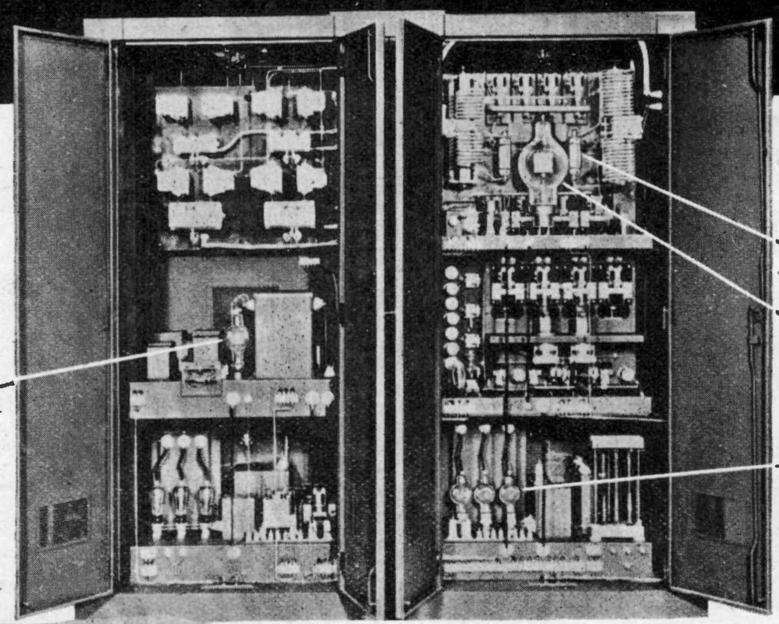
Electronic Engineering

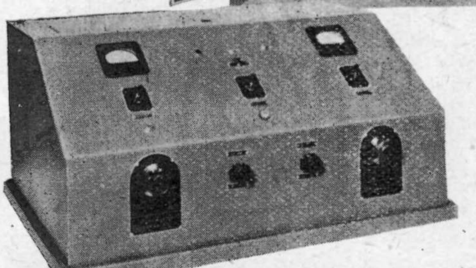
INCORPORATING ELECTRONICS, TELEVISION AND SHORT WAVE WORLD

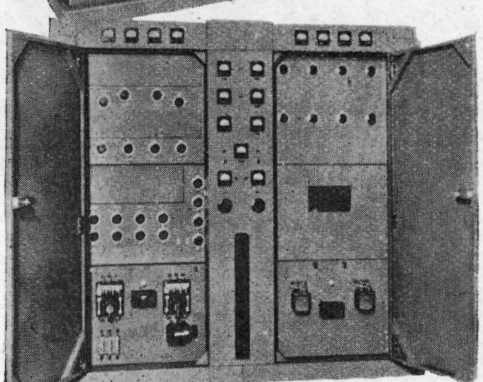
PRINCIPAL CONTENTS

2/- APR., 1942

EIMAC EQUIPPED BRAZILIAN ARMY STATION







Photos from top to bottom show a rear view of transmitter, the remote control and a front view of the transmitter constructed by Maya Rebello & Comp. of Rio de Janeiro for the Brazilian army

With a single 750T in the final stage and a pair of 250T's as modulators this station puts 1200 watts on the antenna. Operated by remote control on four frequencies using phone, CW and ICW.

The transmitter was constructed by Maya Rebello & Comp. of Rio de Janeiro and employs Eimac RX 21 rectifier tubes as well as Eimac vacuum tank condensers in the final circuit. The design and construction does credit to its makers and the use of Eimac Tubes in the most important sockets is convincing evidence of their superiority and position in the world of radio.

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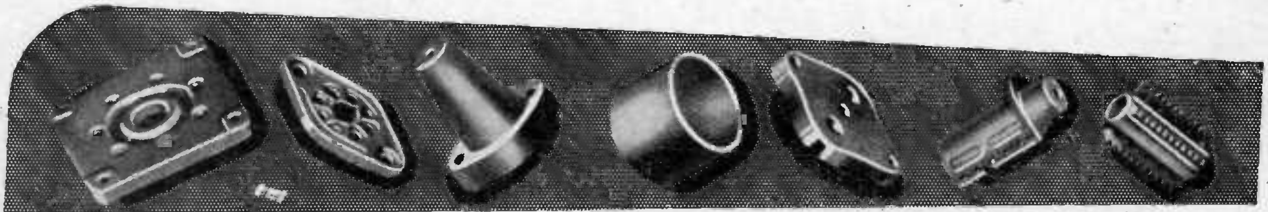

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SIR WILLIAM BRAGG

His Appeal as a Lecturer

Sir William Henry Bragg, O.M., K.B.E., F.R.S., Director of the Royal Institution of Great Britain, died in London on March 12, 1942, at the age of 79. His greatest contribution to science was in X-ray Spectroscopy and Crystal Structure for which he received the Nobel Prize in 1915. Throughout his career he consistently urged the value and importance of scientific research and was a member of the Advisory Council for Industrial Research.

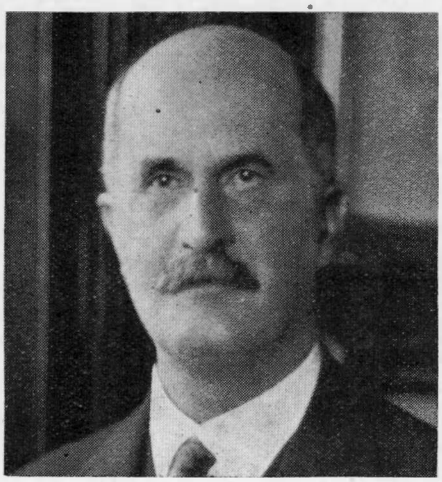
Among his less well-known activities was the delivery of lectures on a variety of scientific subjects to popular audiences at the Royal Institution and elsewhere, and the following note, written by one of his staff, illustrates how he gave the same care and enthusiasm to his work as to the more serious aspects of science.

IT is not easy to give a true picture of Sir William Bragg's success as a lecturer, although to those who heard him often this might seem quite simple. There was the evident aim to please the audience rather than to impress them, but it was usual for both results to be achieved.

At the Royal Institution he found himself free to turn from the rather academic type of lecture and to adopt the Faraday - Tyndall - Rayleigh - Dewar tradition of utilising the appeal of experiments and demonstrations on a generous scale. This he did with great zest. He dearly loved a demonstration, and would often say with reference to the traditional strict limit of one hour for the lectures: "If it is only talk, then you must stop; if it is an experiment, don't leave it out."

However, he never allowed even a good demonstration to hold up the flow of a discourse, and if, in preparation, an experiment developed uncertainties, his verdict would be: "What a pity, but we must keep that until it can be made less troublesome."

Thus it was that he was a comfortable lecturer to demonstrate for, and if the unforeseen hitch did occur, neither the audience nor the anxious demonstrator was allowed to get disturbed. Sir William would find some soothing or humorous way of belittling the trouble and pass quickly to a diverting interest, very nearly in the manner of the late Sir J. J. Thompson.



In the early days, especially of his Royal Institution Lectures, Sir William habitually sought to test his plans by quiet discussions in which he explored the views and reactions of all concerned to his ideas. Thus, when proposing a rather searching course on new developments in crystal structure work, he felt that it demanded some fundamental groundwork on crystal orders and groups—specialist knowledge, so to speak—"but, do you think," he would say, "that our audiences would care to stand that?"

When, however, he was assured that the audience would be receptive he would say: "Then they must have good models to make it clear." Good models, and good big ones, they accordingly had.

Not only crystal types and groups, but models of X-ray reflections from crystal lattices were soon shown, in this case working models with moving levers for the X-ray beams and contact studs for the crystal lattice were made so that as the beam swung round at certain definite positions a series of contacts were made through the lattice studs to signal an X-ray reflection at these angles.

Following such a lead it became very desirable to demonstrate the real thing, and finally it was done: an X-ray spectrometer in operation in the lecture theatre with a projection of a diamond crystal in a beam of X-rays being turned slowly on its scaled table before an ionisation chamber. At certain angles of the rotation the main X-ray beam was diffracted by the diamond into the ionisation chamber and the electrical response which resulted was amplified sufficiently to give a deflection on a galvanometer. The quiet but thrilling verdict of the lecturer was "You *have* done well," and to the audience later "This is quite easy, you know," followed in parenthesis with a disarming smile: "When you know how to do it, of course." W.J.G.

The Input Impedance of a Coupled Circuit System

By T. F. WALL, D.Sc., D.Eng., M.I.E.E.*

IT is hardly necessary to emphasise the practical significance of the "Input Impedance" of a coupled circuit system as used in electronic engineering work. If the locus of the extremity of the input impedance vector is plotted for a range of frequencies, the resultant graph will give not only the resonant frequencies of the system but, amongst other important information, this graph will show at once what consequences will result in so far as the supply of active and reactive current is concerned, if the supply frequency differs from the resonant value by a given percentage.

The mathematical solution of the equations for a coupled circuit is well known for the case in which the resistance of the circuit is relatively small, but with the exception of some special cases, the solution of these equations is very cumbersome and involved and arithmetical and other mistakes are not easily avoided when applying the solution to given circuit constants, whilst in the case for which the resistance of the circuit is not negligibly small, the mathematical solution becomes so involved as to be practically unmanageable.

In this article a description is given of a simple graphical method for obtaining the input impedance of a coupled circuit when the resistances of the component branches have any given values and the application of the method involves no mathematical knowledge except that of the elementary rules for vector operations. By means of such a graphical method not only can the required input impedance be found for any given value of the supply frequency, but the process also enables a ready survey to be obtained as to the general effect of a change of one or more of the circuit constants.

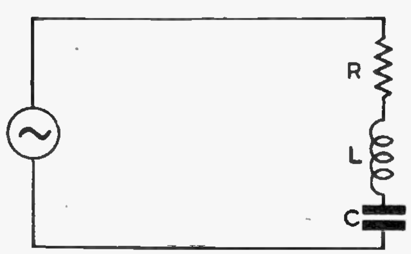


Fig. 1.

In Fig. 1 is shown a simple series circuit comprising a resistance of R ohms, an inductance of L henry and a capacitance of C farad, the circuit being connected to a source of variable frequency f. If $\omega = 2\pi f$ is the value of the "circular frequency" the impedance vector of the circuit may be written.†

$$\mathbf{Z} = R + j(\omega L - 1/\omega C) = R + jX \text{ ohms} \quad (1)$$

where the "real" part of the equation is the resistance R in ohms and the "imaginary" or "j" part is the reactance X, also expressed in ohms. If a pressure **V** be applied to this circuit the relationship between this pressure and the corresponding current will be

$$\mathbf{V} = \mathbf{IZ}. \quad (2)$$

If a number of impedances, $\mathbf{Z}_1$, $\mathbf{Z}_2$, . . . were to be connected across the supply terminals then, since the current will be common to all the impedances, the equation (2) may be written

$$\mathbf{V} = \mathbf{I}(\mathbf{Z}_1 + \mathbf{Z}_2 + \ldots \quad \ldots) \quad (3)$$

That is to say, the total impedance of the circuit is obtained by taking the vector sum of the total number of impedances which are in series in the circuit.

When the frequency is such that $\omega L = 1/\omega C$ a condition of resonance exists and the impedance then becomes equal to the resistance R of the circuit so that the current vector will then be in phase with the supply pressure vector **V** and consequently $\mathbf{V} = \mathbf{IZ} = \mathbf{I}R$. The "admittance" of the circuit shown in Fig. 1 is, $\mathbf{Y} = 1/\mathbf{Z} =$

$$\frac{1}{R + j(\omega L - 1/\omega C)} = \frac{R - j(\omega L - 1/\omega C)}{R^2 + (\omega L - 1/\omega C)^2}$$

$$\text{or } \mathbf{Y} = G - jB \quad \ldots \quad (4)$$

The "real" part G of this admittance vector is the "conductance" and the imaginary part B is the "susceptance." The admittance, conductance, and susceptance are measured in "reciprocal ohms" which may consequently be written $1/\Omega$.

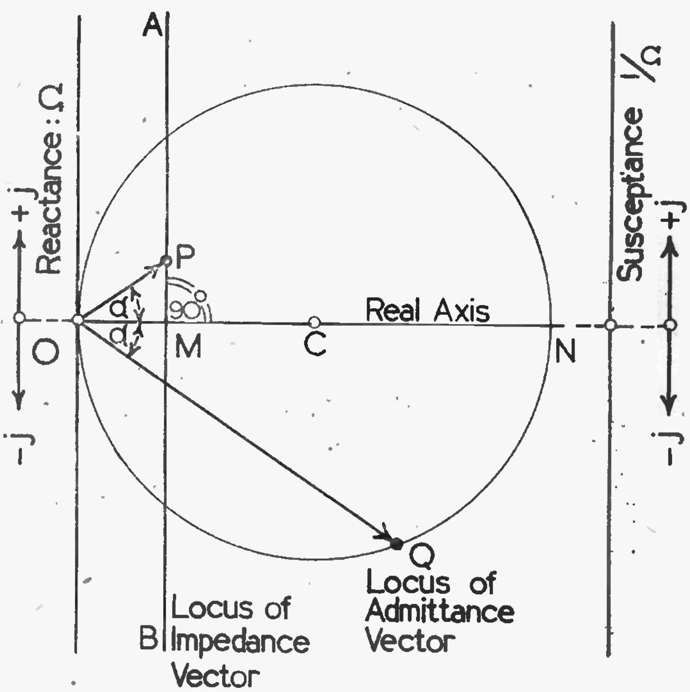


Fig. 2. The graphical construction for determining the impedance of a coupled circuit.

The current in the circuit may then be expressed by the equation,

$$\mathbf{I} = \mathbf{V}/\mathbf{Z} = \mathbf{VY} \quad \ldots \quad (5)$$

If a number of circuits of respective admittances $\mathbf{Y}_1, \mathbf{Y}_2$ . . . be connected in parallel across a common supply pressure **V** the total current which will be supplied will be

$$\mathbf{I} = \mathbf{I}_1 + \mathbf{I}_2 + \ldots = \mathbf{V}(\mathbf{Y}_1 + \mathbf{Y}_2 + \ldots)$$
$$= \mathbf{VY}_T \quad \ldots \quad \ldots \quad (6)$$

so that the total admittance of the parallel system of circuits is obtained by taking the vector sum of the individual admittances. The impedance vector $\mathbf{Z} = R + jX$ may be written in the equivalent form,

$$\mathbf{Z} = Ze^{j\alpha} \quad \ldots \quad \ldots \quad (7)$$

where the magnitude of the impedance is $Z = \sqrt{(R^2 + X^2)}$ and the phase angle α is defined by $\tan \alpha = X/R$. The corresponding admittance vector may then be written,

* Department of Electrical Engineering, University of Sheffield.

† Vector quantities are printed in heavy type.

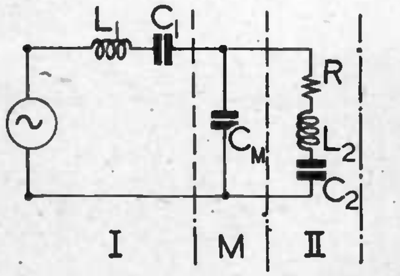


Fig. 3. Example of circuit to which the construction of Fig. 2 applies. Values are as follows:
$L_1 = L_2 = 10^{-5}$ Hy. $C_1 = C_2 = 2.5 \times 10^{-9}$ F. $C_M = 5 \times 10^{-9}$ F. $R = 10\ \Omega$

$$\mathbf{Y} = 1/\mathbf{Z} = 1/Ze^{\alpha} = (1/Z)(e^{-j\alpha}) = Ye^{-j\alpha} \quad (8)$$

Reverting now to the simple series circuit of Fig. 1 which is assumed to be supplied from a source of variable frequency and constant pressure. As the frequency ω varies, the reactance $X = (\omega L - 1/\omega C)$ will also vary and for the particular value ω_0 of the frequency such that $\omega_0 L = 1/\omega_0 C$ that is, when $\omega_0 = 1/\sqrt{LC}$, the total effective reactance becomes zero so that the impedance is then $\mathbf{Z} = R$. As already stated this represents a condition of resonance and is characterised by the fact that the current vector will then be in phase with the pressure vector.

