, the results of the most important works on the subject are brought together in this article. Detailed information is given of the Heusler alloys and those of the iron groups, with numerous graphs, and a bibliography of the subject is appended.

R300.—APPARATUS AND EQUIPMENT.

R321.9.—Sleet Removal from Antennæ.—J. H. Shannon. (*Proc. I.R.E.*, April, 1926, pp. 181—195.)

A method is described for automatically releasing the antenna wires in case of excessive sleet load, for if the wires should break under a heavy coating of ice, serious damage to the self-supporting towers would result, due to the unbalanced load. A description is also given of a new type of suspension condenser developed to prevent the low frequency energy going to the ground, and thus making it possible to melt sleet from the individual antenna wires of the multiple-tuned antenna without the use and inconvenience of complicated switching at each ground point. The mechanical as well as the electrical design of this condenser is said to be unique.

R331.—The Manufacture of Radio Valves. (*Electrical Review*, 23rd April, 1926, pp. 648—650.)

Some impressions of a visit to the Mullard Co.'s thermionic valve factory.

R331.1.—Metals for Radio.—H. Seymour. (*Electrician*, 9th April, 1926, p. 409.)

An account of the properties of tantalum and molybdenum which render these metals valuable in vacuum tube construction.

R340.—Broadcast Reception with Four-Electrode Valves.—F. L. Devereux. (*Wireless World*, 7th April, 1926, pp. 512—516.)

Description of the use of four-electrode valves which, when suitably connected, require a maximum H.T. voltage of only 15 volts, making possible the employment of a small accumulator H.T. battery as anode supply.

R342.—Peaked Audio Amplifiers.—R. Kruse. (*Q.S.T.*, April, 1926, pp. 29—32.)

Account of the development of an audio amplifier having a peaked curve of amplification against frequency, suitable for amateur short-wave C.W. work.

R343.—Un Récepteur Neutrodyné Etuidé pour la Gamme de 200 à 3,000 Metres (A neutrodyne receiver for the range between 200 and 3,000 metres).—L. Berthet. (*Radio-électricité*, 10th March, 1926, pp. 90—92.)

An illustrated description of this receiver with which it is claimed nearly all the European broadcasting stations can be received.

R343.—The Shielded Neutrodyne Receiver.—J. Dreyer, Jr., and R. Manson. (*Proc. I.R.E.*, April, 1926, pp. 217—247.)

An exhaustive account of this device, including a brief historical outline of its development, with 23 figures.

R343.—Selective Reception. (*Electrician*, 9th April, 1926, p. 415.)

A brief account of the Marconi Type RG6A receiver which, it is claimed, can be regarded as the most selective and sensitive receiver of its class yet designed. Owing to the tuning circuits being screened against any alien inductive action, it is very suitable for simplex and duplex telegraph or telephone working in either ship or shore stations.

R344.3.—THE USE OF SMALL RECEIVING VALVES FOR TRANSMITTING.—A. Wood. (*E.W. & W.E.*, April, 1926, pp. 223—224.)

R344.8.—THE WAVE FORM OF THE CURRENT IN AN ELECTRICALLY MAINTAINED TUNING-FORK CIRCUIT.—V. H. SEARLE. (*Philosophical Mag.*, April, 1926, pp. 738—747.)

In view of the frequent use which is made of the electrically maintained tuning-fork as a standard of frequency, an investigation is made of the form of the current flowing through such a circuit and of the purely electrical factors which exert influence on the current form.

R350.—ELEKTRISCHE WELLEN IM GEBIETE DES AÜSSEREN ULTRAROT (Electric waves in the region of the extreme infra red).—M. Lewitsky. (*Physikalische Zeitschrift*, 15th March, 1926, pp. 177—182.)

Two systems of oscillators are described, each consisting of very small pieces of molybdenum wire .2 mm. thick, but in one the length of the individual oscillators varied from .1 to .4 mm., while in the other all the oscillators were of the same length—.1 mm. The little oscillators were fixed to a glass plate in a layer of Canada balsam in parallel rows as near together as possible. Several rows were necessary in order to obtain a sufficiently strong radiation. The oscillators were excited by an induction coil through a transformer with a secondary having as many coils as there were rows. A separate source of voltage for each row was necessary to secure the voltage in each being the same and a spark passing in all the rows, since it was impossible to make the length of the spark-gap exactly equal in every row. Failing this adjustment, a spark would pass only in the row with the least resistance.

The length of the wave radiated by the oscillators was measured with both plane and concave diffraction gratings. The maxima were observed with a thermo element—which had to be very sensitive on account of the extreme weakness of the radiation. Wavelengths ranging from 30 to 915μ were found with the first system and from 34 to 475μ with the second system.

It is stated that, owing to the minute energy of the oscillations, a far more powerful source of these short waves would have to be discovered in order to investigate their properties and laws of radiation.

R376.3.—AN ELECTROSTATIC LOUD-SPEAKER.—Dr. Kröncke. (*Wireless World*, 17th March, 1926, pp. 397—398.)

Details are given of an electrostatic loud-speaker in use in Germany.

R400.—SYSTEMS OF WORKING.

R410.—SINGLE SIDE-BAND TRANSMISSION.—E. K. Sandeman. (*Wireless World*, 31st March, 1926, pp. 487—489; 7th April, 1926, pp. 529—532.)

After reviewing the principles of ordinary telephony transmission, the nature of the wave transmitted from Rugby is explained, and technical details are given of the system used in transatlantic telephony.

R420.—ON THE WIRELESS BEAM OF SHORT ELECTRIC WAVES (I.).—S. Uda. (*Journ. Inst. Elect. Engineers of Japan*, March, 1926, pp. 273—282.)

The electric intensities of the field due to the oscillator itself (without antennæ and reflectors) are first observed in various directions around it. Here the plate and grid coils in the oscillation circuit form the radiators of short radio waves. The distribution of electric field intensities in the horizontal plane containing the oscillator is not uniform in all directions, the maximum values of their vertical components being in the directions of the plane of the plate and grid coils, while in these directions the horizontal component is negligibly small and *vice versa* for directions normal to the plane of the coils.

Polar diagrams are given of the effect upon the field intensities and distribution of placing an antenna, consisting of a brass rod in various positions near the oscillator. The results of trying to obtain a unidirectional field with three rod antennæ are also shown.

R421.—THE LORENZ HIGH FREQUENCY SYSTEM FOR RADIO TRANSMISSION.—F. Gillard. *E.W. & W.E.*, April, 1926, pp. 215—219.)

R430.—LE SECRET EN RADIOTÉLÉGRAPHIE (Secrecy in Radiotelegraphy). — Général Cartier. (*Radioelectricité*, 10th March, 1926, pp. 84—89.)

An illustrated account of an improvement of the Damm system, which was described in *Radioelectricité* for 10th January, 1926, pp. 6—10.

R440.—UNE STATION RADIOÉLECTRIQUE COMMANDÉE À DISTANCE PAR UNE LIGNE TÉLÉPHONIQUE (A radio station controlled from a distance by a telephone line).—L. Chauveau. (*Radioélectricité*, 25th March, 1926, pp. 101—107.)

An illustrated description of the way in which the radio station at Saint-Cyr is controlled from Villacoublay.

R500.—APPLICATIONS AND USES.

R510.—LA T.S.F. DANS LES RÉGIONS POLAIRES (Wireless Telegraphy in the Polar Regions). —W. Sanders. (*Radioelectricité*, 25th March, 1926, pp. 108—109).

An account of the services rendered by radio on the expedition of the "Pourquoi Pas" to the Arctic Seas last summer, a report of which has just been published by Commandant Charcot.

R530.—TELEPHONING ON TRAINS. (*Wireless World*, 7th April, 1926, pp. 517—519.)

Illustrated account of new wireless telephony equipment now working on the German railways.