In Fig. 2, a distance OM to scale, equal to the resistance R ohms of the circuit, is marked off along the horizontal or "real" axis, and along the vertical or "j" axis is marked off the reactance MP to the same scale in ohms and corresponding to the given frequency ω so that the vector OP will then represent the impedance vector $\mathbf{Z}$. As the frequency decreases, the value of $(\omega L - 1/\omega C)$ will decrease and eventually become zero in which case the extremity P of the impedance vector will come into coincidence with M. For a further decrease of the frequency the reactance will become negative so that the extremity P of the impedance vector will then move below the horizontal axis. For all values of the frequency, however, the extremity of the impedance vector will remain on the straight line AMB which is parallel to the "j" axis that is, at right angles to the axis of the resistance which is the horizontal or "real" axis. This impedance vector OP may be written in the form of equation (7), viz., $Ze^{j\alpha}$. The admittance vector Y of this circuit which corresponds to the impedance vector Z will then be obtained by writing as in equation (8).

$$\mathbf{Y} = 1/\mathbf{Z} = (1/Z)e^{-j\alpha} = Ye^{-j\alpha}$$

Now it is easily shown that the extremity of this admittance vector will move over a circuit OQN of centre C and which will pass through the origin O, the diameter ON of this circle being at right angles to the straight line AMB. On the right-hand side of Fig. 2 is shown the scale for the "j" axis of the admittance (that is, the susceptance) in reciprocal ohms $1/\Omega$ and the conductance is marked to the same scale along the horizontal axis. It is seen, therefore, that for any given impedance vector OP the corresponding admittance vector is OQ where the negative angle α which OQ makes with the horizontal axis is equal to the positive angle which the impedance vector makes with this axis. The circle OQN is said to be the "inverse" of the straight line AB with respect to the point O. This principle of "inversion" provides a relatively simple, but extremely powerful method for the solution of many circuit problems which otherwise could only be solved by means of complicated and difficult mathematical methods.

In order to show how these results may be applied to the case of two coupled circuits, the system shown in Fig. 3 will be taken as an example.

Considering first the part II of the coupled circuit of Fig. 3, the vertical impedance line is shown in Fig. 4 by AB and has been drawn at a distance of 10Ω to scale, from the ordinate axis. The corresponding admittance circle OQN will then have a diameter of $1/10 = 0.1\ \frac{1}{\Omega}$. Marked in on this circle will be seen a number of points and the circular frequency ω in mega-units to which each point refers is also marked in. That is to say, this circle gives the admittance for the portion II of the coupled circuit shown in Fig. 3 for all values of the supply frequency. For example, at a frequency of $\omega = 6.6 \times 10^6$ the effective reactance of the portion II of the coupled circuit will be: $(\omega L_2 - 1/\omega C_2) = (6.6 \times 10^6 \div 10^5) - (10^9 \div (6.6 \times 10^6 \times 2.5)) = 66 - 60.6 = 5.4$ ohms.

This reactance is marked off by MP so that OP is the vector of impedance for this frequency. The vector OQ is then drawn making a negative angle α with the horizontal axis equal to the positive angle α which the impedance vector OP makes with this axis. The vector OQ then gives the admittance $\mathbf{Y}_{II}$ of the portion II of the coupled circuit for this particular value of the supply frequency. At this same frequency the admittance of the coupling condenser C_M shown in Fig. 3 is $\mathbf{Y}_M = j\omega C_M = j \times 6.6 \times 10^6 \times 5 \times 10^{-9} = j \times 0.033\ 1/\Omega$. If this susceptance is added to the vector $V_{II} = OQ$ as is shown in Fig. 4 the resultant vector is the total admittance of the two parallel portions II and M of the coupled circuit of Fig.

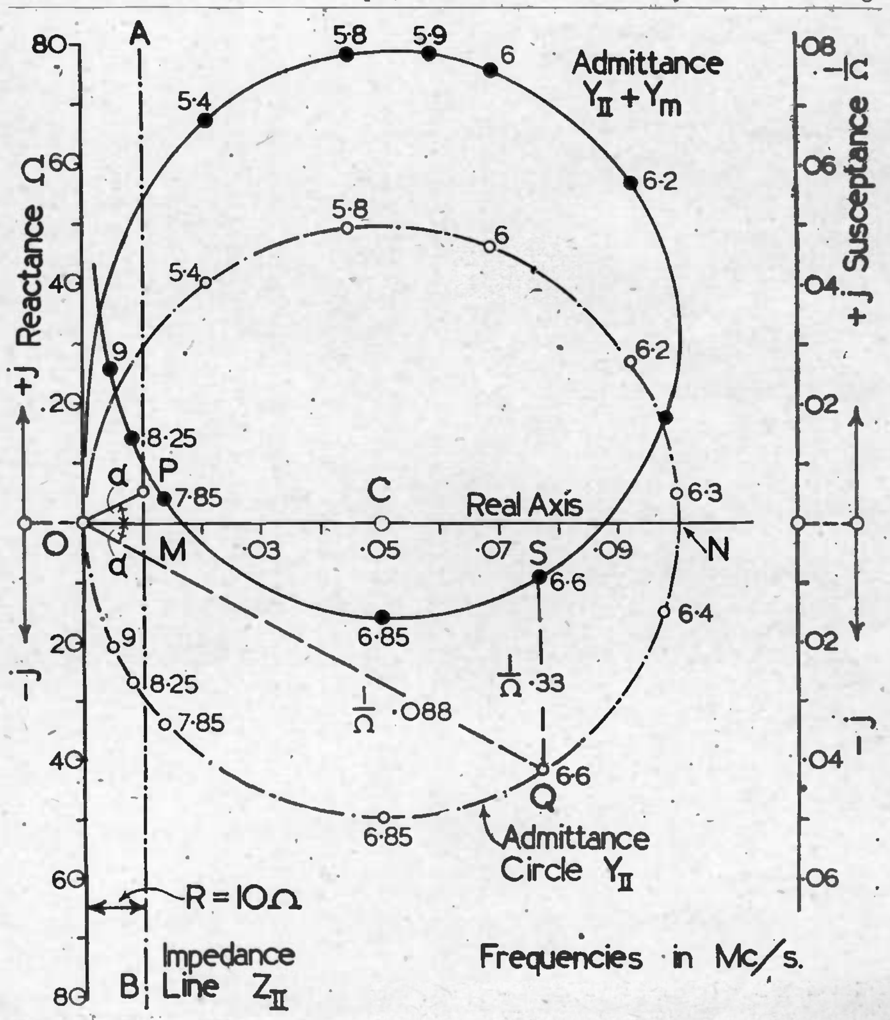


Fig. 4. Graphical construction for the circuit of Fig. 3.

3. That is to say, the point S in Fig. 4 is a point on the resultant admittance curve $\mathbf{Y}_{II} + \mathbf{Y}_M$ shown by the full-line loop in Fig. 4.

If this procedure be carried out for a number of different frequencies the full-line looped curve shown in Fig. 4 will be obtained for the total admittance of the two parallel portions II and M of the coupled circuit.

It is next necessary to convert the admittance looped curve $\mathbf{Y}_{II} + \mathbf{Y}_M$ of Fig. 4 into its equivalent impedance, that is to say, this admittance is to be inverted with respect to the origin O. This is easily done as is shown in Fig. 5 where the vector OV shows the impedance $\mathbf{Z}_{II+M}$ for the frequency $\omega = 8 \times 10^6$ and is obtained by inversion of the corresponding vector of the looped admittance curve of Fig. 4. Finally, to this impedance of the two parallel branches II and M must be added the impedance of the portion I of the coupled circuit of Fig. 3 that is, $\mathbf{Z}_1 = j(\omega L_1 - 1/\omega C_1)$. For the frequency $\omega = 8 \times 10^6$ for example,

$$\mathbf{Z}_1 = j\left(\frac{8 \times 10^6}{10^5} - \frac{10^9}{8 \times 2.5}\right) = j(80-50) = j30 \text{ ohms}$$

and if this reactance is added to the impedance vector OV as shown in Fig. 5 the resultant, as shown by the point W gives the input impedance of the coupled circuit. If this procedure is followed for a number of different frequencies ω the input impedance looped curve shown in Fig. 5 will be obtained, it having been assumed that the resistance of the branch II of the coupled circuit is $R = 10\Omega$. In Fig. 5 is also shown to the same scale, the input impedance looped curve for the case in which the resistance of the branch II of the coupled circuit is $R = 20\Omega$.

Summarising the procedure, the sequence of steps is as follows :—

(i). Draw the vertical reactance line AMB in Fig. 4 for the branch II of the coupled circuit at the horizontal distance $R\Omega$ from the origin O thus giving the impedance $\mathbf{Z}_{II}$ for any frequency.

(ii). Invert the impedance line AMB into the admittance circuit OQN thus obtaining the admittance $\mathbf{Y}_{II} = \dfrac{1}{\mathbf{Z}_{II}}$ for the branch II of the coupled circuit.

(iii). To this admittance circle add the admittance $\mathbf{Y}_M$ of the coupling condenser C_M, thus obtaining the looped curve of Fig. 4 for the total admittance $\mathbf{Y}_{II} + \mathbf{Y}_M$ of the branches II and M in parallel.

(iv). Invert the total admittance looped curve $\mathbf{Y}_{II} + \mathbf{Y}_M$ of Fig. 4 to obtain the corresponding impedance $\mathbf{Z}_{II+M} = \dfrac{1}{\mathbf{Y}_{II} + \mathbf{Y}_M}$ and to this add the impedance $\mathbf{Z}_1$ of the branch I thus obtaining the input impedance $\mathbf{Z}_i = \mathbf{Z}_1 + \mathbf{Z}_{II+M} = \mathbf{Z}_1 + 1/(\mathbf{Y}_M + 1/\mathbf{Z}_{II})$

The input impedance looped curve of Fig. 5 for $R = 10\Omega$, shows that the "j" component of this impedance vanishes for three different values of the supply frequency, viz., for $\omega = 6.34 \times 10^6$; 7.75×10^6; and 8.9×10^6 respectively, so that for each of these frequencies the input current will be in phase with the supply pressure and consequently, each of these frequencies will give a condition of resonance. Of these three frequencies the two extreme values, 6.3×10^6 : and 8.9×10^6 give an input impedance of 10Ω that is, equal to the resistance of branch II of the coupled circuit, whilst for the intermediate frequency of 7.75×10^6, the input impedance is 66.6Ω. It is also of interest to note that the frequency $\omega = 7.75 \times 10^6$ is the condition of current resonance for the two parallel branches II and M in Fig. 3. Thus, in the closed circuit formed by these two branches in parallel the two capacitances C_M and C_2 are in series so that the total effective capacitance is $C_R = \dfrac{C_M \times C_2}{C_M + C_2}$. The resonance frequency for this closed circuit when the resistance is relatively small, is then given by

$$\omega L_2 = 1/\omega C_R \text{ or } \omega = 1/\sqrt{(L_2 C_R)}$$

For the numerical values given in Fig. 3 :

$$C_R = \left(\frac{2.5 \times 5}{2.5 + 5}\right) . 10^{-9} = 1.67 \times 10^{-9}$$

and $L_2 = 10^{-5}$ henry, so that ω

$$= \frac{1}{\sqrt{10^{-5} \times 1.67 \times 10^{-9}}} = 7.75 \times 10^6$$

It is of interest to note that the general solution of the equations for the input impedance of the coupled circuit of Fig. 3 shows that, when $L_1 = L_2$ and $C_1 = C_2$ the frequencies for unity power factor will be given by the three solutions of the equation :

$$R^2\left\{\frac{1}{\omega C_M} - (\omega L_1 - 1/\omega C_1)\right\} + (\omega L_1 - 1/\omega C_R)(\omega L_1 - 1/\omega C_1)\left\{\frac{1}{\omega C_M} - (\omega L_1 - 1/\omega C_R)\right\} = 0 \quad \ldots \quad (9)$$

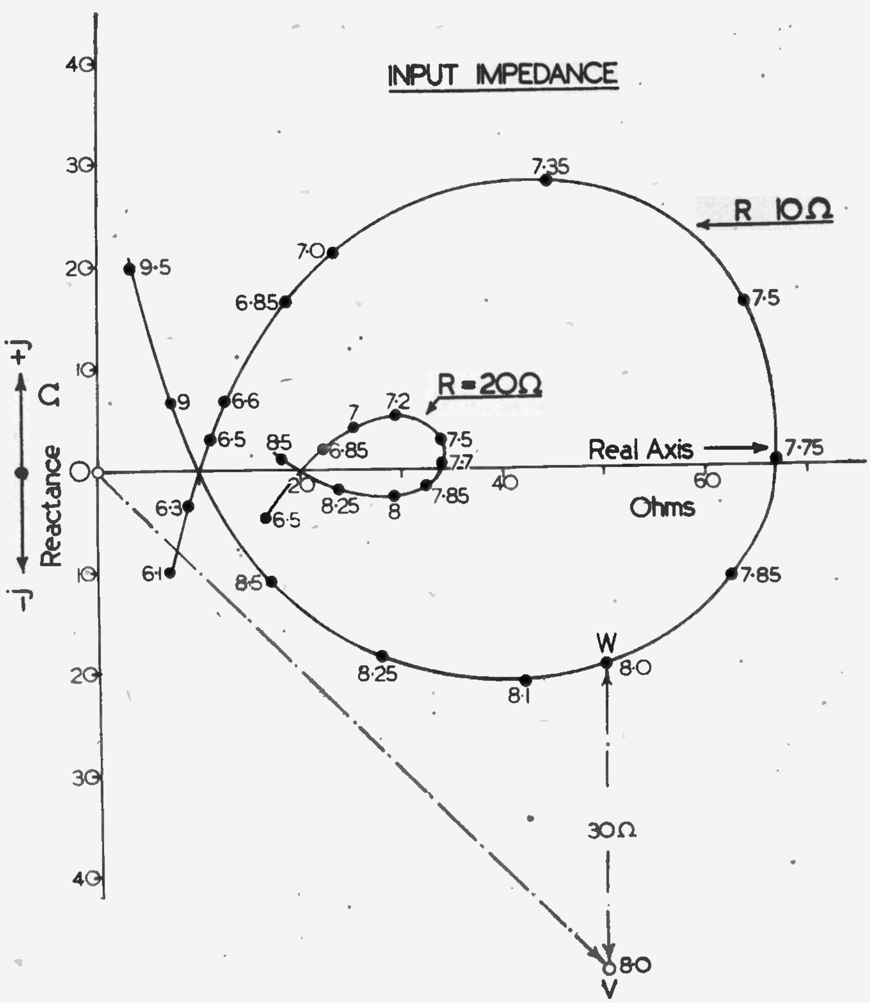


Fig. 5. Imput Impedance diagram for two values of R.

and consequently, each of these frequencies will correspond to a condition of resonance. Thus for the case in which $R = 20\Omega$; $C_M = 5 \times 10^{-9}$ F. $C_1 = 2.5 \times 10^{-9}$F; $L_1 = 10^{-5}$H. the capacitance $C_R = (C_1 \times C_M) \div (C_1 + C_M) = 1.67 \times 10^{-9}$F and the frequencies for *pressure* resonance will be $\omega = 6.75 \times 10^6$; 8.35×10^6 respectively. The frequency for *current* resonance will be $\omega = 7.75 \times 10^6$ (*see* the input impedance loop for $R = 20\Omega$ in Fig. 5). When $R = 0$ the equation (9) reduces to

$$\left(\omega L_1 - \frac{1}{\omega C_R}\right)\left(\omega L_1 - \frac{1}{\omega C_1}\right)\left\{\frac{1}{\omega C_M} - \left(\omega L_1 - \frac{1}{\omega C_R}\right)\right\} = 0 \quad \dots \quad \dots \quad (10)$$

and the solutions are then :
Pressure resonance

$$\begin{cases} \omega = 1/\sqrt{L_1C_1} = 6.34 \times 10^6 \\ \omega = \sqrt{\dfrac{(C_M + 2C_1)}{L_1C_1C_M}} = 8.9 \times 10^6 \end{cases}$$

Current resonance

$$\omega = 1/\sqrt{(L_1C_R)} = 7.75 \times 10^{-6}$$

If the coupling coefficient of the circuit of Fig. 3 is defined by

$$k = \sqrt{\frac{C_1C_2}{(C_1 + C_M)(C_2 + C_M)}}$$

then for $C_1 =$

$$C_2,\ k = \frac{C_1}{C_1 + C_M}.$$

If ω_0 denotes the circular frequency for *current* resonance, that is

$$\omega_0 = 1/\sqrt{(L_1C_R} = \sqrt{\frac{C_M + C_1}{L_1C_1C_M}}$$

then the *pressure* resonance frequencies will be given by

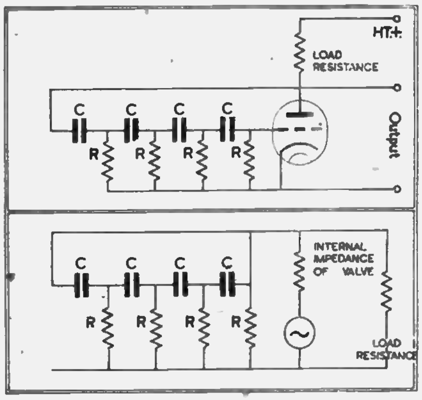
$$\left.\begin{matrix}\omega_1 \\ \omega_2\end{matrix}\right\} = \omega_0\sqrt{1 \pm k}$$

A Simple R.C. Oscillator

by W. BACON, B.Sc.,

THE majority of valve oscillators incorporate some form of inductance capacity tuning. There are, however, a number of circuits in which inductance is dispensed with and the frequency of the oscillation produced determined entirely by means of resistance-capacity networks.

Such an arrangement has the advantage of improved stability since one component likely to cause considerable variations, the inductance, has been eliminated. Very low frequencies, also, are more easily produced. Frequency change for a given condenser swing is in addition generally greater, since in the majority of cases the frequency of these oscillators depends directly on the capacity instead of on the square root of the capacity.



Figs. 1 and 2.

A classification of the principal circuits of this type is made below, a simple one which is not so well known being described in greater detail.

(1) The multivibrator is perhaps the most familiar. It consists in essence of a two-stage resistance capacity amplifier, the output of which is coupled to the input. An almost square wave form, rich in high harmonics, is produced. The frequency generated may be synchronised with a multiple or submultiple of an external frequency.

(2) Positive feedback sufficient to cause oscillations is applied to an amplifier in the normal way. Negative feedback is also applied through a resistance-capacity circuit arranged to give zero negative feedback at one frequency only. Oscillations then take place at this frequency. (*See* H. H. Scott, *Proc. I.R.E.*, Feb., 1938).

(3) An amplifier with an uneven number of stages is provided with phase advancing interstage couplings. At some frequency this will result in output and input being in phase. If amplification is sufficient for output to be greater than input, then if these two are coupled together an oscillation of this frequency will be set up.

(4) An amplifier with an even number of stages is provided with alternate phase advancing and phase retarding interstage couplings. As in the case of (3), with output coupled to input and sufficient amplification there will be some frequency at which output and input are in phase and at which oscillation takes place. An example is the oscillator made by Messrs. Muirhead and Co.

A One-Valve Circuit

The circuits described above use two or more valves. The arrangement of Fig. (1), uses only one. A description of it may therefore be of interest.

The grid of the valve, which should be a triode of fairly low impedance, is connected to the anode by means of a four-stage resistance capacity network.

For oscillation to take place two conditions must be satisfied.

(1) A signal applied to the grid must reappear after travelling round the network with at least its original magnitude.

(2) The output from the network must be in phase with the input to the grid.

The frequency of oscillation is determined by condition (2) and will be such that the change of phase through the network is 180 degrees. A signal at the grid will then be changed through a further 180 degrees when it appears at the anode, which together with the change through the network will cause it to reappear at the grid in phase.

If the limbs of the network are as shown, then there will be roughly 45 degrees phase shift in each stage, and the frequency of oscillation will be given approximately by

$$1/2\pi f.C = R, \text{ or } f = 1/2\pi CR.$$

With this condition it will be seen that each stage at least halves the voltage, *i.e.*, the total attenuation of the network is 1 to 16. The amplification of the valve must thus be sufficiently great for the voltage developed across the load to be more than 16 times the input signal to the grid.

It will be seen from Fig. 2 that it is essential for R to be large in comparison with either the load resistance or the internal impedance of the valve since the feedback circuit will then have the minimum loading effect on the valve.

An interesting application is to the case of an existing amplifier which is required to be provided with self-generated tone. Provided the first stage of the amplifier is resistance coupled, an oscillator constructed on these lines may simply be plugged in in place of the first valve. A convenient and compact tone generator is thus provided.

Can Sound-on-Film Supplant the Record?

by R. HOWARD CRICKS, F.R.P.S.*

EVER since the commercialisation of the sound film in the kinema over twelve years ago, endeavours have been made to adapt its principles to other applications. At frequent intervals we are assured that the gramophone disk is doomed, and that every drawing-room will contain a film phonograph (to use the recognised American term).

One argument used by opponents of the disk is that it has for many years been supplanted in the kinema by the sound film, except for the "non-sync." (those records played during intervals, and not synchronised with film). This fact, however, has little bearing upon the general argument, for the principal reason for the abolition of the disk as a carrier of sound for the film was the risk of synchronism between film and disk being lost, often with humorous results. Another factor was that even the 16 in. 33⅓ r.p.m. disks used gave a running time of less than ten minutes, so necessitating frequent change-overs to maintain continuity.

Quality of sound, be it noted, did not enter into the question. Until comparatively recently, it has been admitted that the disk was capable of a higher quality of sound than the sound track on the film.

The commercial gramophone record has a great advantage over any other system of sound storage: that it is made by a mass-production process in which the actual labour time per disk has been reduced to about one minute. As far as one can see, such a development of mass-production methods is an utter impossibility in regard to the sound film.

It is virtually certain, too, that a film phonograph can never be made as inexpensively as a disk reproducer. Therefore, so far as mass sales are concerned, the disk is likely to continue to hold its own for many years to come.

On the other hand, the actual manufacturing cost of the final pressing is not necessarily so important a factor as it may seem in the nett cost to the consumer. There are numerous factors which help to swell the price of disks—not excluding manufacturers' profits.

Taking the better class of record, one might say that the cost per minute of running time averages from 1s. to 2s. If a narrow-gauge film could be produced at say ½d. per foot, carrying four tracks and running at a speed of say 15 ft. per minute (one-sixth the speed of 35 mm. sound film) we should arrive at a cost of about 3d. per minute. According as to whether the process of arriving at the retail price is additive or multiplicative, so this manufacturing cost may or may not prove a deterrent to further progress.

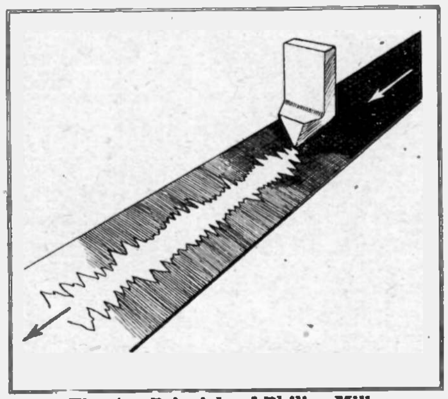


Fig. 1. Principle of Philips-Miller Mechanographic Recording System.

Type of Film Recording

There are certain undeniable advantages to be gained by the substitution of film for the disk. As an indication of what can be done, let us first consider a few of the suggestions that have been made in recent years.

One of the most obvious is for recording programmes for subsequent radio transmission. As far as the B.B.C. is concerned, magnetic recording has been generally preferred; but films have been widely used by Continental stations.

In a beautifully fitted studio in Aldwych, a large proportion of the Luxemburg programmes were recorded for shipment to the Continent and transmission over the air back to British listeners. The system employed was that developed by the firm of Philips, and it was the Philips-Miller mechanographic system that was used in Aldwych and in a number of Continental studios.

In this system, the recording is done not by photographic means, but by means of a tiny chisel which vibrates vertically and cuts into a very thin opaque layer upon a moving film. The chisel has an obtuse-angled V point, and thus the deeper the cut the wider becomes the clear area of the track. (Fig. 1). Such a track can be either reproduced from the original, or can be printed by photographic means.

Another mechanical recording system was demonstrated in London in 1933, by a French inventor, René Nublat. Known as "Le Ruban Sonore," the principle involved was that a diamond point vibrated by the sound impulses actually cut the film in two halves, the jagged edge of the cut forming the recording. A recording thus produced was naturally rather fragile, and an ingenious system was used for duplicating; by means of an anamorphotic lens system the tiny modulations (of the order of 0.1 mm.) were enlarged 10 diameters in the direction of the modulation only, and printed upon an ordinary positive film.

Multiple-Track Films

Turning to more orthodox systems, several types of apparatus have been developed in which a number of tracks —four or six—were recorded side by side on film, and after one track had been played through, the direction of travel of the film was reversed and the next track reproduced.

Such a system was developed just before the war for the purpose of recording complete books for the use of the blind. The reproducing apparatus was so simple that a blind person could easily manipulate it, and a complete book could be recorded on a couple of rolls of film.

Advantages of Film Recording

Examination of the above-mentioned applications of the sound film demonstrates that the principal advantage enjoyed by the film over the disk is its ability to play without interruption for a considerable length of time. At the existing standard running speed of sound film, 1,000 ft. of 35mm. film or 400 ft. of 16 mm. lasts for approximately 11 minutes; if such a film were to carry four tracks, we could have three-quarters of an hour of music with only momentary interruptions while the tracks were changed over.

There is in fact no technical difficulty in using an endless film which will thus repeat its message continuously until the machine is switched off. This is a possible application which should be carefully hidden from publicity experts —a machine which would continuously reiterate the virtues of somebody's soap or pickles is an appalling thought.

However, outside the advertising field there are few applications where this advantage *by itself* would be of sufficient importance to justify the considerably greater cost, as compared with disks. Broadcasting is admittedly one such application. Dance organisers at present using disks might find a longer playing time advantageous. Cafés and bars might provide another market, although the continual stream of music poured forth on the radio meets the demands for a non-stop performance practically as well as a film.

Considering only this factor of longer playing time, it is difficult to see any possible application which would make the marketing of such equipment commercially practicable.

Lessened Background Noise

However, there is another factor to be considered: the superior quality of reproduction now obtainable, under

* Hon. Sec. British Kinematograph Society.

favourable conditions, from film, and of the several factors involved, easily the first is the virtual absence of background noise.

The fundamental failing of the disk is the fact that reproduction of the full frequency range recorded involves the production of atrocious scratch, which for many people entirely mars any enjoyment they may get from the improved frequency bandwidth. Some listeners with a musical ear deliberately prefer a "mellow" reproduction of records caused by the introduction of an effective scratch filter.

We must not regard this ground noise as a defect altogether beyond improvement; nevertheless, it is safe to assume that a scratch-free record, whatever might be achieved experimentally, is never likely to be commercially practicable, because of its very short life under varied playing conditions. The scratch is primarily due to abrasives deliberately introduced into the material of the disk, with the object of causing the needle rather than the groove to wear; only if the needle point and its angle of contact were very closely standardised could the abrasive quality of the disk be reduced without leading to excessive wear of the groove, and consequent distortion of sound.

Increased Volume Range

Contrast with this the very low ground noise (and consequently increased frequency and volume range) obtainable with film. Some interesting data have been presented recently by the Bell Telephone Laboratories in connexion with stereophonic recording. At the World's Fairs at San Francisco and New York, over half-a-million people were given physiological tests, which showed that for 95 people out of 100, the lowest audible sound is 27 db. above .0002 dyne/cm^2 at 100 c.p.s., 2 db. at 1,000 c.p.s., -2 db. a 2,000, and + 8 db. at 10,000. For 50 per cent. of people, the lowest levels of audibility are from 15 to 20 db. above these figures. The noise level of a quiet kinema has been stated at 25 db., but with the audience present 42 db. The threshold of pain occurs at 120 db.[1]

Hence the requirement laid down for stereophonic sound was a volume range of 80 db. above ground noise. Actually, the limit of volume range in a track 80 mils. in width is of the order of 50 db.; the additional 30 db., as already explained in this journal is secured by the use of an auxiliary control track, which automatically reduces the amplifier gain to suit the volume of the original recording.

Noise Reduction

A similar effect can be achieved, without the complications of a control track, by means of so-called noiseless recording. Under optimum conditions, we can secure a range of 80 db. above ground noise; in practice, allowing for film wear, the limit might be fixed at 60 to 70 db. This still represents a very conisderable improvement over the disk.

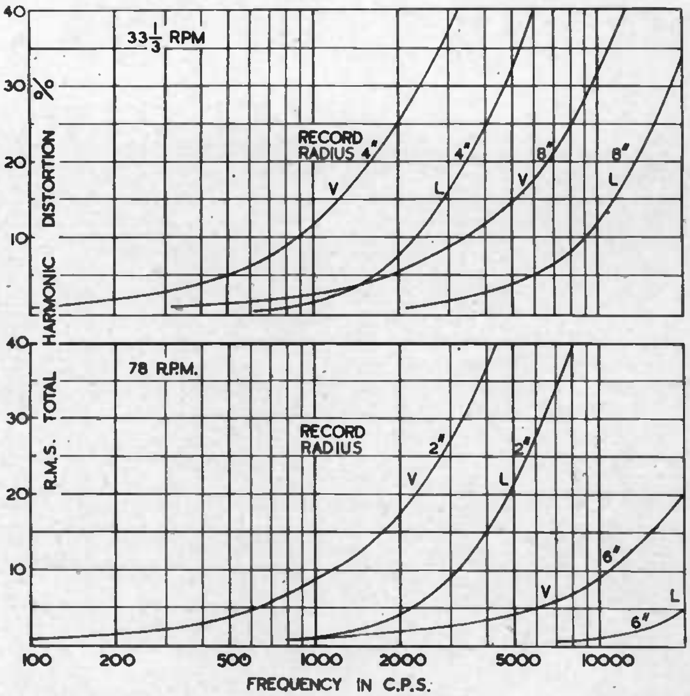


Fig. 2. Harmonic Distortion of Disc Recordings:
(From Jour. S.M.P.E.)

Briefly, the principle of noise reduction is that the print, which is the principal source of ground noise, is in quiet passages rendered almost opaque, so that dust and small scratches—the common cause of noise—are not likely to make themselves evident.

In either density or area recording, an increased light transmission in the positive is associated with an increase in volume level, which thus masks any ground noise produced. The principal difficulty is that if the noise reduction system operates too rapidly, one can hear the "breathing" effect from the speakers, while if it operates too slowly, the first few cycles of any sudden sound have their peaks chopped off.[2]

Volume Expansion

It is quite possible to combine volume contraction in recording and volume expansion in reproduction with a noise-reduction system. Thus in recording, a range of perhaps 90 db. can be compressed into 60 db., using the same control currents as for the noise reduction system; in reproduction, the expansion circuit is operated by the variation of mean current from the photo-cell, due to the varying mean transparency of the track. Volume contraction and expansion form, of course, an important part of all systems of stereophony.[3]

It is inherently desirable that expansion in reproduction should be associated with contraction in recording. However, some recordists have found the use of automatic contraction helpful, while at least one leading make of sound reproduction equipment embodies controllable volume expansion. The normal method of operating such systems is, of course, by means of a variable-mu valve actuated by a portion of the signal current, rectified and smoothed.[4]

Audibility of Ground Noise

The question of frequency response, is, of course, intimately associated with ground noise. In the case of the disk, the frequency characteristic necessary in reproduction to compensate for the characteristic curve of the disk tends to concentrate random ground noise into a frequency band near the top end of the scale; hence the reproduction of the full frequency band necessarily entails, as already mentioned, an increase in ground noise. In the case of film, however, the reproducer characteristic may be flat to within a few db. (corrections being necessary chiefly to suit the acoustic conditions of reproduction) hence ground noise remains more generally distributed throughout the spectrum.

Thus ground noise is less obtrusive with the film, and furthermore provides no limitation to frequency range and never attains the prominence inevitable with a good disk reproduction.

Harmonic Distortion

Most of the foregoing developments in sound film technique contribute to the reduction of harmonic distortion. The various causes of such distortion in the film are discussed hereunder.

It may be of interest first to study the remarkable curves of Fig. 2, produced some years ago by Harvard University. They suggest that pure reproduction of the higher frequencies cannot be expected of any type of disk.[5]

Running Speed and Frequency Range

It would obviously be of value for most applications and for several

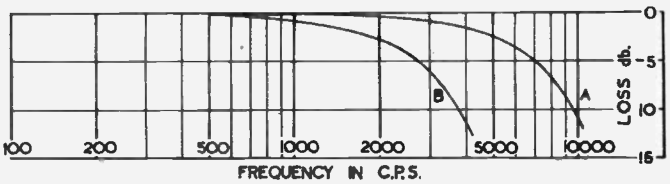


Fig. 3. Sound-track Losses due to Light Scatter: (*a*) 35 mm. Positive Emulsion, (*b*) same emulsion run at 16 mm. speed.