R530.—LONG WAVES FOR TRANSATLANTIC TELEPHONY. (*Wireless World*, 17th March, 1926, pp. 411—412.)

Account of an interview with M. Marius Latmer, in which he expresses his belief that long waves, rather than short, will be used for transatlantic wireless telephony.

R540.—SHORT WAVES IN IRAQ.—Capt. Durrant. (*Wireless World*, 7th April, 1926, p. 528.)

R557.—BROADCASTING IN RUSSIA. (*Electrical Review*, 16th April, 1926, p. 623.)

There are six broadcasting stations of 2,000 watts under construction, and one of 50,000 watts, with five stations in Moscow, where the public reading rooms are equipped with receivers and loud-speakers. It is estimated that over 20,000 Russians in Moscow alone have managed to build and operate their own sets without the knowledge of the authorities. Broadcasting in Russia is under the control of the Commissariat of Posts and Telegraphs.

R557.—BROADCASTING IN AUSTRALIA. (*Electrical Review*, 16th April, 1926, p. 623.)

Australia has at present ten broadcasting stations situated in or near large towns. Two of these, the Sydney station and that of Perth, are rated at 5 kilowatts and work on wavelengths of 1,100 and 1,250 metres respectively. The remainder, with the exception of 3LO, the Melbourne station, which is rated at 5 kilowatts, are medium or low-power stations. All of them work on wavelengths between 300 and 500 metres. One, Brisbane, which is rated at 3,750 watts, and works on a wavelength of 385 metres, is conducted by the Government; the Post Office has placed telephone lines at the companies' disposal for simultaneous broadcasting.

The revenue from licence fees is divided amongst the broadcasting companies, a larger proportion being paid to those which operate high-power stations. The area allotted to each company is divided into zones, and the amount of the licence fee depends upon the zone in which the listener lives. At present, those whose homes are within a radius of 250 miles of a broadcasting station pay 35s. for the first year and 27s. 6d. a year afterwards.

R565.—RECENT ADVANCES IN MARINE RADIO COMMUNICATION.—T. M. Stevens. (*Proc. I.R.E.*, April, 1926, pp. 197—204.)

The development and use of vacuum tube apparatus by commercial and Government stations has not only doubled the range of marine communications, but has also made it possible to carry on a more extensive service with a far smaller number of corresponding stations on shore. Discontinuance of the use of spark apparatus at coast stations, and to a large extent on shipboard, has almost totally eliminated the interference formerly experienced.

R582.—TRANSMISSION AND RECEPTION OF PHOTO-RADIOGRAMS.—R. Ranger. (*Proc. I.R.E.*, April, 1926, pp. 161—180.)

A survey of the development of the art of electric picture transmission from its inception in 1842 to the present day.

The basic elements of all picture transmission systems are shown to consist of synchronously covering a surface, point by point, at both transmitter and receiver, and electrically identifying point values at the receiver so that any integral section of the received copy will have the same relative tonal value as the identical integral section on the transmitting surface.

A recent development by the Radio Corporation of America, known as the "photoradiogram" system, is described at length. This is a picture shorthand method, evolved from the standpoint of economy, and claimed to have considerable possibilities commercially, in particular for the newspaper service, and the transmission of words either printed, typewritten or handwritten.

R600.—STATIONS: DESIGN, OPERATION AND MANAGEMENT.

R611.—THE RUGBY WIRELESS STATION.—Dr. W. H. Eccles. (*Nature*, 17th April, 1926, pp. 557—558.)

Description of the most powerful wireless station in the world, designed by the Wireless Telegraphy Commission, and erected by the Wireless Section of the Engineering Department of the Post Office.

The station abounds with novel features, to mention only the form of the antenna, which consists merely of one conductor running round the circumference of the site, and the means of supplying it with oscillatory current—a valve-maintained tuning-fork.

R615.57.—AMERICA'S NEW HIGH-POWER BROADCASTING STATION.—A. Dinsdale. (*Wireless World*, 31st March, 1926, pp. 495—497.)

A description of the station at Bound Brook, N.J., giving particulars and photographs of the plant.

R625.—INTERNATIONAL RADIO TELEGRAPHY. (*Electrical Review*, 16th April, 1926, p. 623.)

Representatives of the principal wireless telegraph companies interested in international radio communication met recently at Monte Carlo. The chief aim of the conference is to prepare for the opening up, within a short period, of wireless communication between Brazil and other countries. The powerful station at Rio de Janeiro is nearing completion, and satisfactory trials have already been made; 21st April has been fixed as the date on which direct wireless services between Brazil and the United States, France, Great Britain, Germany and Italy will be inaugurated. The Rio de Janeiro station has twelve pylons 200 metres high and a power of 500 kw. Transmission on short wave will be employed as well as on the long wave, which has already been tested.

R800.—NON-WIRELESS SUBJECTS.

R539.—ON ENTROPY OF RADIATION II.—M. Saha and R. Sur. (*Philosophical Magazine*, April, 1926, pp. 890—893.)

A mathematical note.

R.539—DIE GRUNDGESETZE DER ELEKTRISCHEN AND MAGNETISCHEN ERREGUNG VON STANDPUNKTE DER QUANTENTHEORIE (The fundamental laws of electric and magnetic excitation from the standpoint of the quantum theory).—P. Debyi. (*Physikalische Zeitschrift*, 18th February, 1926, pp. 67—74.)

A mathematical discussion.

621.374.3.—SOME APPLICATIONS OF THE A.C. POTENTIOMETER.—T. Spooner. (*Journ. Scien. Instruments*, April, 1926, pp. 214—221.)

Certain applications of the A.C. potentiometer are described for which the Tinsley-Gall type is especially suitable. These include the measurement of the values of inductance and effective resistance, and the amplification factor of audio-frequency amplifiers.

621.374.9.—SUR UN NOUVEL ENREGISTREUR DE TEMPÉRATURE ET DE PRESSION POUR L'ÈTUDE DE LA HAUTE ATMOSPHÈRE (A new instrument for recording temperature and pressure for the investigation of the upper atmosphere) —E. Delcambre, P. Idrae and F. Geoffre. (*Comptes Rendus*, 29th March, 1926, pp. 858—859.)

Esperanto Section.

Abstracts of the Technical Articles in our last Issue.

Esperanto-Sekcio.

Resumoj de la Teknikaj Artikoloj en nia lasta Numero.

R100.—GENERALAJ PRINCIPOJ KAJ TEORIO.

R113.1.—VELKADO.—Lekcio farita de Prof. E. W. Marchant, D.Sc., antaŭ la Radio-Societo de Granda Britujo.

La temo pri velkado estas konsiderita laŭ ĝenerala vidpunkto. Fruaj raportoj pri ŝirmado pro geografiaj kaŭzoj estas menciitaj, notinde rezultoj cititaj de D-ro. Eccles kaj Sir Henry Jackson. Similaj efikoj ĉe ricevado de diversaj brodkastaj stacioj estas ankaŭ aluditaj. Poste estas konsiderita la efiko pro l'atmosfero, kun diskuto pri la produkto de ionizita tavolo. Oni montras, ke la mallongaj limoj de sendada formularo malaplikebligas ĉi tiujn rilate al la distancoj atingitaj per malgrandaj potencoj je mallongaj ondoj.

Sekvas priskribo de la lastatempa eksperimentado pri la Tavolo Heaviside, kun aparta aludo al la laboro de Prof. E. V. Appleton koncerne la mezuradon de l'angulo de la malrekta radio, al la laboro de S-ro. Hollingsworth, taksante, ke la Tavolo kuŝas je 70 k.m., kaj al la laboro de la Kompanio Marconi dum ties mondvojaĝo. Oni ankaŭ publikigis la longan diskutadon, kiu sekvis la lekcion.

R143.—PERDOJ ĈE INDUKTANCAJ BOBENOJ.—La Bezono por Normo de Efikeco.—S. Butterworth.