(*From Jour. S.M.P.E.*)

reasons (notably that of cost, and of ease of handling) if the running speed of sound film could be substantially decreased. However, the reproducible frequency range is naturally a function of running speed, although other factors come into play. We may consider briefly to what extent the running speed could be satisfactorily reduced below the existing standard of 90 ft. per minute for 35 mm., and 36 ft. for 16 mm.

The factors limiting frequency range (excluding electrical losses, which can be always compensated) may be briefly listed as follows:—

Recording

1. Finite slit width in recorder.
2. Light diffusion in negative.
3. Negative image spread.
4. Negative emulsion grain.

Duplication

5. Light diffusion in printing.
6. Slippage and lack of contact in printer.
7. Positive image spread.
8. Positive emulsion grain.

Reproduction

9. Finite slit width in reproducer.
10. Masking effect of dirt and oil on positive.
11. Flutter and other mechanical faults of reproducer.

In regard to (1) and (9), customary theoretical figures of slit width are in recording 0.3 mil., and in reproduction from .5 to 1 mil. The half-wave-length of a 10,000-cycle note at the standard speed of 18 in. per second is 0.9 mil.; thus, while in recording it would be possible to include considerably higher frequencies, 10,000 cycles is beyond the limit of some reproducers.

However, it would be perfectly possible to use a smaller slit in reproduction, provided an exciter lamp of higher wattage were also used.

Image Spread and Diffusion

Under the heading of image spread we may include photographic phenomena such as the liability of emulsion grains to "catch" an exposure given to adjacent grains, and also the tendency for developability of grains to spread to adjacent grains. Diffusion refers to optical effects, notably to halation, or the reflection of light from the surface or back of the film base to the rear of the emulsion.

Image spread is chiefly detrimental in variable-area recording, when it is also known as rectification, for it is similar in its effects to other forms of rectification of sound signals. It causes the well-known "shushing" of sibilants, and too-explosive consonants. It is fortunate that this phenomenon works in opposite directions in negative and positive, and consequently it is only a matter of maintaining correct negative and positive track densities to secure complete cancellation. The falling off of the higher frequencies, as shown in Fig. 3, cannot, however, be completely compensated.[6]

Light diffusion both in recording and printing has been largely overcome by the use of ultra-violet light in both operations. The photographic emulsion is virtually opaque to the shorter wavelengths, hence, as illustrated in Fig. 4, a surface image is produced, and little or no diffusion takes place within the emulsion, while reflections from the base are also eliminated.

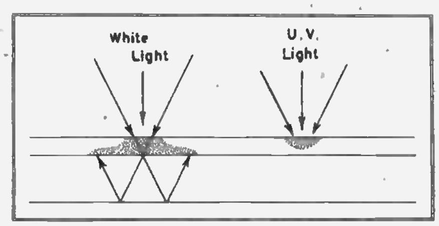


Fig. 4. How Light Scatter is avoided by the use of U.V. Light.

Image Grain

Emulsion grain is a more complex problem. Since the average grain size of photographic emulsions ranges from 0.2 to 2.5 μ, it might be thought that granularity could have no appreciable effect upon resolution. Difficulty arises, however, from the clumping together of grains in development, while if the grain size is reduced below a certain figure, in addition to loss of photographic speed diffraction effects may be produced by the granular pattern, leading to undesirable colouration of the image. The latter point might, however, be unimportant in the case of a film intended solely for carrying a sound track, and not having an associated picture.

However, the Ilford "High Resolution" emulsion has a resolving power as high as 400 lines per mm.[7] If emulsion grain represented the sole restriction of frequency range, we could reproduce up to 10,000 c.p.s. at a film speed of only 1 in. per second!

Special fine-grain emulsions have recently been introduced in the United States for sound recording and printing. The point has apparently been reached where the question of image colour hinders further progress.[8]

Mechanical Losses

The purely mechanical factors of slippage and lack of contact between the two films in printing have hitherto proved in practice one of the most serious limitations to high-frequency recording. Because these defects give rise to distortion of the higher frequencies, it has become customary in recording to insert a low-pass filter, cutting at about 7,000 to 8,000 c.p.s.

However, special non-slip printers have now been perfected, and the use of such machines may be regarded as a necessary preliminary to any reduction of running speed.

Mechanical difficulties in the reproducer must not be overlooked. Not the least of such difficulties is known as flutter.

While variations of film speed having a low frequency give rise to audible pitch changes, and are known as "wow," pitch variations of higher frequency, known as "flutter," have rather different effects.[9] The general cause is the film jerking off each sprocket tooth in turn, due to slight discrepancies in pitch. The result is illustrated in Fig. 5 (of course much exaggerated); this shows a sinusoidal wave-form of moderately high frequency, whose original form is shown in the dotted curve, distorted at the point *A* where the film has disengaged from a sprocket tooth and finds its velocity momentarily decreased until at the point *B* it is in full engagement with the next tooth. The temporary change in frequency gives rise to dissonant side-bands producing harsh sounds, most marked in the middle frequencies, and hence most noticeable in speech, which may be rendered unintelligible.

A somewhat similar aural effect can be obtained by the fact that when film

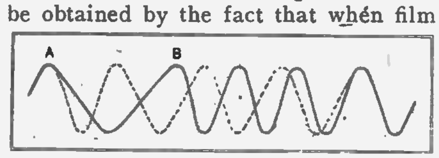


Fig. 5. The Effect of Flutter upon Frequency.

is scanned on a drum, it tends to assume a polygonal path around the drum, due to its greater flexibility across the perforations. The result is a momentary loss of focus of the beam.[10] (Fig. 6 (p. 726).

These considerations suggest that if film speed is to be appreciably reduced, it is essential that perforations be dispensed with. So long as synchronism with a picture is not necessary there appears to be no inherent difficulty in devising driving mechanism which will maintain a sufficiently constant speed and—an important point—will isolate the scanning point from the take-off and take-up reels. In the Philips-Miller system the film is driven by rubber-covered drums, whose drive incorporates a device giving a slightly variable speed, to maintain the loops constant.[11]

(*Concluded on p. 726.*)

Frequency Modulation

Part VI.—Frequency Modulated Reception

by K. R. STURLEY, Ph.D., A.M.I.E.E.

THE chief difference between frequency and amplitude modulated reception lies in the method of making intelligible the audio frequency signal conveyed in the modulation. The principle underlying methods of detecting frequency modulation is the conversion of the frequency into an amplitude change of carrier, which is then applied to an amplitude detector such as a diode. The conversion must be accomplished in a linear manner, *i.e.,* the amplitude change is directly proportional to the frequency change, and also efficiently so that the resultant amplitude modulation is high. Many of the advantages of frequency modulation disappear if the frequency-amplitude conversion efficiency is low. One of the earliest methods[1] was to apply the frequency modulated wave to a circuit off tuned from the carrier unmodulated value. For example, a parallel tuned circuit, connected in the anode of a tetrode or pentode valve, produces an output voltage-frequency curve as shown in Fig. 1, when a constant amplitude variable frequency voltage is applied between grid and cathode. If this circuit is detuned (above or below) from the carrier unmodulated frequency, frequency modulation results in an output voltage of amplitude proportional to the frequency deviation of carrier. It will, however, only be linearly proportional if the carrier frequency deviation is confined to the linear part AB of the curve. By applying the output voltage

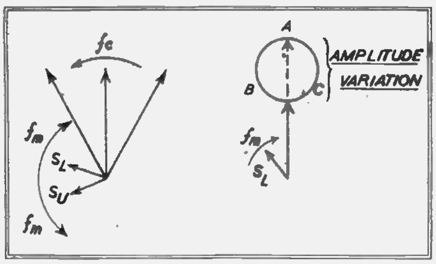


Fig. 2. Frequency Amplitude conversion by suppression of one sideband.

to an amplitude detector, such as a diode, an audio frequency signal, corresponding to the original signal modulating the transmission, is obtained. Although variation of frequency as well as amplitude of the output voltage is occurring it is only the amplitude change which is detected by the diode, for the latter cannot differentiate against change of frequency. It is clear that this method of detection is very inefficient, partly because it is dependent on the slope of the output voltage-frequency curve, which for practical cir-

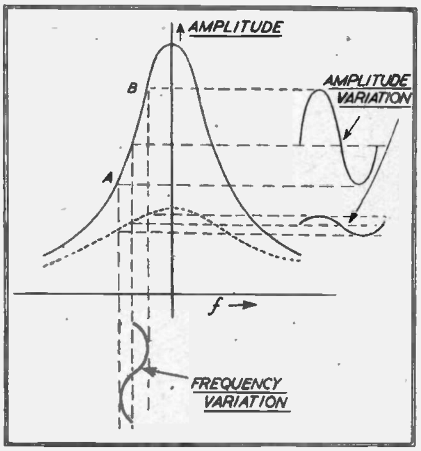


Fig. 1. Frequency Amplitude conversion of a detuned circuit.

cuits is not very high, but mainly because the tuned circuit is operated in the detuned condition where overall amplification is low. An amplitude modulated signal is amplified at the flat top portion of the output curve where amplification is maximum. Furthermore full advantage cannot be taken of increased deviation of carrier for the circuit must be damped (*see* the dotted curve in Fig. 1) to increase the linear part of the curve and conversion efficiency is thus reduced.

A second method of detection suppresses one set of sidebands, and the principles involved are best understood by taking the carrier and sideband analysis set out in the first article. There we showed that a frequency modulated wave was represented by a carrier frequency (equal to the central unmodulated value) and pairs of sidebands spaced ± fm, ± 2fm, etc., from the carrier, the odd numbered sideband pairs combining to give a resultant at 90° to the carrier and the even ones having a resultant in line. The addition of the first pair of sidebands to the carrier gives the frequency (and partially amplitude) modulated carrier of Fig. 2, and taking this as a basis we see that suppression of one of the sidebands results in the mainly amplitude modulated carrier, whose locus of operation is the circle ABC. The amplitude modulation is not directly proportional to the original frequency modulation even when all sidebands (instead of one pair) are considered and detection of the amplitude variation by a diode produces a distorted audio frequency output containing mainly second harmonic. The suppression of one half of the sidebands is clearly inefficient since the transmitted energy in these is not used.

Both disadvantages may be overcome by applying the frequency modulated wave to two channels,[5] one containing a filter suppressing the upper set of sidebands and the other a filter suppressing the lower set. Fig. 3 illustrates the schematic diagram. The diode detector outputs are connected in opposition so that an unmodulated carrier produces zero volts across AC. The amplitude variations of the carrier at the outputs of the two filters are in phase opposition (the upper sideband in Fig. 2 is subtracting from the carrier when the lower is adding) so that modulation causing the volts to rise across AB reduces the volts across BC and there is a double increase in the audio frequency output voltage change across AC. This phase opposition also leads to cancellation of the second harmonic distortion in the amplitude variation, and the resultant voltage across AC is therefore a reproduction of the audio frequency signal modulating the transmitter.

A third (the most popular) method employs a frequency discriminator similar to the one used for automatic frequency correction of the oscillator in amplitude modulated superheterodyne receivers. In an A.F.C. system this discriminator translates I.F. carrier frequency error into a D.C. bias voltage, which is (for example) increasingly negative for frequencies below, zero at the correct carrier setting and positive

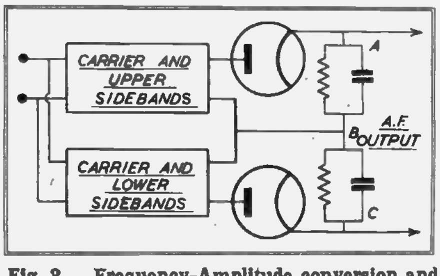


Fig. 3. Frequency-Amplitude conversion and detection by means of sideband suppression using both sidebands.

for frequencies above. If, therefore, we apply a sinusoidal frequency modulated carrier to such a circuit, the actual D.C. bias voltage will remain constant, provided the unmodulated carrier frequency is located correctly, but there will be a sinusoidal A.C. component in the output, which will correspond in amplitude to the original frequency modulation. There are two types of discriminator, one known as an amplitude and the other as a phase discriminator and both can be equally effective as frequency-amplitude converters.

The first type in essence consists of a valve (to the grid of which is applied the frequency modulated signal) having two series connected anode circuits, one tuned above and the other below the unmodulated carrier or central frequency by equal amounts. The outputs from the two circuits are connected to diode detectors (Fig. 4a), the D.C. load resistances of which are connected to give opposing voltages. Thus the total D.C. voltage across A.C. is zero when the input voltage has a frequency equal to the central frequency midway between the resonant points of circuits 1 and 2. When the input frequency is changed to bring it closer to the resonant point of 1 the D.C. voltage across AB rises and that from 2 across BC falls, *i.e.,* there is a double increase in volts across AC similar to that realised by the second method. The action of the discriminator is illustrated in Fig. 4b, which shows the frequency response curves for circuits 1 and 2; since the detected voltages are in opposition the active voltage is represented by the difference between the two curves, and this is indicated by the dotted curve. By applying a frequency modulated wave (unmodulated carrier equal to the central frequency 4.5 Mc/s) an amplitude modulated output is obtained. The principle of operation is similar to that for the first method except that the carrier deviation is accommodated on two tuned circuits, with consequent increase in efficiency and frequency range over which the frequency-amplitude conversion is linear. The frequency response curves in Fig. 4b are obtained from the generalised curve of a single tuned circuit due to Beatty,[2] who shows that the ratio of maximum response at the resonant frequency f_r to that at any off-tune frequency Δf is given by

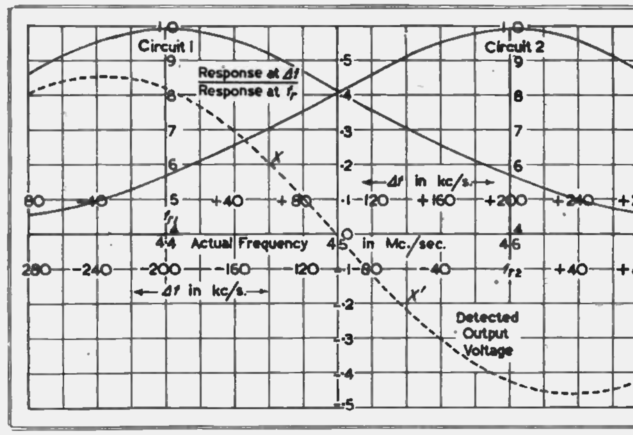


Fig. 4b. Frequency response curves and detected output voltage for the amplitude discriminator.

$$R_{\Delta f} = \frac{\text{Response at } f_r + \Delta f}{\text{Response at } f_r}$$

$$= \frac{1}{\sqrt{1 + \left(\frac{Q 2\Delta f}{f_r}\right)^2}} \quad \ldots \quad \ldots \quad (1)$$

where Q = the magnification of the circuit. The horizontal frequency scale is marked in Δf, the off-tune frequency from the resonant frequencies of 1 and 2 (4.4 and 4.6 Mc/s) and in actual frequencies. For maximum conversion efficiency the slope XOX′ of the dotted curve, and hence the slope of the response curves of 1 and 2, must be as steep as possible. Now the slope of the response curve of either circuit is obtained by differentiating expression 1 with respect to Δf.

$$\text{Slope} = \frac{dR_{\Delta f}}{d(\Delta f)} = \frac{\frac{1}{2}\,\frac{4Q^2}{f_r^2}\,\Delta f}{\left[1 + \left(\frac{Q 2\Delta f}{f_r}\right)^2\right]^{3/2}}$$

$$= \frac{4Q^2\Delta f}{f_r^2\left[1 + \left(\frac{Q 2\Delta f}{f_r}\right)^2\right]} \quad \ldots \quad (2)$$

and the value of Δf for maximum slope is obtained by differentiating (2) with respect to Δf and equating to 0, which gives

$$1 + \left(\frac{Q 2\Delta f}{f_r}\right)^2 - 2\left(\frac{Q 2\Delta f}{f_r}\right)^2 = 0$$

$$\text{or } \frac{Q 2\Delta f}{f_r} = \pm 0.707 \quad \ldots \quad \ldots \quad (3\,a)$$

$$\Delta f = \pm \frac{0.3535 f_r}{Q} \quad \ldots \quad (3\,b)$$

Hence for maximum conversion efficiency we must select Q to satisfy expression 3a when Δf = 100 kc/s (half the distance between the resonant frequencies of circuits 1 and 2) so making the central frequency 4.5 Mc/s.