Oni diskutas la bezonon por starigo de normo, per kio la funkciado de agorda bobeno povas esti difinita. Valoro bazita je la faktoro de potenco estas proponita, tial ke ĉi tio estas sufiĉe konstanta ĉirkaŭ la sfero de funkciado de bone desegnita bobeno. La bobenon oni povus uzi kun norma cirkvito de, ekzemple, 0.002μF kaj de ekstera rezisteco de 20 omoj, kaj kun norma bobeno, kies potenca faktoro estas 0.005. Oni sugestas, ke la proporcio de volta pligrandiĝo ĉe la provata bobeno al tiu ĉe la norma estas la " Faktoro de Intenseco " difinanta la efikecon de la bobeno. Tabelo montras ciferojn por kelke da bone konataj vind-metodoj.

R144.—EFEKTIVA REZISTECO DE INDUKTANCAJ BOBENOJ JE ALTA FREKVENCO.—S. Butterworth.

Ampleksa konsiderado pri la temo de altfrekvenca rezisteco.

En Parto Ia (kiu aperis en la Aprila numero), oni diras, ke la diskutado celas planon desegnan por trovi por ĉiu racia bobenformo la plej bonan fadenan diametron kaj interrespondan perdon.

Konsiderinte ĝenerale la kuprajn perdojn ĉe induktancaj bobenoj, la aŭtoro transiras al detala studo pri la alternkurenta rezisteco de longa rekta fadeno, pritraktante respektive frekvencojn malaltajn, altajn, kaj mezaltajn. Li poste pasas al la konsidero pri kirlkurentaj perdoj en cilindro, kiam tio estas metita en konstantan magnetan kampon, pritraktante respektive frekvencojn malaltajn kaj altajn. Li donas esprimojn por la efektivaj rezistecoj je la ekzemploj konsideritaj, kun tabelo por faciligi la kalkuladon.

En Parto IIa (Majo), la alternkurenta rezisteco de du paralelaj fadenoj estas konsiderita kaj la rezonado etendita rilate al mallongaj bobenoj (solenoidaj aŭ diskaj), kun interspacaj paralelaj vindaĵoj. La rezonado estas poste aplikita rilate al solenoidoj unutavolaj de ampleksoj pli ofte renkontitaj en la praktiko, kaj de diskaj bobenoj unutavolaj.

Pluaj tabeloj estas presitaj por la kalkulado de certaj terminoj aperintaj en la diversaj esprimoj uzitaj. La korekton kontraû memkapacito oni diskutas, dum sekcio pritraktas la apartigon de la perdoj ĉe unutavolaj bobenoj. La artikolo finiĝas per tre utila sekcio ilustranta la efikon de interspacado.

La demando pri la plej bona bobenformo estas prokrastita ĝis la formularo por mult-tavolaj bobenoj estos pritraktita.

R300.—APARATO KAJ EKIPAĴO.

R330.—DETALOJ PRI GERMANAJ VALVOJ POR AMATOROJ.

Tabelo elĉerpita el *Die Audionvohre und Ihre Wirkung* (de D-ro. Gustav Liebert), kies recenzo aperas sur la antaûa paĝo en sama numero. La tabelo montras la Tipon, Fabrikiston, Filamentan kaj Anodan Konstantojn, Amplifecon, Rezistecon, kaj utilojn de proksimume 40 diversaj valvoj germanaj.

R355.55.—NOVA VALVA REKTIFIKATORO.—L. A. Sayce.

Priskribo pri nova termiona rektifikatoro fabrikita de la Phillips Lamp Company. La valvo havas filamenton kaj du anodojn por provizi plenan ondan rektifadon, kvankam la aŭtoro ilustras cirkviton por nur duononda rektifado, kun la du anodoj paralele aranĝitaj. Rektifita elmeto ĝis 1.3 amperoj estas atingebla. La filamento bezonas provizon 2-voltan, haveblan pere de ekstra vindaĵo ĉirkaû la transformatoro.

R381.4.01.—LA REKT-LINIA INTERRILATO.—D-ro. Oliver Hall.

La artikolo diskutas la komparon inter kondensatoroj de la duonronda kaj de la " kvadrat-leĝa " specoj. Pro restanta kapacito kaj hazarda kapacito en la cirkvito, kvadrat-leĝa kondensatoro donas nur linian interrilaton ĉirkaû la supra parto de la ciferplata gradaro, kaj oni montras, ke la ĉeesto de ĉi tiuj fiksaj kapacitoj malatingebligas rektlinian interrilaton en la praktiko.

Oni montras per tabeloj kaj kurvoj ke, ĉar la skalo de variado de kondensatoro estas malpliigita, la duonronda speco, se uzita por skalo de, ekzemple, 20 metra agordo, efektive produktas rektlinian interrilaton. Simila ekzemplo pruviĝas por la reguligo de frekvenco ĉirkaŭ malgranda skalo de variado.

LABOREJAJ NOTOJ.—E. Bainbridge Bell.

R.387. (1) Elektrostatika ŝirmilo. —Priskribas metodon fari ŝirmilon por utiligo inter du " flanformaj " bobenoj uzitaj kiel aerkerna transformatoro.

R381.5 (2) Kondensatora Potenciometro.—Priskribas la uzon de du kondensatoroj laŭserie aranĝitaj por la korekto de " antena efekto " ĉe kadra anteno, kaj diskutas aranĝojn por variigi ilin kontraŭdirekte, tiel ke ilia tuta kapacito restas konstanta, kaûzanta nenian ŝanĝon de kadra agordo.

R387.—HIDRARGAJ KONTAKT-KOMUTATOROJ KAJ KONEKTAJ TABULOJ.—T. B. Baker.

La uzo de plastika amalgamo, anstataŭ pura hidrargo, estas rekomendita por ĉi tiu celo, kun instrukcioj por la preparado de taŭga amalgamo, ekzemple, de hidrargo kaj stano. Kelke da malsamaj bazoj estas priskribitaj, kun diversaj kontaktiloj por provizi variaĵojn de komutmetodoj. Multobla konekta tabulo laŭ la sama principo estas ankaŭ priskribita, kaj ĝiaj utilecoj ilustritaj. Oni donas instrukciojn pri la konstruo de la diversaj partoj.

R500.—APLIKOJ KAJ UZOJ.

R582.—SENFADENA FOTO-TELEGRAFIO.

Priskribo pri la sistemo de Thorne Baker, kun diskuto pri ĝia apliko al brodkasta sendado.

R. 600—STACIOJ: DESEGNADO, FUNKCIADO, KAJ ADMINISTRADO.

R611.—LA RADIO-STACIO RUGBY DE LA BRITA POŜT-OFICEJO.

Resumo de referato legita de S-ro. E. H. Shaughnessy, O.B.E., antaŭ la Senfadena Sekcio de la Institucio de Elektraj Inĝenieroj. Priskribitaj estas la potencilaro, la mastoj kaj antenoj, sed la pligranda parto de la referato estas dediĉita al priskribo de la senfadena aparataro.

Generado de la alta frekvenco por radio-telegrafa sendado estas per valve funkciigita agordilo, kies elmeto estas amplifita, 9a harmoniko elfiltrita, kaj ĉi tiu frekvenco plue amplifita ĉe la agordila sekcio. Ĝi estas poste pasigita tra tri sinsekvaj ŝtupoj de amplifado, antaŭ ol ĝi atingas la antenajn cirkvitojn, la ŝtupoj traktantaj enmetajn potencojn de 4, 50, kaj 1,000 kilovatoj respektive. Presitaj estas diagramoj de la agordila sekcio, la aranĝoj por potenca amplifado, la antena kaj fermita cirkvitoj, k.t.p. Al la resumo estas aldonita fotografaĵaro, ilustranta diversajn el la objektoj kaj sekcioj aluditaj en la teksto. Presita ankaŭ estas diskutado pri la referato.

R800.—NE-RADIAJ TEMOJ.

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

Komenciĝo de serio pri tiu temo. La enkonduka parto emfazigas la gravecon kaj utilecon de matematiko, kaj indikas la amplekson de la serio. La sekcioj pritraktotaj estos (I.) Elementa Algebro, (II.) Ebena Geometrio, (III.) Trigonometrio, (IV.) Elementa Kalkuluso, (V.) Vektoroj.

Komenciĝas la unua sekcio pri Elementa Algebro, kun klarigoj kaj ilustraĵoj pri la fundamentaj leĝoj de algebro rilate al adicio kaj subtraho.

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.

How Far is that Station?

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

SIR,—I have read the article in the current number of your magazine entitled "How Far is that Station?" with much interest, but cannot agree with the results. Take the example Cambridge to KDKA.

Lat. Cambridge = 52° 12′N.
Lat. KDKA = 40° 27′N.

One is going from north to south, therefore one's course is south.

Again—

Long. Cambridge = 0° 08′E.
Long. KDKA = 79° 56′W.

One is going from east to west, and the course is West. That is, south and west course. How does your contributor make it west of north?

Again, I have worked out both course and distance as one would navigate a ship using Nories' tables, and I cannot agree either course or distance. You will find the method given in the Admiralty *Manual of Navigation*, also in other standard works.

Lat. Cambridge	52° 12′N.	Mer. parts.	3,685	Long.	0° 08′E.
,, KDKA	40° 27′N.	,, ,,	2,658		79° 56′W.
Dif. Lat. ...	11° 45′	Dif. do.	1,027	D. Long.	80° 4′
	60°				60°
	7,05′S.				4,804′W.

$$\textit{Tan}\text{ course } \frac{d\text{ Long.}}{d\text{ Mer. parts}} = \frac{4{,}804}{1{,}027}$$

4,804 *log* 3·681603
1,027 *log* 3·011570

·670 033 = *log tan* of course
= 77° 56′ nearly S. and W.

Dif. Lat. *sec* course = 705 *sec* 77° 56′

705 *log* = 2·848189
77° 56′ *log* sec. = 10·679751

13·527940

Discarding 10 gives 3·527 940 = *log* of distance = 3,372 naut. miles.

Glasgow. JAMES ANDERSON.

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

SIR,—I have just returned from abroad and received your letter of the 21st ult., which I will answer without delay as some time has elapsed. The information of your correspondent, Mr. Anderson, is incomplete, and he shows that he is confusing the geometry of a sphere with his experience of plotting on squared paper. He says that to go from 52° N. to 40° N. one is going "from north to south." It does not follow. If the second place was on the other side of the world by 180° one would go *northwards* to get there. Again, cut the earth in half by a line passing east and west through London. The cut would pass through Panama (and south of it from Glasgow). Obviously, then, all places in North America lie to north of west from England. And remember, lines of *latitude* are not "great circles."

Your correspondent quotes a method taken from the Admiralty *Manual of Navigation*. I happen to have the 1914 edition of this, and I see that he is employing Chapter IV. on thumb-line sailing. This has nothing to do with the case, and is a device for reaching a given port by a single unchanging compass bearing, and is a longer way round. Let him go on to Chapter V., "The Great Circle Track," and study that. But as seamen use haversines in their calculations, and land mathematicians do not employ these tables, the method is of little value for them and for wireless.

To say more would involve a long explanation of the subject. Mr. Anderson should get hold of a globe in a shop or somewhere and lay off a few straight lines across it with the edge of his handkerchief. He will see that places which lie in a straight line look very funny when plotted back on the distorted "Mercator," as I have already said.

Braintree. H. E. ADSHEAD.

Power Loss in Condensers.

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

SIR,—With reference to my article on air condensers in the April issue of *E.W. & W.E.*, Mr. Butterworth asks the question: Has the power factor of an air condenser of capacity less than 200μμF ever been measured at radio frequencies without assuming another air condenser free from loss? As far as I am aware, no satisfactory method has been published by means of which the power factor of such small air condensers may be determined directly and absolutely. Mr. Wilmotte's work, to which Mr. Butterworth referred, enables us to assign an upper limit to the power factor of an air condenser of, say, 600μμF, but it has not been applied directly to smaller condensers. It is, of course, possible to compare a number of small condensers with each other, and then to put them in parallel and compare their sum with a larger condenser which has been standardised in this way, and by such measurements an upper limit can be assigned to the power factors of small condensers, though the accuracy obtainable diminishes as the condensers become smaller.

Alternatively, if we know the power factor of a variable air condenser at a point near the top of its scale, then by assuming that the total power losses are independent of the condenser setting, we can assign an upper limit to the power factor of the condenser at any lower setting. If the actual air space is free from power loss, then we arrive at the true power factor at the lower setting, but if there is a small amount of loss in the air, the calculated power factor will be rather high.

The measurements referred to in my article were essentially of a comparative nature. Mr. Wilmotte had, however, also made measurements on some of the condensers, so that the values given are not without foundation on an absolute basis.

National Physical Laboratory, Teddington. L. HARTSHORN.

The Mystery of Fading.

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

SIR,—I have read with considerable interest the article by Dr. Oliver Hall, entitled "The Mystery of Fading," particularly in view of the fact that there is a certain similarity between some of the curves shown and some of those given in an article by the writer in the issue of *E.W. & W.E.* for July, 1925.

Dr. Oliver Hall plots certain curves, and derives certain deductions therefrom, the curves being obtained by aural methods. It is stated that signal intensity is estimated by listening to the output of a loud-speaker some twelve feet from the observer. The article states that "it is scarcely necessary to say that all observations of this kind cannot be compared with instrumental observations, but where instrumental observations are not possible aural methods are not to be despised." While broadly agreeing with this statement, the writer ventures to suggest that aural observations may be a source of considerable error, and lead to totally inaccurate deductions.

If we assume that the voltage produced across the terminals of the loud-speaker is directly proportional to the received signal energy, then we obtain a first approximation by plotting estimated sound intensity against time. It is important to remember, however, that this estimated sound intensity is in no way absolute. It is entirely a matter of comparison and relativity, since there is a personal element. The most important factor enabling us to determine an increase or decrease in volume is the rate of change. A very small increase or decrease occurring during a short period is immediately appreciated by most listeners, whereas it is almost impossible to detect a very large change in intensity when the time period is long.

Hence, it follows that any curves which are plotted by aural means really only show variations where the rate of change is comparatively great. Dr. Oliver Hall states in the article that "practically every case of fading in the second set of observations took place quite suddenly." This statement, derived from aural observation, certainly means that at the period immediately preceding minimum the rate of change was great, but it gives little indication of what was actually happening during the periods immediately preceding the period before minimum.

The writer does not suggest that the received current was not substantially constant during the periods before the minimum period, particularly in the case of the Bournemouth fade, where the curve is almost identical with that shown on page 651 of *E.W. & W.E.*, July, 1925, by the writer. It is interesting to note, however, that while a curve such as Fig. 2 shown in Dr. Oliver Hall's article may be obtained by aural observation, a totally different curve may be obtained for actual signal strength as measured by the aid of instruments.

All the curves shown by Dr. Oliver Hall are of an irregular character, which leads him to state that "Fading is an irregular phenomenon, and the worst thing that an investigator can do is to start off with the preconceived notion that fading is connected with some definite numerical quantity. . . ."

The writer would venture to suggest that a few observations such as those recorded are certainly not sufficient to justify the opinion that fading is irregular. Surely Dr. Oliver Hall must be aware of the very large number of records of competent observers showing perfectly regular fading. The writer was under the impression that fading was recognised as being either periodic or aperiodic, and, further, that modern theories as to its cause and nature explain equally well either a regular or irregular variation. Had Dr. Oliver Hall taken accurate plottings, true curves would have been obtained, which no doubt would be capable of mathematical treatment and help to remove some of the "mystery." Perhaps Dr. Oliver Hall would be good enough to explain a little more fully the justification of his statement that "Fading is an irregular phenomenon."