$$\text{For circuit 1 } Q_1 = \frac{0.3535 \times 4.4}{0.1} = 15.55$$

$$\text{For circuit 2 } Q_2 \quad \frac{0.3535 \times 4.6}{0.1} = 16.25$$

In practice the result is satisfactory if $Q_1 = Q_2 = 16$. The composite dotted curve in Fig. 4b shows a turn over effect at top and bottom and this causes flattening of the amplitude of the audio frequency output wave with consequent production of odd harmonics (3rd, 5th, etc.) when the carrier is fully frequency modulated ± 100 kc/s. Under these conditions there is approximately 6.5 per cent. third harmonic, but if the maximum deviation of the carrier is limited to ± 75 kc/s, third harmonic does not exceed 3.5 per cent. Should it be necessary to reduce distortion for ± 100 kc/s deviation, the separation of the resonant frequencies of 1 and 2 may be increased to (for example) 400 kc/s instead of 200 kc/s. At the same time Q must be halved (*see* expression 3a for which Δf is now 200 kc/s) and the curves in Fig. 4b are applicable provided the horizontal off-tune frequency scale is multiplied by 2 and the actual frequency scale amended accordingly. For ± 100 kc/s frequency deviation, distortion is reduced from its original 6.5 per cent. to 1.5 per cent. third harmonic, but this improvement is gained at the expense of frequency-amplitude conversion efficiency which has been halved. Conversion efficiency is best expressed in terms of peak output voltage per 1 kc/s frequency change from the central value (4.5 Mc/s) per 1 volt peak input at the grid of the discriminator valve. It is obtained by multiplying expression (2) by 2 g_m the factor 2 is necessary since expression 2 gives the slope of the response of one circuit alone and the composite dotted curve, which is the difference between the slopes of 1 and 2, is twice that of either, where R_D is the resonant impedance of either circuit in Fig. 4a, including damping from its diode and diode load resistance R_3, *i.e.,* each circuit is damped by the resistance R_3 (C_3 is a coupling condenser (.0001 μF) of low

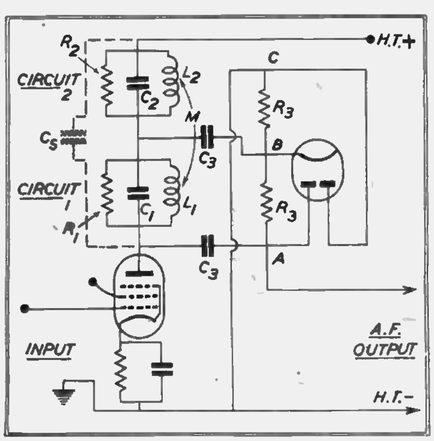


Fig. 4a. Amplitude discriminator as a frequency amplitude converter.

reactance) in parallel with $R_3/2$, that due to diode conduction current, giving a total damping resistance of $R_3/3$. Since the overall Q (including damping) of the tuned circuits is fixed at 16, the maximum value of R_D for a minimum tuning capacitance of 50 $\mu\mu$F is

$$R_D = \frac{Q}{\omega C} = \frac{16 \times 10^{12}}{6.28 \times 4.5 \times 10^6 \times 50}$$
$$= 11{,}300\ \Omega.$$

and $g_m R_D = 22.6$
if $g_m = 2$ mA/volt.
Hence conversion efficiency is

$$\frac{g_m R_D 8 Q^2 \Delta f}{f_r^2 \left[1 + \left(\frac{Q^2 \Delta f}{f_r}\right)^2\right]^{3/2}}$$

$$= \frac{22.6 \times 8 \times 256 \times 100}{(4.5 \times 10^6)^2 (1.5)^{3/2}}$$

= 0.1242 peak volts per kc/s per 1 volt peak input.

To obtain actual audio frequency output peak voltage it is necessary to multiply the above by the detection efficiency of the diodes, usually about 85 per cent., which would make the sensitivity 0.1055 volts per kc/s per volt input. Stray capacitance C_8 from anode of the discriminator valve to earth forms undesirable coupling between the two circuits 1 and 2 and it should be made as small as possible. Its effect can be reduced by using larger tuning capacitances C_1 and C_2 and by providing mutual inductance coupling between L_1 and L_2 in opposition to C_8. Cancellation of this stray coupling is achieved by making

$$\frac{M}{\sqrt{L_1 L_2}} = \frac{C_8}{\sqrt{C_1 C_2}}$$

where M = mutual inductance between L_1 and L_2 in a positive direction[3] (in a negative direction it adds to the coupling due to C_8).

The phase discriminator,[4] a later development, uses the fact that the voltage across the secondary circuit of a doubled tuned transformer is 90° or 270° out of phase with that across the primary at the resonant* frequency to which both are tuned. In one of its simplest forms (*see* Fig. 5) the secondary is centre-tapped and half its voltage in series with the primary voltage is applied to one diode D_1 and the other half also in series with the primary to a second diode D_2. The primary voltage is developed across the R.F. choke between the centre tap of the secondary and the centre point of the diode load resistances R_3 and R_3 by means of the coupling condenser C_3. The D.C. outputs of the two diodes are connected in opposition and an overall frequency response curve similar to the dotted composite curve of Fig. 4b is obtained when both primary and secondary are tuned to the central frequency, f_c. An understanding of the operation of the phase discriminator giving two voltage peaks off-tuned from the resonant frequency of the primary and secondary circuits is best gained by reference to the vector diagram of Fig. 6. The primary voltage vector is E_1 and the half secondary voltage vectors $\pm E_2/2$ are shown in phase opposition because of the centre tap. At resonance the primary and secondary vectors are at right angles, but for frequencies above and below f the two secondary vectors are tilted either to positions $\pm E_2'/2$ or to positions $\pm E''_2/2$. The amplitudes of the secondary voltages decrease as the off tune frequency increases as shown in Fig. 6. The primary voltage vector also decreases in amplitude though to a much less extent, and we shall ignore the reduction for the purposes of this explanation. The voltages applied to the diodes are represented by the sum of the primary and half secondary vectors, *viz.*, E_{D1} and E_{D2}. It will now be clear that E_{D1} has a maximum and E_{D2} a minimum in the neighbourhood of the 45° position of the half secondary vector. The actual angle of the vectors for maximum and minimum diode voltages is dependent on the relative values of the primary and half secondary voltages, *i.e.*, upon the coupling between the two circuits, increase of coupling increasing the off-tune frequency at which the peak of the composite curve of Fig. 4b occurs. A detailed analysis of the phase discriminator cannot be given here owing to lack of space and we must content ourselves with stating the formulæ* involved. The diode voltages are

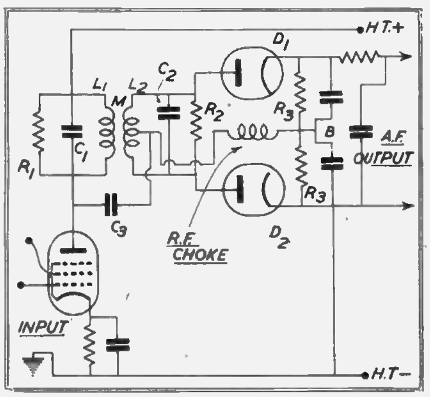


Fig. 5. The phase discriminator as a frequency-amplitude converter.

$$E_{D1} = \frac{g_m R_{D1}\left[1 + j Q_2\left(\frac{2\Delta f}{fc} + \frac{k}{2}\sqrt{\frac{L_2}{L_1}}\right)\right]}{\left(1 + j Q_1 \frac{2\Delta f}{fc}\right)\left(1 + j Q_2 \frac{2\Delta f}{fc}\right) + Q_1 Q_2 k^2} \quad \ldots \ldots (4\,a)$$

where g_m = mutual conductance of the valve preceding the discriminator.
R_{D1} = resonant impedance of the primary when not coupled to the secondary.
Q_1, Q_2 = overall magnification of primary and secondary circuits.
Δf = off-tune frequency from fc.
$k = \frac{M}{\sqrt{L_1 L_2}}$ = coupling coefficient.
L_1, L_2, = inductance of primary and secondary coils.

$$E_{D2} = \frac{g_m R_{D1}\left[1 + j Q_2\left(\frac{2\Delta f}{fc} - \frac{k}{2}\sqrt{\frac{L_2}{L_1}}\right)\right]}{\left(1 + j \frac{Q_1 2\Delta f}{fc}\right)\left(1 + j \frac{Q_2 2\Delta f}{fc}\right) + Q_1 Q_2 k^2} \quad \ldots \ldots (4\,b)$$

The reversal of sign before the k term in the numerator is the only difference between E_{D2} and E_{D1}. The slope of the composite curve in Fig. 4b at the central frequency fc is obtained by differentiating $2E_{D1}$† with respect to Δf

$$Sf = fc = \frac{2 g_m R_{D1} Q_2^2 k \sqrt{\frac{L_2}{L_1}}}{fc\,(1 + Q_1 Q_2 k^2)\left(1 + \frac{Q_2^2 k^2 L_2}{4L_1}\right)^{\frac{1}{2}}} \quad \ldots \ldots (5)$$

maximum slope is found by differentiating 5 with respect to k (the real variable) and equating to 0. This gives

$$Q_1 Q_2 k^2 = \frac{\sqrt{Q_1^2 Q_2^2 + 2 Q_1 Q_2^3 \frac{L_2}{L_1}} - Q_1 Q_2}{Q_2^2 \frac{L_2}{L_1}} \quad \ldots \ldots (6)$$

* These formulae are developed in Part II, Chapter 13, of the author's book on "Radio Receiver Design," after certain simplifying assumptions have been made[6].

† The slope of the composite curve is twice the slope of the E_{D1} or E_{D2}—frequency curve.

Optimum values of $Q_1Q_2k^2$ for different values of L_2/L_1 and Q_2/Q_1 are tabulated below.

TABLE I.

Q_1/Q_2	$Q_1 Q_2k$.					
0.5	.786	.707	.625	.578	.544	.52
1	.856	.785	.707	.657	.625	.598
2	.909	.855	.786	.740	.707	.68
L_2/L_1	1	2	4	6	8	10

The peak response off-tune frequencies for the composite curve are given approximately by

$$\frac{Q\,2\Delta f}{f_c} = A$$

where A is dependent on the coupling k between the two circuits and the secondary circuit magnification Q_2. Its values for different values of Q_2k are given below.

TABLE II.

Q_2k	0.01	0.1	0.25	0.5	0.75	1	1.5	2.
A	1.0025	1.025	1.064	1.132	1.2045	1.28	1.442	1.62

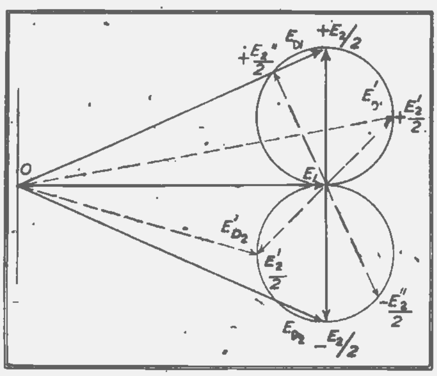
To illustrate the design of such a circuit let us assume that $L_1 = L_2$, $Q_1 = Q_2$ and g_m = 2mA/volt. From Table I maximum slope (optimum frequency-amplitude conversion) is obtained when $Q_2k = 0.856$.

Table II gives A for the above value of Q_2k as $A = Q_2\Delta f/fc = 1.235$, and if Δf = 100 kc/s as for the first calculation on the amplitude discriminator

$$Q = \frac{1.235\,f_c}{0.2} = \frac{1.235 \times 4.5}{0.2} = 27.9$$

A suitable minimum value of tuning capacitance is 100 $\mu\mu$F (it will have to be greater than for the amplitude discriminator because stray capacitance is greater) so that

$$R_{D1} = \frac{Q}{\omega C} = \frac{27.7 \times 10^{12}}{6.28 \times 4.5 \times 10^6 \times 100} = 9{,}800\ \Omega$$



Phase discriminator.

From 5

$$S_f = f_c = \frac{2 \times 2 \times 9{,}800 \times 27.9 \times 0.856}{1{,}000 \times 4.5 \times 10^3\,(1 + 0.856^2)\left(1 + \frac{0.856^2}{4}\right)^{\frac{1}{2}}}$$

= 0.108 volts per kc per volt input.

This compares favourably with the conversion efficiency of the amplitude discriminator operating under similar conditions.

In calculating the damping resistances required to give the overall values of Q_1 and Q_2 from any given coil Q, we must note that damping of the primary is produced by the conduction current of both diodes, *i.e.*, the damping due to this cause is from $R_3/2$ in parallel with $R_3/2$, *i.e.* $R_3/4$. Damping from diode conduction current across the secondary is equivalent to R_3; that from each secondary $R_3/2$ is stepped up due to the centre to $2R_3$ across the complete secondary thus giving $2R_3$ in parallel with $2R_3$ or a total of R_3 for both diodes.

The phase discriminator is adjusted by disconnecting the coupling condenser C_3 (Fig. 5) and, with loose coupling, tuning primary and secondary circuits to give maximum current in either diode at $f = f_C$. C_3 is now connected and the coupling adjusted until the required off-tune peaks are obtained at $f_C \pm 100$ kc/s by means of a high resistance voltmeter (with reversible connexions) placed across AC in Fig. 5. Incorrect primary tuning affects the symmetry of the composite curve (Fig. 4b) about f_C, increase of tuning capacitance increasing the off-tune frequency of the lower frequency peak and reducing its amplitude and vice versa, whilst incorrect secondary tuning affects the control frequency reducing it below f_C if the tuning capacitance is increased.

The output from the phase discriminator is connected via a radio frequency filter and, if necessary, a de-emphasising circuit attenuating the higher audio frequencies to the audio frequency amplifier. The latter should follow standard high fidelity practice with flat frequency response from 30 to 15,000 c.p.s. and low distortion. The design of such stages is well known and selected references are given in the Bibliography.[6 7 8 9 10]

Summarising the result of our examination of frequency modulation, we see that there are no inherent difficulties; in the case of the receiver an amplitude limiter and frequency-amplitude converter are the only additions required to the ultra high frequency amplitude modulation counterpart and these added complications are more than justified by the noise free high fidelity reception that is possible. We may therefore confidently expect that frequency modulation will play an important part in broadcast communication in England after the war, particularly for the sound channel of television programmes.

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A New Method of C.W. Reception

The Relaxation Amplifier

Under this heading, DR. M. WALD describes in the December issue of *The Wireless Engineer* a circuit based on the well-known multivibrator or relaxation oscillator.

The anode of the second valve in the multivibrator circuit is coupled back the grid of the first through a diode which is biased by a small battery. The negative bias voltage is selected that at the working point the resistance of the diode is high compared with that of the grid resistance.

The system is thus in stable balance in the absence of an external impulse on the grid of the first valve.

When an impulse is applied, no feedback occurs if the impulse is negative as it increases the negative bias of the diode anode. With a positive impulse the diode anode becomes positive and a feed-back current flows giving rise to a relaxation oscillation, the duration of which is determined by the time constant of the coupling condenser and diode load resistance and grid resistance. By adjusting the values of these an audio frequency can be produced by the application of a sinusoidal oscillation of higher frequency, and this audio note will be maintained as long as the impulses are applied to the grid of the first valve.

The author suggests that an important application of the oscillator is in the reception of C.W. signals and it avoids the complication of a B.F.O. It also has a strong inherent A.G.C. effect, which is of advantage.

DATA SHEETS XXVI & XXVII. Skin Effect

Electronic Engineering

IT is well known that as the frequency of the current flowing through a wire is increased so a larger and larger percentage of the total current flows in the portion of the wire nearest the surface. At very high frequencies the current is concentrated in a very thin skin at the surface of the wire. Due to this reduction in the effective cross-sectional area of the wire its effective resistance increases with frequency and this phenomena is usually referred to as " skin effect."

Actually, the " skin effect " is not solely a function of frequency, but of the factor " x " where

$$x = a.m = a\sqrt{\frac{8\pi^2\mu f}{1{,}000\rho}} = \sqrt{\frac{8\pi\mu f}{R_{DC}}} \quad (1)$$

$$= \sqrt{2}.(a/\delta) \quad \ldots \quad \ldots \quad (2)$$

where a = radius of wire in cms.
f = frequency in c.p.s.
μ = permeability of the wire material in c.g.s. units.
ρ = resistivity of the wire material in microhms/cm³
δ = depth of penetration in cm.
R_{DC} = resistance per cm. length to direct current.