PAUL D. TYERS.

Watford, April, 1926.

"Aperiodic" or "Untuned"?

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

SIR,—There seems to be a growing tendency towards the misuse of the term "aperiodic." The untuned primary coil of the popular "low-loss" pattern short-wave tuner is often spoken of as "untuned *or aperiodic*" as if the terms were synonymous, which they are not.

The meaning of the term "untuned" is exactly what one would expect—the circuit or inductance referred to is not intentionally tuned to a definite frequency. Of course, any circuit which contains capacity and inductance must have a natural frequency (even when not purposely tuned) but in the type of tuner referred to, the natural frequency of the aerial or primary coil is so arranged to be outside the working frequency range of the secondary (tuned) coil.

"Aperiodic" means "without period," or as applied to tuning circuits, without any definite natural frequency. Thus, an aperiodic coil will respond to *all* frequencies with equal efficiency thus being the exact reverse to a tuned coil, which responds to one definite frequency only. In a rejector circuit, for instance, such as is used for tuning out local interference, the coil by-passes all the interfering frequencies, but rejects the desired one, which passes in the usual way to the tuner of the receiving set.

In such a circuit, the rejector coil is always wound with very thick wire, so as to reduce the resistance of the coil, thus reducing damping, and increasing selectivity. Clearly, if we desire to make an aperiodic coil, we must do the reverse, that is, use very thin wire, which will have a high resistance, in fact, resistance wire. If the resistance of the coil is correct, then we shall have a truly aperiodic coil.

A tuning coil or circuit can *only* be aperiodic when

r^2 is greater than $4L/C$,

where r = resistance,
L = inductance,
C = capacity,

and therefore, the untuned primary coil of a short wave or Reinartz pattern tuner, containing four or five turns of stout copper wire, with negligible resistance, cannot be described as aperiodic, but simply "untuned" which is more nearly correct.

F. A.

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

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

SIR,—May I suggest that in your editorial of May, 1926, it is rather misleading to say :—

"that as

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

by treating these as algebraic equations, and squaring and adding each side, it follows that

$$D^2 = -\omega^2."$$

By the application of algebraic methods to these equations we obtain—

$$D^2 = +\omega^2.$$

The truth of the expression—

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

is obtained by writing—

$$d/dt \sin \omega t = w \cos \omega t$$
$$d^2/dt^2 \sin \omega t = -\omega^2 \sin \omega t$$

and hence the operator—

$$d^2/dt^2 = -\omega^2.$$

The expression $j\omega L$ is obtained in a similar way by writing instead of $i = I \sin \omega t$,

$$i = I.e^{j\omega t}$$

whence $di/dt = j\omega i$.

In the one case $-\omega^2$ is written for the operator D^2, and in the second case $j\omega$ for the operator D.

The replacing of the operator D by jw is a convenience for determining the effective resistance and effective inductance of a circuit containing a periodic electromotive force that many students of electricity and magnetism would not care to abandon, but your valuable journal and your contributors have done us yeoman service by drawing attention to the precise meaning of such an expression as $R+j\omega L$ for impedance.

Portsmouth, Hants. MALCOLM G. RILEY.

[The statement which Mr. Riley kindly suggests is rather misleading is really a mistake. It is not by squaring and adding each side, but by multiplying the two left-hand sides and the two right-hand sides and equating the products, that we get $D^2 \sin \omega t = -\omega^2 \sin \omega t \cos wt$, and hence $D^2 = -\omega^2$. By squaring and adding each side we get $D^2 (\sin^2 \omega t + \cos^2 \omega t) = \omega^2(\sin^2 \omega t + \cos^2 \omega t)$, and hence $D^2 = w^2$. Thus the application of simple algebraic methods leads to two contradictory results. Although caused by a careless slip on our part, this brings out more clearly than ever the impossibility of regarding D as an ordinary algebraic quantity.—G. W. O. H.].

Fading.

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

SIR,—In my opinion the cloud has not been regarded sufficiently as a source of trouble concerning fading or as a reason for freak reception, especially of the local kind.

The effect of air pressure on reception is, I think, more likely to be due to movements of clouds caused by the change in air pressure rather than an alteration in the ionisation of the atmosphere, the change in pressure usually being insufficient to be effective.

Further, the conductivity of a cloud is far greater than that of ionised air. When the water in the cloud has dissolved a little carbon dioxide thus forming carbonic acid the conductivity will rise rapidly. Thus a cloud is a large reflector moving about in the air, reflecting and deflecting radio waves, giving rise to freak reception, and local fading.

Many amateurs and professionals would, I think, do well to give the Heaviside layer a rest and pay more attention to the cloud.

W. H. MADDISON

Stamford Hill, N.16. (2BOX).

"Effective Resistance of Inductance Coils at Radio Frequency." By S. Butterworth.

Part III of this article is unavoidably held over until next month on account of pressure on our space.

"The Use of Small Receiving Valves for Transmitting." By A. G. Wood.

We are asked to explain that the article under the above title, published in *E.W. & W.E.*, for May, was long delayed before publication was given and, therefore, the results obtained compare unfavourably with present DX results which have made such remarkable progress since the date when this article was prepared.

ERRATUM.

May issue :—

Page 265, Editorial, 2nd column, line 8, *for* "squaring and adding," *read* "multiplying."

Book Reviews.

THE SLIDE RULE SIMPLIFIED. By D. E. Rogers, pp. 76. Drawing Office Supplies, Ltd. Price 5s.

This is a plain straightforward book of instruction on the Slide Rule, in which every operation is clearly explained and illustrated by numerous examples. Even those who have used a slide rule for many years will find some useful hints on such things as taking out cube roots; at least that was our experience and we can recommend the book.

MODERN RADIO COMMUNICATION. By J. H. Reyner, pp. xi.+208 with 121 Figs. Pitman. Price 5s.

This is a book which we can recommend to any earnest student of the subject. It assumes an elementary knowledge of electricity and magnetism but deduces everything as far as possible from first principles. It is as non-mathematical as it is possible to make a text-book covering the syllabus of the City of Guilds examination in this subject. It has only been possible to cover the ground in 200 pages by omitting those branches of the subject which are now only of historical interest, and this is indicated in the title. Text and diagrams are clear and well arranged.

LOUD-SPEAKERS. By C. M. R. Balbi, pp. xv.+96 with 57 Figs. Pitman. Price 3s. 6d.

This is a popular non-mathematical but scientifically correct description of the principles and practice of loud-speaker construction and operation. All the various types are described and the important subjects of diaphragms and horn are discussed. The concluding chapter is entitled "Advice to intending purchasers" and there is a list extending to eleven pages of the principal loud-speakers on the market with notes and particulars of each type. This should prove very useful to intending purchasers.

STÖRBEFREIUNG IN DER DRAHTLOSEN NACHRICHTENÜBERMITTLUNG. [The Elimination of Interference in Wireless Telegraphy.] By M. Singlemann, pp. 151 and 239 Figs. Hermann Meusser, Berlin. Price 8.50 marks.

This forms volume 7 of a series on "Die Hochfrequenztechnick," edited by Dr. Carl Lubben. Only a few pages are devoted to the underlying principles, the greater part of the book consisting of diagrams of connections illustrating almost every receiving arrangement which has been devised, each diagram having a brief description of its principal points. Each section, such as Heterodyne Receivers, Directive Receivers, Elimination of Distortion, etc., etc., is introduced by a brief general description. To one familiar with the principles, the book offers a useful classified compilation of circuits. G.W.O.H.

DER DETEKTOR. By Dr. R. Lehnhardt, pp. 95 and 62 Figs. Hermann Meusser, Berlin. Price 5.80 marks.

This is volume 8 of the same series. The title should be "Detectors other than Thermionic Valves," since only 9 pages are devoted to these, against 67 pages on contact detectors, the remaining few pages dealing with sundry other types. In the few pages devoted to the thermionic valve, however, the author accomplishes a wonderful feat in developing the two-electrode valve without any mention of Prof. Fleming. A somewhat strange remark is that "the first grid tube was proposed by de Forest, but in Germany by v. Lieben."

Crystal detectors are dealt with fairly fully, both in theory and practice. A table is given of a great number of minerals with figures which are not defined, but which are probably the necessary applied electromotive forces to give good results. A final section deals with the use of a crystal as a generator of oscillations. A very good bibliography of the subject is given. G.W.O.H.

Modern Printing Telegraphy.

An attractive booklet with the above title has been received from Messrs. Creed & Co., Ltd., of Croydon. We need hardly say that the name of Creed is associated all over the world with progress and masterly achievement in the field of printing telegraphy. In the current number of the *Zeitschrift für Hochfrequenztechnik* we noticed with a touch of pride that the wireless transmitting and receiving rooms at the German Main Telegraph Offices in Berlin were equipped with Creed apparatus. Messrs. Creed & Co. have acquired the Murray Multiplex System which they now manufacture in addition to the Creed High-Speed Printing Telegraphs. The booklet gives illustrated descriptions of the various pieces of apparatus, such as keyboard perforators, transmitters, receivers, printers, relays, undulators, phonic motor distributors employed in one or both of the systems.

Proceedings of the Wireless Section of the Institute of Electrical Engineers.

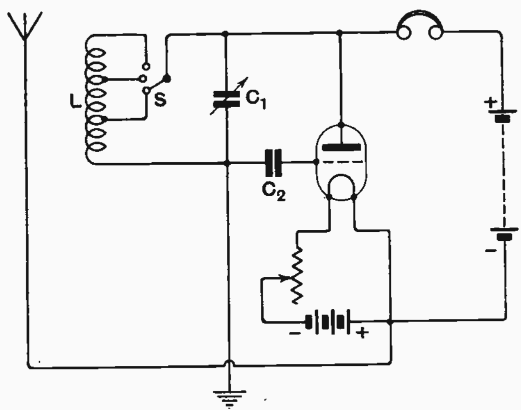
As we announced in a recent number, the Council of the Institution decided to publish the papers read before the Wireless Section, separately from the main proceedings. Volume I., No. 1, has now been published and it is stated that there will be three issues yearly, viz., in March, June and September. The first number contains Major Benyon's address as President of the Section, "The Performance of Amplifiers," by H. A. Thomas, and "Frequency Variations in Thermionic Generators," by Lt.-Col. Edgeworth, together with the discussions which took place at the meetings.

Some Recent Patents. [R008

A PECULIAR RECEIVING CIRCUIT.

(*Convention date* (*U.S.A.*), 30*th June*, 1924. *No.* 236,156.)

A rather peculiar type of receiving circuit is described in the above British Patent by C. E. Ogden and P. V. Ogden. The object of the invention is to produce a receiver particularly suitable for portable use, when an aerial is not always practicable, signals being obtained by means of an earth connection. The accompanying illustration shows the circuit. It will be seen that an oscillatory circuit consists of a variable condenser C_1 and an inductance L connected between the anode and grid of a three electrode valve, the usual condenser C_2 being included.

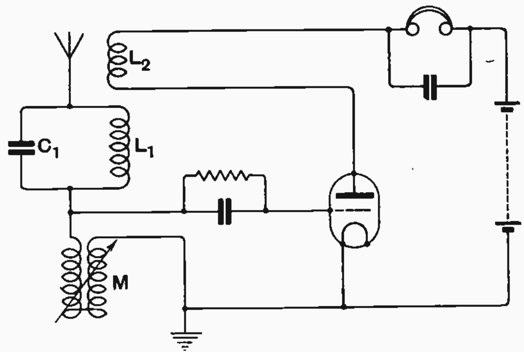


No grid-leak is shown and we presume that the valve is soft. The system is earthed at one side of the oscillatory circuit. The usual filament and anode batteries are provided, and telephones are included between the high tension battery and the anode. Reaction is controlled by means of the tapping switch *S*, which varies the amount of inductance in circuit, and also by controlling the filament temperature or emission. It is stated that the use of an aerial increases the strength of the signals, the aerial, if used, being connected to the filament.

REGENERATION CONTROL.

(*Application date*, 5*th January*, 1925. *No.* 248,876.)

The above British Patent, granted to H. Tyler, deals essentially with the control of reaction. It will be seen from the accompanying illustration that the aerial circuit is tuned by means of a variable condenser C_1, an inductance L_1, and a variometer M. Potentials are taken across the variometer M, and applied between the grid and filament of the valve, the usual grid condenser and leak being included. A coil L_2 is included in the anode circuit of the valve and is coupled into the inductance L_1. It is stated that the control of reaction is very smooth and not in the

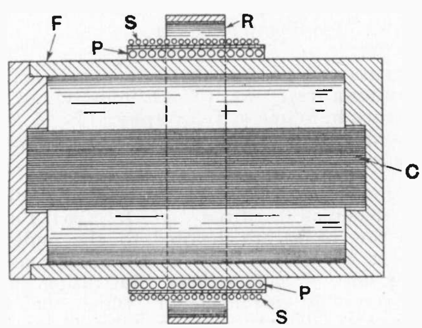


least critical. It is further stated that the circuit gives more volume than is obtained with the normal arrangement.

RADIO FREQUENCY TRANSFORMER CONSTRUCTION.

(*Convention date* (*France*), 21*st November*, 1924. *No.* 243,379.)

A rather interesting method of adjusting a transformer is described in the above British Patent, which is granted to the Société Française Radio-Electrique. The method of control is particularly applicable to supersonic intermediate transformers, in which a number having the same natural frequency are desired. Formerly, transformers have been adjusted subsequent to manufacture by varying the number of turns until the



desired natural frequency is obtained. This elaborate method, however, is entirely obviated by the method of construction which is illustrated by the accompanying diagram. It will be seen that the transformer comprises two sets of windings

P and S, one wound upon the other on an insulating former F. The former contains an iron core C, comprising a large number of very fine wires, suitably annealed so as to have minimum losses. The core is arranged so that there is a very large air space between itself and the windings. The transformer is adjusted by means of a conducting ring R, which is capable of longitudinal movement with respect to the core and the windings. Thus it will be seen that the ring may be brought gradually into the flux, so that the flux which is embraced may be varied. and in this way a number of transformers may easily be matched.

THE R.I. TUNER.

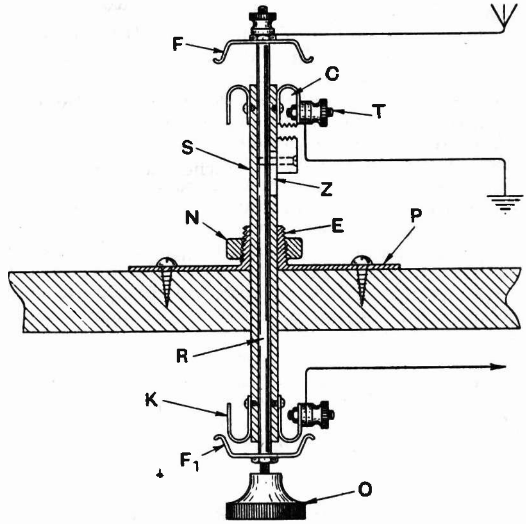
(*Application date, 25th February*, 1925. *No.* 249,292.)