We can express the ratio of the A.C. resistance to the D.C. resistance of a round wire as:

$$\frac{R_{AC}}{R_{DO}} = \frac{x}{2} f(x) \quad \ldots \quad (3)$$

The expression for $f(x)$ in terms of Bessel Functions is given and equation (3) is plotted on Data Sheet No. 27 for values of x between 1 and 50 covering values of R_{AC}/R_{DC} between 1.005 and 17.

For low and high values of x, A. Russell has given simpler expansions.

For $x \not> 2$

$$\frac{R_{AC}}{R_{DC}} = 1 + \frac{1}{12}\left(\frac{x}{2}\right)^4 - \frac{1}{180}\left(\frac{x}{2}\right)^8 + \frac{1}{2440}\left(\frac{x}{2}\right)^{12} \quad (4)$$

For $x > 4$

$$\frac{R_{AO}}{R_{DC}} = \frac{1}{4} + \frac{x}{2\sqrt{2}} + \frac{3}{16x\sqrt{2}} \quad \ldots \quad (5)$$

where (5) gives four figure accuracy for $x \not< 8$.

At ultra high frequencies where x will be always very large we can approximate (5) to

$$\frac{R_{HF}}{R_{DC}} \approx \frac{x}{2\sqrt{2}} \approx a\sqrt{\frac{\pi^2\mu.f}{1{,}0000\rho}} \quad \ldots \quad (6)$$

and if we insert the D.C. resistance per cm. length of wire, $R_{DC} = \frac{10^{-6}.\rho}{\pi a^2}$,

$$R_{HF} \approx (1/a)\sqrt{10^{-15}\mu\rho.f} \text{ ohms/cm.} \quad (7)$$

Depth of Penetration.

When x is very large we can express the ratio of the current density J_r at a radius r of the wire cross-section to the current density J_a at the surface of the wire by*

$$\frac{J_r}{J_a} \approx \sqrt{\frac{a}{r}}\,\text{exp.}\left\{j\omega t - (1+j)(a-r)m/\sqrt{2}\right\} \quad (8)$$

(x must still be large for the radius r)
The magnitude of this ratio is:

$$\left|\frac{J_r}{J_a}\right| \approx \sqrt{\frac{a}{r}}\,\text{exp.}\left\{-(a-r)m/\sqrt{2}\right\} \quad (9)$$

If we now make

$$(a-r) = \sqrt{2}/m = \delta = \sqrt{\frac{1000\rho}{4\pi^2\mu f}} \text{ cms.} \quad (10)$$

the current density at δ cms. from the surface will be $(1/e) = 0.368$ of that at the surface.

Now in practical cases when x is very large the skin depth will be very small compared with the radius of curvature. When this last condition is satisfied (whatever the shape of the conductor) the current distribution near the surface will be sensibly the same as for an infinite plane.

The D.C. resistance per cm. of a tubular wire with a wall thickness " δ " is then (when $a \gg \delta$).

$$R_{DC} = \frac{\rho.10^{-6}}{2\pi a\delta} = \frac{1}{a}\sqrt{10^{-15}\mu.\rho.f} \text{ ohms/cm.} \quad (11)$$

This is identical to the high frequency resistance R_{HF}/cm. given by (7). The depth " δ " is therefore designated the " Depth of Penetration " and is the factor which determines the H.F. resistance and shielding properties of a given material. If we now write (8) as

$$\frac{J_r}{J_a} \approx \sqrt{\frac{a}{r}}.\,\text{exp.}\left\{j\omega t - (1+j)(a-r)/\delta\right\} \quad (12)$$

It will be seen that the current density decreases exponentially with the distance from the surface and is still 2 per cent. of the surface value at a depth $(a-r) = 4\delta$. The H.F. resistance would actually be reduced by removing the core of the wire so as to make it into a thin tube. This is due to the current flowing 180° out of phase at a depth of $\pi\delta$ (*see* equation (12)).

The values of m and δ have been plotted against frequency on Data Sheet No. 26 for different non-magnetic materials. In the case of ferro-magnetic materials the permeability varies with frequency as well as flux density, becoming unity somewhere between 10^9 to 10^{11} c.p.s. An example of this effect is given by the curves (5) for pure nickel, the dotted curves being for higher frequency.

It should be realised that at H.F. the resistance of a length of wire will be increased by radiation resistance as well as by " skin effect " and this extra loss will have to be added if of sufficient magnitude. *Example.* Determine the resistance per cm. length of a 1 mm. diameter copper wire at 1 Mc/s. Find also the thickness of silver plating required for screening at 100 Mc/s.

From Data Sheet No. 26 $m = 214$ and $x = 10.7$ from Eq. 1.

Therefore from Data Sheet No. 27 $R_{AC}/R_{DC} = 4.04$ and R_{AC} per cm. $= \frac{1.724 \times 10^{-6}(4.04)}{\pi \times 2.5 \times 10^{-3}} = 0.89 \times 10^{-3}$ ohms/cm.

At 100 Mc/s from Data Sheet No. 26, $f = 10^8$ and $\delta = 0.00061$ cm. For a 2 per cent. current density the thickness required is therefore $4\delta \approx 0.0025$ cms.

* Where exp. $(n) = e^n$

DATA SHEET XXVIII.

The Shunt Loaded Tuned Circuit—*contd.*

THE performance of a shunt loaded tuned circuit was examined in last month's Data Sheets Nos. 23-25. Generally, in practical design problems the performance requirements will be expressed in terms of a given passband for a specified maximum permissible attenuation at the extremities of the band. The carrier frequency will usually be settled, and it will be required to determine the CR product that may be employed.

The relative gain is given by:

$$\frac{Z}{R} = \left\{\sqrt{1 + \left\{K[1 \pm (\Delta f/f_0) - (1 \pm (\Delta f/f_0)^{-1}]\right\}^2}\right\}^{-1} \quad (1)$$

(*see* equation (9) p. 673).

The value of (1) is governed by the squared term under the square root. Let the required value of the term inside the squared bracket equal n, then:

$$1 \pm (\Delta f/f_0) - (1 \pm (\Delta f/f_0))^{-1} = \pm n/K \quad (2)$$

Expanding by the binominal theorem and subtracting the equation using the −ve signs from that using the +ve signs we obtain:

$$\frac{2\Delta f}{f_0} = \frac{n}{K} = \frac{n}{\omega_0 CR} = \frac{R}{n}\sqrt{\frac{L}{C}} \quad (3)$$

or

$$2\Delta f = \frac{n}{2\pi CR} = \frac{nf_0}{K} \quad (4)$$

where $2\Delta f$ is the total pass-band. The required time constant CR is independent of the resonant frequency $f = 1/(2\pi\sqrt{LC})$. The table on Data Sheet 28 shows the required values of n to give attenuations of from 1 to 6 db.

It will be realised from last month's article and Data Sheets that the passband $2\Delta f$ is not symmetrical about the resonant frequency f_0 so that the carrier frequency should be made a little higher than f_0, when improved symmetry is required.

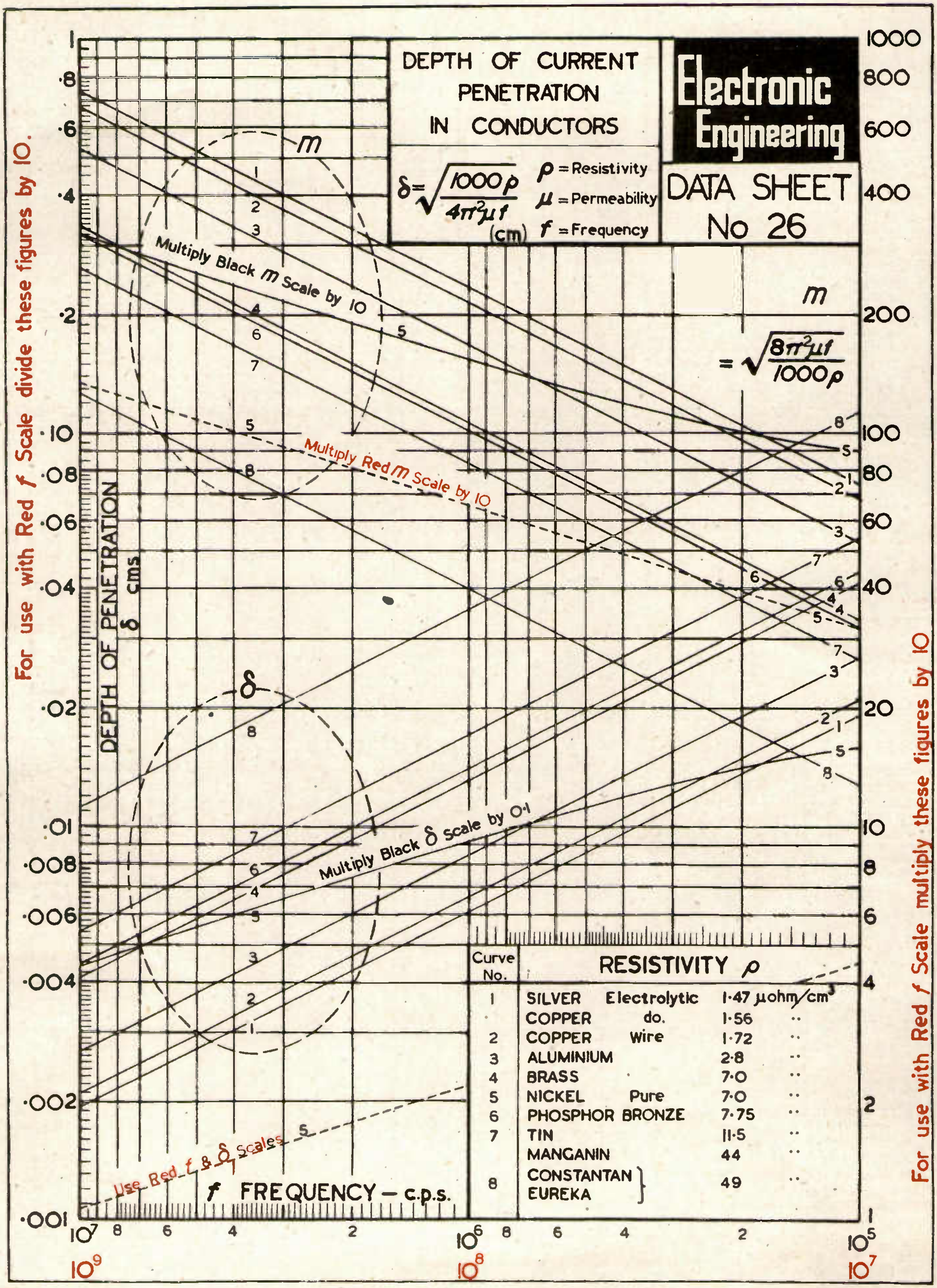
DEPTH OF CURRENT PENETRATION IN CONDUCTORS

$$\delta = \sqrt{\frac{1000\rho}{4\pi^2\mu f}} \text{ (cm)}$$

ρ = Resistivity
μ = Permeability
f = Frequency

Electronic Engineering

DATA SHEET No 26



Curve No.	RESISTIVITY ρ			
1	SILVER	Electrolytic	1·47	µohm/cm³
	COPPER	do.	1·56	..
2	COPPER	Wire	1·72	..
3	ALUMINIUM		2·8	..
4	BRASS		7·0	..
5	NICKEL	Pure	7·0	..
6	PHOSPHOR BRONZE		7·75	..
7	TIN		11·5	..
	MANGANIN		44	..
8	CONSTANTAN / EUREKA		49	..

Electronic Engineering

DATA SHEET No. 27

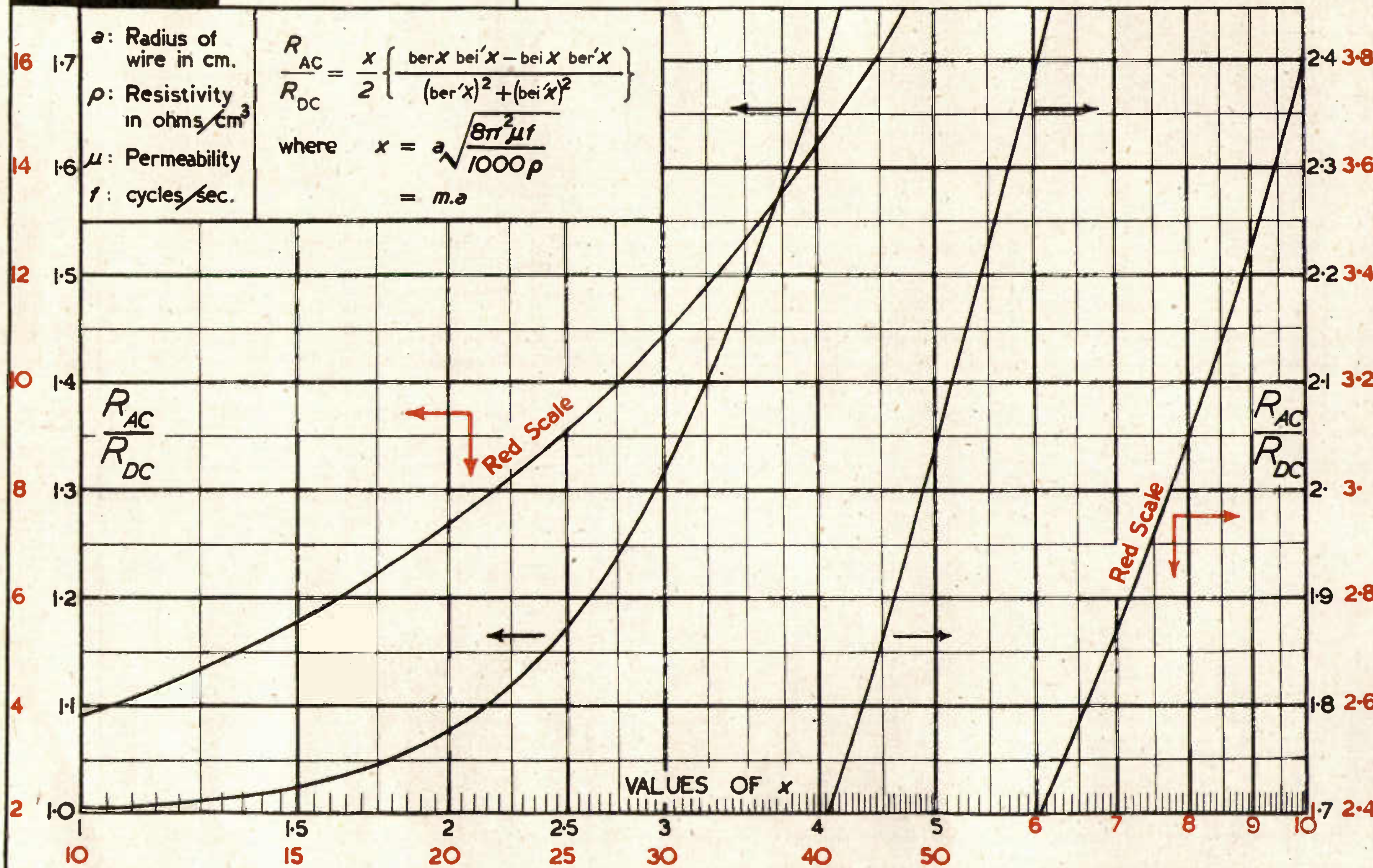
THE A.C. RESISTANCE OF A ROUND WIRE

a: Radius of wire in cm.
ρ: Resistivity in ohms/cm^3
μ: Permeability
f: cycles/sec.

$$\frac{R_{AC}}{R_{DC}} = \frac{x}{2}\left\{\frac{\text{ber}\,x\ \text{bei}'x - \text{bei}\,x\ \text{ber}'x}{(\text{ber}'x)^2 + (\text{bei}'x)^2}\right\}$$

where $x = a\sqrt{\dfrac{8\pi^2\mu f}{1000\rho}}$

$= m.a$

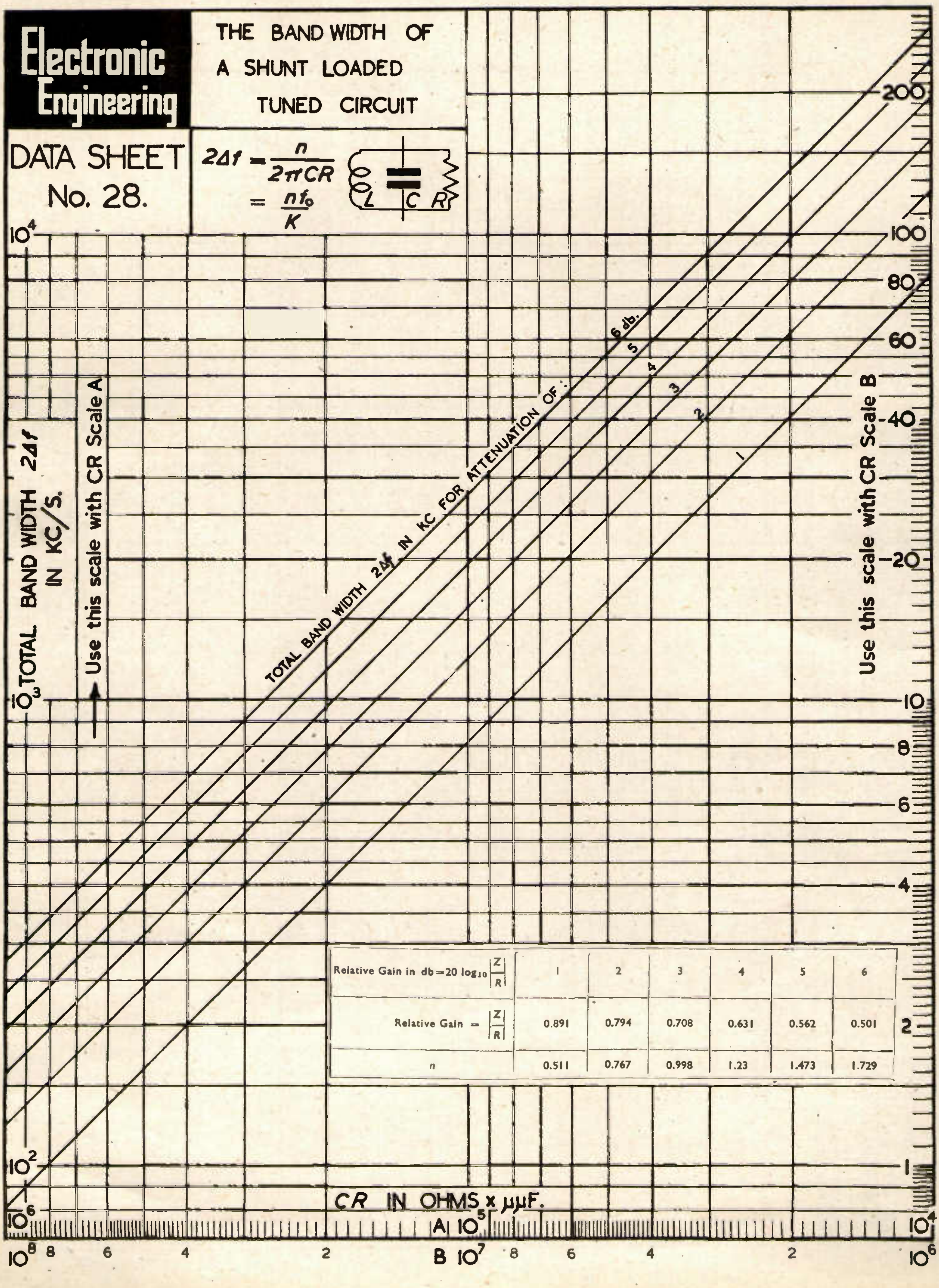


Electronic Engineering

THE BAND WIDTH OF A SHUNT LOADED TUNED CIRCUIT

DATA SHEET No. 28.

$$2\Delta f = \frac{n}{2\pi CR} = \frac{n f_0}{K}$$



Relative Gain in db $= 20 \log_{10} \left\| \frac{Z}{R} \right\|$	1	2	3	4	5	6
Relative Gain $= \left\| \frac{Z}{R} \right\|$	0.891	0.794	0.708	0.631	0.562	0.501
n	0.511	0.767	0.998	1.23	1.473	1.729

Errors in Photography of Cathode-Ray Tube Traces

The Effects of Screen Curvature

By H. MOSS, Ph.D., and E. CATTANES*

SUMMARY : This discussion is limited to effects in low voltage, sealed, high vacuum cathode-ray tubes. It is shown that when measuring the deflections along the curved surface of the screen, as is usual in visual work, the deflection is a linear function of the voltage to within the measurement accuracy of about 1%, provided that the voltages are symmetrically applied to the plates. When recording the trace photographically however, a large error can occur due to screen curvature. The variables on which this error depends are discussed, together with the appropriate technique to overcome them.

The following conventions are used. Symmetrical deflection implies that the potential in the median plane of the deflector plates is always equal to that of the final anode. θ = angle between the tube axis and the beam after deflection. V = potential between the plates.

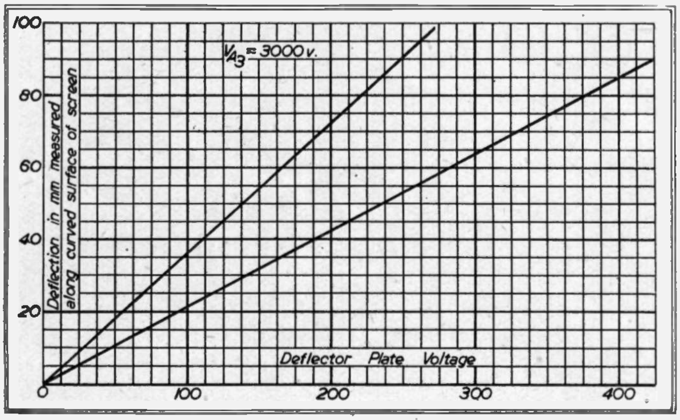


Fig. 1. Deflection characteristics for two types of tube. The departure from linearity is less than 1 per cent.

IT is easily shown that when a voltage is applied symmetrically between the plates of a C.R. tube that the tangent of the angle of deflection is strictly proportional to the applied voltage if we assume that the plates are parallel and that the fringing fields are negligible. In practice the plates of a modern cathode-ray tube are rarely parallel, and fringing fields are inevitable, so that we should expect some departure from the simple $V = k \tan \Theta$ law. Fig. 1 shows two curves of deflector plate voltage (symmetrical) against deflections measured along the curved surface of the screen for two tubes having widely different plate geometries. In both tubes, however, the screen radius is approximately 360 mm. and is approximately equal to the distance between the screen and the centre of deflection. It will be noted that the departure from linearity is not detectable over the angles used and is certainly less than 1 per cent. Fig. 2, however, shows the deflections measured along the curved surface of the screen plotted against the corresponding tangent of the angles of deflection. It will be seen that for a deflection of 90 mm., the arc and the tangent differ by about 2 per cent. Since, however, Fig. 1 shows linear voltage/deflection relations when the deflection is defined as the curved distance along the screen, it follows that the $V = k. \tan \Theta$ law is subject in these cases to an error of about 2 per cent. for a deflection angle of approximately arc tan 90/360 = 14°. The sense of the error is to increase the plate sensitivity with increasing deflection. It will be seen therefore that even if the screen were flat, so that the deflection measured along the screen surface were proportional to $\tan \Theta$, the non linearity would be small. In practice, of course, it would be difficult if not impossible to produce commercially tubes of 12 inch overall diameter, in which the screen were flat over about 8 to 9 inches. Fortunately, as shown above, the use of the normal curved screen compensates for the slight departures from the $V = k. \tan \Theta$ law, when measurements are made along the screen surface, as is most convenient in visual work.

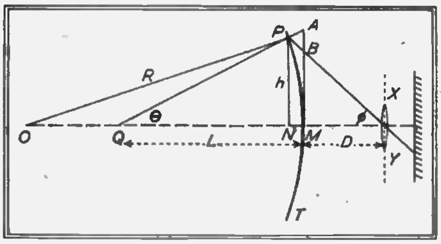


Fig. 3. Diagram for determining error due to curvature of screen.

Photographic Recording

When the traces are recorded photographically, however, an entirely different position can arise unless care is taken in the choice and setting up of the equipment. The screen curvature can result in a rapid decrease in the apparent sensitivity with increase of deflection—this decrease in sensitivity being much greater than the slight increase due to departure from the $V = k. \tan \Theta$ law. This contingency can be explained by reference to Fig. 3 in which PMT represents the section of the screen by a plane through the tube axis, O is the centre of curvature of the screen, and Q is the centre of deflection of the electron beam QP. XY represents the plane of the camera lens.

The true deflection is proportional to $\tan \Theta$, *i.e.*, to AM where A is the intersection of QP produced and the tangent to the screen at M. The deflection as seen by the film or plate is proportional to BM. Hence the absolute error is $AM - BM = AB$, and the per cent. error 100. AB/AM. An expression for this quantity is easily found in terms of the quantities $R, L, D,$ and h, whose significance is obvious from Fig. 3

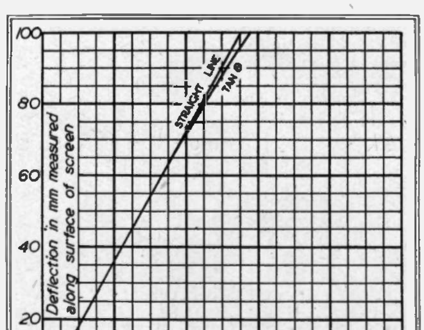


Fig. 2. Deflection v. tangent of deflection angle showing departure from linearity.

* Messrs. A. C. Cossor, Ltd.

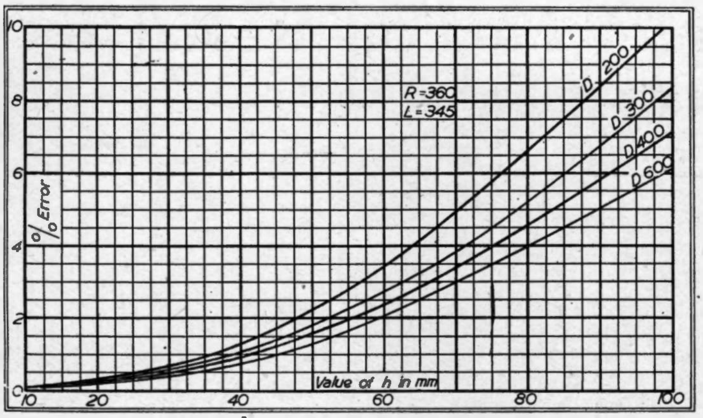


Fig. 4. Curves of per cent. error for various values of "h" (Fig. 3) and D the lens-screen distance.

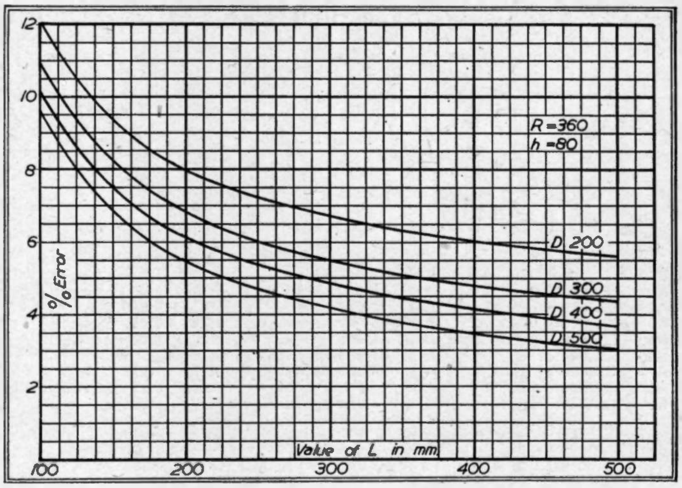


Fig. 5. Curves of per cent. error plotted for various values of L, the plate-screen distance, and D.

Error is $AB/AM =$

$$\frac{L.\tan\Theta - D\tan\phi}{L.\tan\Theta} \quad \ldots \quad (1)$$

Now from Fig. 3 we have

$$NM = R - \sqrt{(R^2 - h^2)}$$

whence

$$\tan\Theta = \frac{h}{L - R + \sqrt{(R^2 - h^2)}}$$

and

$$\tan\phi = \frac{h}{D + R - \sqrt{(R^2 - h^2)}}$$

substituting these values in (1) we obtain after some reduction

Fractional error =

$$\frac{L + D}{L} - \frac{[R - \sqrt{(R^2 - h^2)}]}{[D + R - \sqrt{(R^2 - h^2)}]} \quad (2)$$

Fig. 4 shows curves plotting the per cent. error deduced from (2) against values of h for various lens to screen distances D. The curves relate to a tube in which the screen radius $R =$ 360 mm. and in which the length of the deflection lever $L = 345$ mm. It will be seen that the errors involved are serious and remain so even when the lens to screen distance is made much larger than is convenient. Fig. 5 shows that keeping h and R constant ($h = 80$ mm.), the error is not greatly dependent on L, *i.e.*, little can be done to improve matters by increasing the deflector plate to screen distance in the tube.

It should be noted that the error plotted along the ordinate in Fig. 4 is the departure from linearity assuming a strict $V = k. \tan\Theta$ law. As already seen this law is subject to a small error in the other direction—thus at 90 mm. deflection the overall departure from linearity from voltage to photographic trace, is some 2 per cent. less than that shown in Fig. 4.

Technique to Minimise Errors

There are various obvious methods by which the errors in photography might be minimised. The use of a substantially flat screen is not impossible, but on a large tube it would involve using a very thick screen, and this in turn raises considerable difficulties in any bulb heat treatment during manufacture. In addition, a thick bulb wall over the screen would cause errors due to refraction. Various suggestions have been made regarding the construction of flat screens by deposition of the fluorescent material on mica instead of on the bulb, but such methods are hardly commercially practicable, and would materially reduce the usefulness of the tube for visual work.

Undoubtedly, the best solution is to employ small high definition tubes; since in photographic recording the absolute size of the trace is of little moment provided that the tube focus is adequate to permit optical enlargement of the records obtained. No difficulties arise in making small tubes with a substantially flat screen over about 3 inches diameter, and the photographic error is then negligible, even when the lens to screen distance is small. Thus the whole equipment becomes compact and readily portable.

As an example, we can consider the Cossor 4½ inch 09 type cathode-ray tube as used in the 339 oscillograph in conjunction with the type 427 camera. The tube has a flat screen over a central ring 45 mm. in diameter, and the remainder of the screen is a portion of a sphere of 270 mm. radius. A full-size picture is obtained on the 427 camera for a 6 cm. trace on the tube. Thus the region of the bulb surface photographed which is outside the flat portion is only about 7.5 mm. wide and the resulting error at full deflection can be shown to be less than 1 per cent., although the lens to screen distance is only 130 mm.

Reference

"Recent Developments in Engine Indicators." E. M. Dodds. Paper before Inst. Automobile Engineers, Nov., 1937.

A Cathode-Ray Method of Wave Analysis

(V. O. Johnson)

Complete periodic functions when transformed into a corresponding voltage wave, may be analysed with the use of a cathode-ray oscillograph. The complex wave is represented upon the fluorescent screen of a cathode-ray tube by a vertical displacement at the same time that a sinusoidal horizontal oscillator exists. If the frequency of the sinusoidal oscillation bears an integral relation to the fundamental frequency of the complex wave a Lissajous figure is viewed on the screen. The areas of these Lissajous figures are directly related to the coefficients of the Fourier series of the complex wave. The area is determined by measuring a photograph of the figure using a polar planimeter. The method is based on the theory developed by Mr. L. W. Chubb in connexion with the Chubb Polar Analyser. Advantages of the method are that it is quick and convenient, only standard laboratory equipment is necessary and with special equipment it promises to make possible the analysis of ultra high frequency waves.

—*Elec. Eng.* (*Trans.*), Vol. 16, No. 12 (1941), p. 1032.

Electronic Switching in Medical Research

Simplified Apparatus for Multiple Recording

by G. D. DAWSON, M.Sc., M.B., Ch.B.

IN electroencephalography, the study of the electrical potentials produced by the brain, it is necessary to make at least two simultaneous records of these electrical changes from different parts of the brain. This may be done in several ways. Two traces may be recorded from two adjacent single-beam cathode-ray tubes, from a double-beam tube or a single beam tube and some form of switch. This last is attractive as a single beam oscilloscope is already available in many laboratories. Also a single beam gas-focused tube is both easier to obtain and cheaper at present than is the double-beam type.

It has already been shown by Walter[1] that a motor-driven commutator was satisfactory for recording the lower frequencies of brain potentials. It was decided to test an electronic switch to see if the switching rate could be made high enough to prevent loss of form of the faster waves from the brain. The fastest waves recognised in electroencephalography are about fifty per second and probably the fastest waves of importance are about twenty to twenty-five per second. Thus a switch-rate of 1,000 per second is desirable.