Some details of the R.I. tuner are described by W. A. Appleton and J. Joseph in the above British Specification. The tuner consists of a continuous winding on a cylindrical former with a small air space between the various sections, which are of increasing size. The inductance is tapped at each section, the tappings being brought to a multi-stud switch. In addition, a cylindrical reaction coil is mounted at one end of the cylinder, and is connected by a bevelled gear wheel to a controlling knob at the other end of the cylinder, which also carries the multi-contact switch. The switch arm is of the double type, that is, it is of sufficient area to embrace two studs at a time. Thus it will be seen that the section of the coil nearest to the one in use is short-circuited, and the switch is also connected so that the whole of the inductance out of circuit is also short-circuited.

A SAFETY LEAD-IN TUBE.

(*Application date, 20th April*, 1925. *No.* 248,590.)

P. J. Ambrose describes the construction of a safety lead-in tube. The lead-in is of the type comprising an insulating tube in which a rod carrying contacts is capable of being moved so as to connect either the aerial to the set or to earth. The particular form of lead-in is shown in the accompanying illustration, and consists of an insulating tube S, which is gripped by means of a nut N in a split threaded extension E of a flange plate P, which is screwed to the window frame or the wall. The tube carries at its external end a contact C and a terminal T, which communicates with the earth. A similar pair of contacts K are fixed at the internal end of the tube, and are provided with another terminal, which is connected to the receiver. A conducting rod R is provided with a knob O by means of which it is moved. The rod carries at either end fingers F and F_1. and at the external end a terminal to which the aerial lead is connected. Thus it will be seen that when the knob is pushed in, the fingers F_1 will touch the contacts K, thereby connecting the aerial lead to the set. When the knob is pulled out the fingers F will touch the contacts C, thereby connecting the aerial lead straight to earth, and at the same time disconnecting the set from the aerial lead. An additional feature of this invention is the provision of a spark gap on the side of the tube. The gap comprises the usual pair of serrated edges, one fixed to the contact ring C, and the other fixed to an extension at right angles to the rod. This extension works in a slot Z in the tube. Thus when the knob is

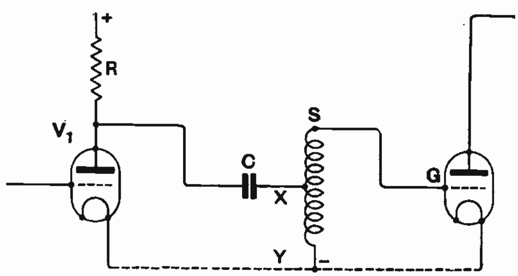


pulled out and the aerial is earthed there is a considerable distance between the gap, this helping to isolate the receiver from the aerial lead, but when the knob is pushed in and the set is connected to the aerial the movable element of the gap is brought into close proximity with the fixed element thereby acting as an efficient spark gap.

AN M.-L. INTERVALVE COUPLING.

(*Application date, 29th December*, 1924. *No.* 249,234.)

A very interesting form of intervalve coupling is described by the M.-L. Magneto Syndicate Limited and D. K. Morris, Ph.D., in the above British Patent. The object of the invention is



to produce a coupling device having the same efficiency as an ordinary intervalve transformer, but at the same time eliminating some of the inherent defects, particularly those due to saturation and hysteresis effects. The invention consists essentially in separating the direct anode current component from an auto transformer, merely applying the alternating current potentials to the primary winding. The accompanying diagram should illustrate the principle, in which it will be seen that the anode circuit of the first valve V_1 contains a high resistance R. Alternating potentials are produced across this resistance, and are applied by means of a condenser C between the points X and Y, *i.e.*, the primary winding of an auto-coupled transformer. The high potential end of the secondary S is connected to the grid G of the second valve. Thus it will be seen that direct currents are confined to the anode circuit of the valve V_1, and only alternating currents are applied to the auto transformer. It will be obvious that the absence of the steady current from the primary windings of the transformer eliminates the possibility of distortion due to saturation and other similar troubles. The Patent Specification also gives details of the construction of a unit for this purpose, comprising a combination of resistance, a coupling condenser, and an auto transformer, the whole being contained within a suitable case, appropriate terminals being provided. The arrangement also enables the device to be used as an ordinary auto transformer and stopping condenser, or, if desired, an ordinary choke and a stopping condenser.

SUPERSONIC TRANSMISSION.

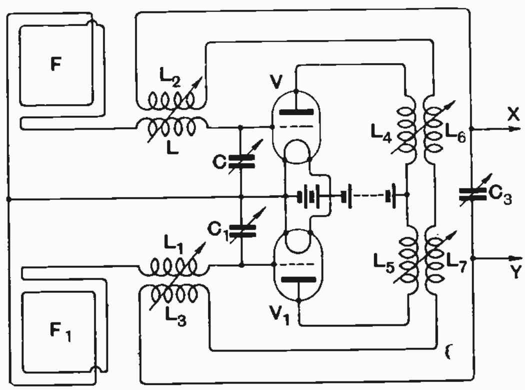
(*Application date, 20th December*, 1924. *No.* 248,868.)

A system of broadcast transmission designed to lessen the effects of interference is described by B. H. N. H. Hamilton and J. Robinson in the above British Patent. The ordinary method of supersonic reception consists in beating a local oscillation with the received signals so as to provide an intermediate beat frequency which is subsequently amplified and detected. According to this system, however, instead of introducing the local oscillation at the receiver another carrier wave is transmitted, so that the two are received simultaneously, and beat together, amplification being carried out at the intermediate beat frequency, after which the amplified currents are detected. One modification of the system consists in providing one high power main carrier wave, which is modulated, and providing a number of localised low power transmitting stations, which simply emit a carrier wave of such a frequency as to give the desired beat frequency in the receiver.

A SYSTEM OF ATMOSPHERIC ELIMINATION.

(*Convention date* (*France*), 30*th November*, 1923. *No.* 225,570.)

L. Levy describes in the above British Patent a system of atmospheric elimination dependent upon the balancing out of currents due to undesired signals or atmospherics. The arrangement should be clearly understood by reference to the accompanying illustration, in which two receiving frames are shown associated with two valves having a common output. Two frames F and F_1 are connected to the grid circuits of valves V and V_1, and are tuned by condensers C and C_1, the grid circuits being coupled by inductances L and L_1 to inductances L_2 and L_3 respectively. The anode circuits of the valves V and V_1 respectively contain inductances L_4 and L_5, which in turn are coupled to inductances L_6 and L_7, the inductances L_2 and L_3 being connected in series with L_6 and L_7, and are tuned by a variable condenser C_3. Any potentials occurring in this tuned circuit are amplified at the points X and Y, *i.e.*, across the variable condenser C_3, and are subsequently rectified and further amplified if desired. The frame F is tuned by the condenser C to a wavelength slightly above that of the desired signal, while the frame F_1 is tuned to a wavelength slightly below that of the desired signal. It is stated that any atmospheric or similar parasitic shock excitations will cause equal and opposite currents to flow in the output circuit of L_6, L_7 and L_3, C_3, with the result that substantially no potential will occur across the points X and Y. When, however, oscillations due to the desired signals are received, *i.e.*, at frequencies intermediate between that to which the two frame

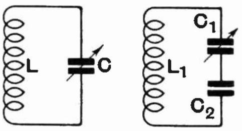


circuits are tuned, the current in one circuit will lead and the current in the other circuit will lag with reference to the voltage produced by the wave in the two circuits, and, consequently, there will be a phase difference between the potentials between the two grids and filaments. This means that opposition will not occur in the output circuit L_6, L_7, owing, of course, to the reactive coupling between L_2, L, L_3 and L_1, and it is further stated that the potential induced by the received signal tends to lead by ninety degrees. This results in phase opposition occurring between the two sets of grid potentials. Hence an appreciable voltage will be produced across the points X Y due to the received wave, which is then amplified and utilised without interference from any atmospherics.

CONSTANT BEAT FREQUENCY.

(*Convention date* (*Germany*), 15*th November*, 1924. *No.* 243,018.)

Telefunken Gesellschaft fur Drahtlose Telegraphie M.B.H. claim in the above British Patent Specification an arrangement of two or more tuned circuits provided with a common tuning adjustment, such that the frequency difference between two circuits is always constant. An arrangement of this description would be very useful in heterodyne or super-heterodyne circuits, where it is desired to adjust two tuned circuits with only one control, so that a constant beat frequency, for example, is obtained without the necessity of using a variable condenser of any special law.

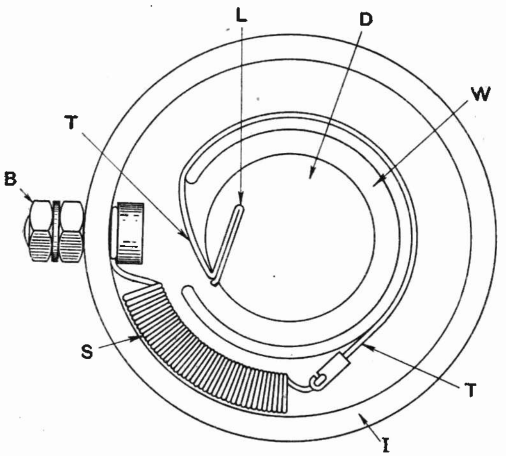


It will be seen that the two inductances L and L_1 are tuned respectively by variable condensers C and C_1, the variable condenser C_1 being in series with a fixed condenser C_2. It is found that by suitably proportioning the condensers C_1 and C_2, and inductances L_1 and L_2, rotation of the one control knob operating both condensers results in a constant frequency difference. The values of the components are such that the two variable condensers are of similar capacity, while the inductance L_1 is slightly smaller than the inductance L. The specification shows the mathematical justification of this relation, and indicates how actual values may be calculated.

ANOTHER VARIABLE GRID-LEAK.

(*Application date, 29th May,* 1925. *No.* 250,052.)

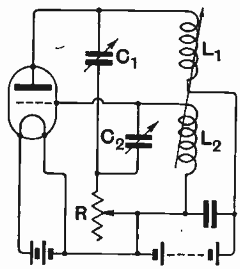
The construction of a variable grid-leak is described by W. P. Fraser in the above British Patent. The leak is of the type comprising a flexible high resistance conductor, part of which is short-circuited by coming into contact with a metallic surface. Thus, in the accompanying illustration, which merely shows a plan view of such a resistance, the resistance element comprises a piece of tape T, treated with indian ink. One end of the ink conductor is connected to a helical spring S, provided with a terminal B. The other end of the tape is fixed in a small slot L, in a metallic drum. The insulating case I, which contains the device is also provided with a concentric insulating sleeve W, around which the tape passes. Thus it will be seen that on rotating the drum by means of a knob fixed to a shaft (not shown) the tape will be wound round the periphery of the drum, thereby short-circuiting a considerable portion of the resistance element, with a corresponding decrease in the total resistance in circuit. The other connection, of course, is made to the metallic drum.



MAINTAINING CONSTANT FREQUENCY.

(*Application date, 9th April,* 1925. *No.* 250,022.)

K. R. Edgeworth describes in the above British Patent Specification a method of maintaining constant frequency in an oscillating valve. It is stated in the specification that stray capacitative coupling between the grid and anode circuits of a valve, anode potentials, and filament emission all have a controlling influence upon the frequency of oscillation. The object of the invention is to

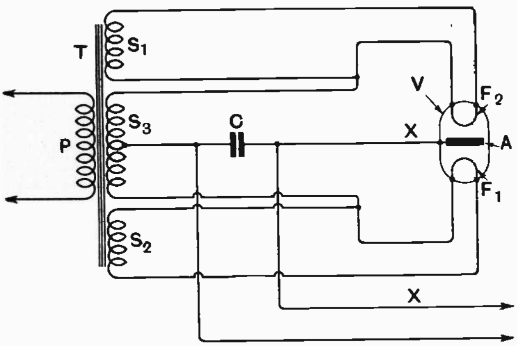


provide a form of coupling for the production of oscillations in which the frequency is maintained substantially constant. The invention consists in providing tuned anode and grid circuits, and including a common resistance in the two oscillatory circuits. Thus, in the accompanying illustration, a valve is provided with an anode oscillatory circuit consisting of an inductance L_1, and a capacity C_1, and a grid circuit comprising an inductance L_2, and a capacity C_2, the two circuits being coupled by a variable resistance R. The inductances L_1 and L_2 are also coupled together so as to produce a non-regenerative effect equal and opposite to that due to the inherent capacity coupling in the circuit. It is stated that the arrangement is exceedingly stable in operation.

A DOUBLE FILAMENT RECTIFYING VALVE.

(*Convention date (U.S.A.),* 18*th July,* 1924.
No. 237,233.)

The Dubilier Condenser Company (1925) Limited and H. W. Houck described in the above British Patent the construction of a multi-filament rectifying valve. The accompanying illustration shows a double filament valve suitable for full wave rectification of single phase current. It is well known that when a valve filament is heated electronic emission occurs, and the flow of electrons to the anode or plate can only take place when the potential of the anode is positive with respect to the filament. This rectifying effect is well known, and is utilised in a particular valve in the following manner: The valve V containing the filaments F_1 and F_2, and anode A is used with a special

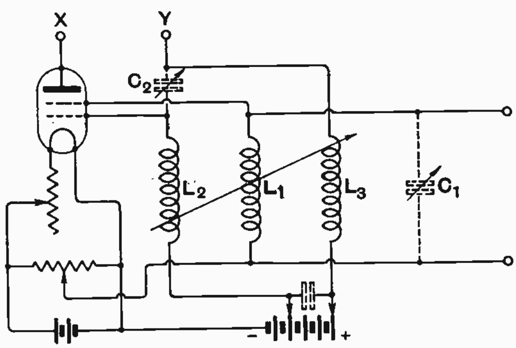


type of transformer T. The transformer is provided with a primary P. There are three secondary windings, S_1, S_2 and S_3; S_1 and S_2 are used to heat the filaments, and the centre tap winding S_3 is used to produce the high or low voltage current which is to be rectified. The two filament windings are connected respectively to the extremities of the centre tap secondary, the centre tap of the secondary being connected through the load circuit, shunted by a condenser C, to the anode A. When the filaments are energised, emission will occur, and when the potential of one filament is negative with respect to the other an electronic stream will pass from that filament to the anode. Since the potential of the other filament with respect to the anode is positive there will be no electronic stream. At the next half cycle the other filament will be negative with respect to the anode, while the former filament will be positive, with the result that an electronic stream will be established between the anode and the other filament, the current always returning to the anode along the same conductor X. In other words, a rectified current effect is obtained. An additional feature of the invention is the arrangement of the filaments so that any one filament is screened from the other filaments by the anode, thereby preventing an electronic short circuit between the filaments.

A FOUR-ELECTRODE VALVE CIRCUIT.

(*Convention date* (*France*), 15*th December*, 1923. *No.* 226,228.)

A four-electrode valve circuit including three coupled inductances is claimed in the above British Patent by the Compagnie Générale de Télégraphie sans Fil. The accompanying diagram illustrates the arrangement of the circuit. The four-electrode valve is of the usual type comprising filament, anode and inner and outer grids. The input circuit comprises a tuned circuit L_1 C_1, connected between the outer grid and the filament. The inner grid circuit includes an inductance L_2, which is given a certain positive potential with respect to the filament, while the anode circuit from which the output is taken at X Y includes an inductance L_3, the potential of the anode being positive with respect to the filament. The three inductances L_1, L_2 and L_3 are coupled together. The specification



also provides for the inclusion of a variable condenser between the inner grid and the high potential end of the inductance L_3. It is stated that the amplification which is obtained with this arrangement is considerably greater than that derived from the more normal connections.