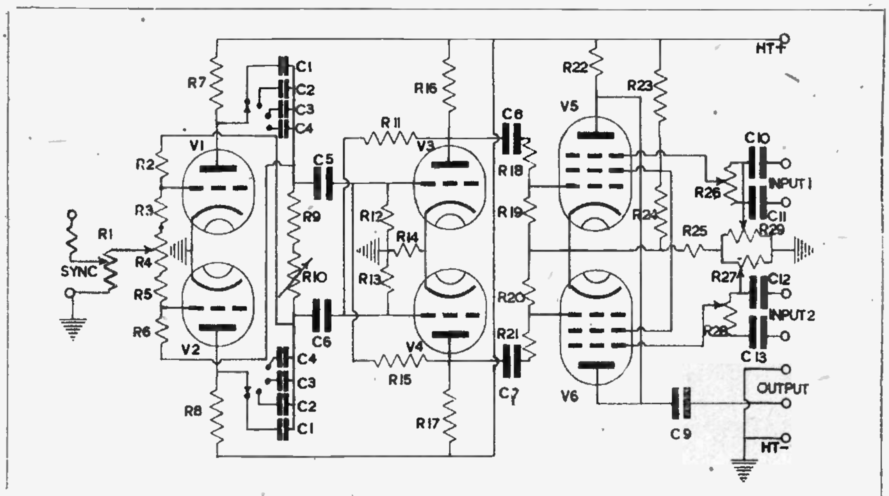


Fig. 1. Clothier's electronic switching circuit (see ref. on p. 723). The component values are listed below.

R1	10,000 ohms.	R11	15,000 ohms.	R21	1.0 meghom.	C1	0.1 mfd.
R2	100,000 ohms.	R12	10,000 ohms.	R22	50,000 ohms.	C2	0.02 mfd.
R3	25,000 ohms.	R13	10,000 ohms.	R23	15,000 ohms.	C3	0.005 mfd.
R4	250,000 ohms.	R14	25,000 ohms.	R24	10,000 ohms.	C4	0.001 mfd.
R5	25,000 ohms.	R15	15,000 ohms.	R25	1,200 ohms.	C5	0.0001 mfd.
R6	100,000 ohms.	R16	25,000 ohms.	R26	0.25 megohm	C6	0.0001 mfd.
R7	10,000 ohms.	R17	25,000 ohms.	R27	1,000 ohms.	C7	0.5 mfd.
R8	10,000 ohms.	R18	1.0 megohm	R28	0.25 megohm	C8	0.5 mfd.
R9	25,000 ohms.	R19	1.0 megohm	R29	1,000 ohms.	C10—C13	2.0 mfd.
R10	1.0 megohm	R20	1.0 megohm				

Valves—V_1 and V_2—R.C.A. type 79 or equivalent single triodes.
V_3 and V_4— do.
V_5 and V_6—R.C.A. 6C6 or 6J7.
H.T. voltage 275.

Several types of switch were tried, but that described by Clothier[2] gave much the best results. This circuit (Fig. 1) consists of a multivibrator (V_1V_2) the output of which is fed to a differentiating circuit ($C_5C_6R_{12}R_{13}$). The extremely sharp pulses which result are used to trip a trigger circuit (V_3V_4) which has two stable states. The square wave from the anodes of V_3 and V_4 is applied to the signal grids of the switching pentodes (V_5V_6). The two wave forms to be studied are applied to the suppressor grids of V_5 and V_6.

The control R_4 unbalances the time constants of the two sides of the multivibrator. This changes the relative brilliance of the two traces on the cathode-ray tube. It is useful if large swings cause the traces to cross as a slight difference in density on the records makes them easy to identify. The rate of switching is controlled by the condensers C_1C_2, etc. Normally a rate of 200-500 per second is used for visual observation with time base traverse rates of one in three to five seconds. For recording the fastest rate is used. Vertical separation of the traces is obtained by unbalancing the bias on the switching pentodes.

The slowest switching rate of Clothier's original circuit was provided for observation of successive traces. This and the control for synchronising it to a time base have been omitted. The separation control has also been made to give greater separation and to work in one direction only. This is advisable in medical work where similar waves might otherwise be confused. The input gain controls were replaced by 0.5 meg. resistances as their function is carried out earlier in the amplifiers. Double triodes for V_1V_2 and V_3V_4 were not available and type 57 tubes have been used throughout with satisfactory results.

Switching with this circuit is very good up to about 1,200 per second. The records are clean and background between the traces is practically non-existent. The intermittent nature of the record shows only on steep wave fronts. The wave form of a 100 c.p.s. sine wave is quite clear and faster frequencies than that can be counted. Coupling between the traces is only present on large overloads. If more than two simultaneous traces are needed the

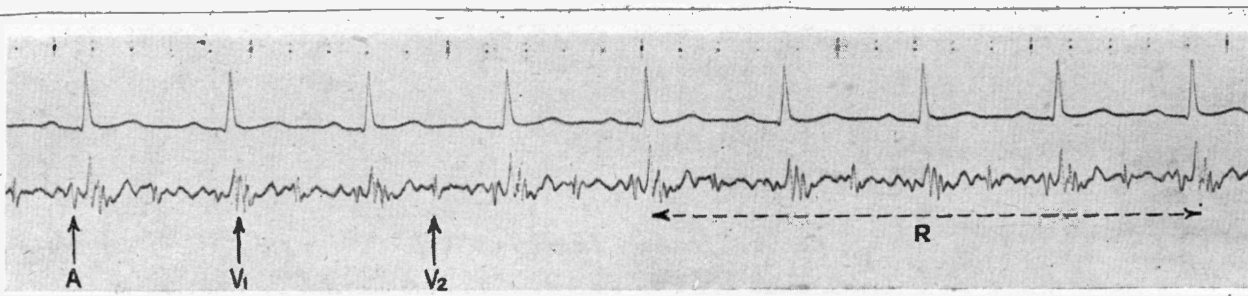


Fig. 2. Human electrocardiogram recorded simultaneously with the actual heart sound picked up by microphone on the chest wall. The portion of the record marked R corresponds to the period of respiration.

same square wave generator (V_1 and V_2, V_3 and V_4) may be used to switch a second pair of pentodes to feed a second cathode-ray tube.

Records taken with this switch and a single-beam gas-focused tube with 500 volts H.T. show that, besides being completely satisfactory for recording brain potentials, it is suitable for other medical applications such as recording heart muscle action potentials and sounds.

[1] Walter W. G. and MacMahon, 1938, *J. Mental Science*, 84, 781.

[2] "A Hard Valve Electronic Relay Switch," W. K. Clothier. *Journ. Scientific Instruments*, Sept. 1939. Vol. 16, p. 285.

TYPICAL OSCILLOGRAPHIC RECORDS.

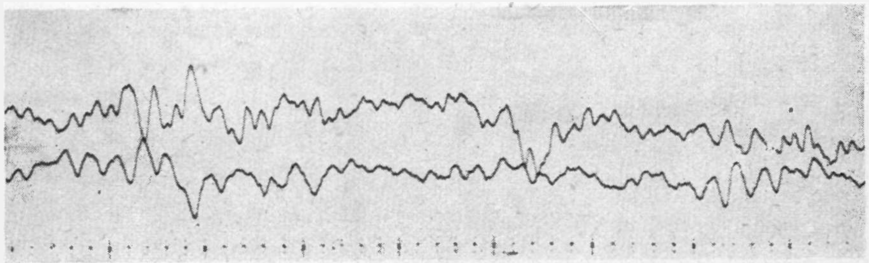
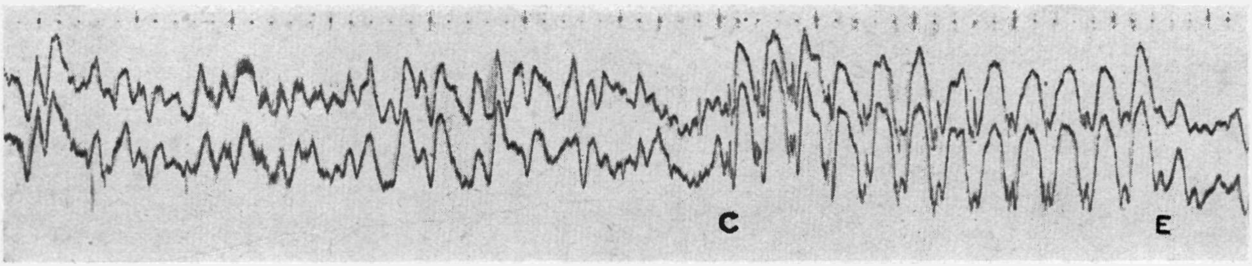
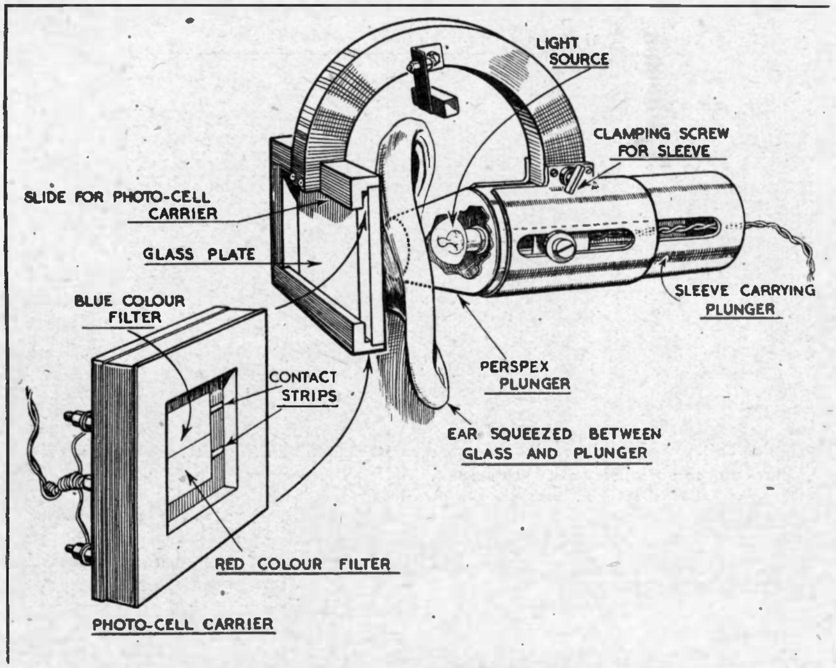


Fig. 3 (above). Potentials in the brain of an epileptic patient during intervals between attacks. See below.

Fig. 4 (below). Potentials in the human brain during an epileptic attack. The commencement C and end E of the attack are marked. Timing marks on top of record are 1/5th second.





A Photoelectric Blood-Oxygen Indicator

A description of an apparatus for continuously indicating the oxygen saturation in circulating blood by photoelectric means, devised by E. A. G. Goldie, M.A., which originally appeared in *The Journal of Scientific Instruments*, Feb., 1942.

THE photometric estimation of oxygen saturation of hæmoglobin in solution has been described by Brinkman[1] and Kramer[2], but application of the method to the circulating blood in man (due to Matthes[3]) has suffered hitherto from the impossibility of eliminating the effects of change in quantity of blood in the trans-illuminated part with consequent unreliability of calibration, since a change in light absorption may be due to a change either in blood quantity or in oxygen saturation.

The light transmitted by the pinna of the ear, where the quantity of blood is varying and the transmission of the tissues (cartilage, skin, etc.) remains constant at any particular site, would follow on theoretical grounds the relationship

$$\log L = \log L_t - aD \quad \ldots \quad (1)$$

where L is the total light transmitted, L_t the light transmitted by the tissues alone, a the effective absorption coefficient of the blood present, and D the effective depth of the layer of blood transilluminated; the light source is assumed constant. This relationship has been shown[2] to hold for films of blood in glass cells, and Squire[4] has shown that it is permissible to treat blood contained in tissues as having the same optical properties as in glass cells.

Suppose we have a photocell and amplifier system in which

$$I = -(\log L + S), \quad \ldots \quad (2)$$

where I is output current, L the light falling on the photocell, and S a variable dependent on the sensitivity of the amplifier and which may, therefore, be varied as desired. (The minus sign in equation (2) indicates that an increase in light falling on the photocell produces a fall in output current, as provided by the arrangement of the amplifier. Let S be such that when $L = L_t$ (*i.e.*, all blood is squeezed out of the trans-illuminated part of the ear), $I=0$; then if blood is allowed to return to the ear,

$$I = kaD \quad \ldots \quad \ldots \quad (3)$$

Hence if two such photocell-amplifier systems are used, with red and blue filters over the respective photo-cells, the ratio of their output currents will remain constant for any given degree of oxygen saturation, irrespective of changes in blood quantity; and will vary with changes in oxygen saturation by an amount depending on the differing absorptions of oxygenated and reduced hæmoglobin in the red and blue regions.

Method

In order to avoid the use of battery coupled amplifiers the light source is interrupted. A 3.5 v. pocket lamp bulb is fed with half-wave rectified A.C. from a metal rectifier and transformer.

The desired logarithmic characteristic may be obtained by using a barrier-layer type cell working into a high resistance load; a load of 0.5 meg. which forms the grid resistance of the first stage of the amplifier, is suitable; the voltage appearing across this load is found experimentally to be proportional to the logarithm of the incident light on the cell within the desired range. The photocells consist of a single element 10 mm. by 5 mm. with a contact strip at each end bisected by a non-conducting line. Each half is covered by a suitable colour filter (Ilford nos. 304 and 204) and the cells, filters and contact strips are mounted in a carrier, whereby they can be slid out of position without disturbing the position of the device on the ear. The arrangement will be clear from the figure.

Two identical resistance-capacity amplifiers of conventional design are used, giving a maximum voltage gain of some 10,000. It is convenient to derive the power supply from batteries; a separate high-tension supply is employed for each amplifier. The amplifier alternating input voltages are rectified by diodes and applied to the grids of the output valves in such a sense as to produce an increase of current with a decrease of input voltage. The gains of the amplifiers are controlled by the use of variable-mu valves; and the output currents of each amplifier may be read by meters.

A suitable current ratiometer has been constructed consisting of two coils on the same spindle maintained in a non-uniform field by a torsionless suspension (similar to a Megger movement). The deflexion of the instrument is proportional to the ratio of the currents in the coils and sensibly independent of their magnitude; full-scale deflexions are given by ratios of 1:1 and 1:1.5 respectively. The light source, photocells and carrier are mounted on a duralumin yoke; it is arranged that the ear may be squeezed between two parallel surfaces so as to render it bloodless without altering the relative positions of light source, ear and photocells. The whole assembly is mounted on a headband so that movements of the subject's head do not disturb the position of the device of the ear.

By reason of the ratiometer design, the scale shape obtained is not uniform, but is expanded at the end corresponding to oxygenation. At this end the accuracy is of the order of ± 2 per cent., at the other end somewhat less. The scale ranges from full oxygenation down to 70 per cent. A second scale ranging down to 55 per cent. has been constructed by adjusting the relative position of photocells and filters so that the photocell behind the blue filter also receives some light through the red filter.

References.

1 Brinkman *Acta Med. Skand.*, 94, p. 459 (1938).
2 Kramer. *Z. Biol.*, 96, p. 61 (1935).
3 Matthes. *Arch. Exp. Path. Pharmak.*, 176, p. 683 (1934).
4 Squire, *Clin. Sci.*, 4, p. 3 (1940).

BOOK REVIEWS

The Story of Electromagnetism

Sir William Bragg. 64 pp. 18 figs. (G. Bell & Sons, 1/6 net.)

This book is based on the subject of a lecture which the author has given to Air Force Training Corps cadets, but can be read with pleasure by all engineers whose recollections of fundamentals in radio are growing dim. Its very reasonable price should ensure that it is added to every collection of scientific books. It has the added attraction that the majority of the figures have been taken from Faraday's original notes of researches.

Radio Receiver Circuits Handbook

E. M. Squire. 101 pp. 50 figs. (Pitman 5/- net.)

The first edition of this book appeared in 1937 and the improvements which have been made in receiver practice since that year have been embodied in a series of complete circuit diagrams in the new last chapter.

This book differs from the average run of radio books in that it caters for the practical radio man without introducing too much theoretical discussion (which many object to as irrelevant). After what the author calls the "practical theory," notes on the operation of the circuits are given with suggestions for fault finding.

The stages in the receiver are covered in sequence from R.F. amplifiers to L.F. output valves with illustrative circuit diagrams and typical component values are given in each case. The book can be recommended to those who are starting radio maintenance or servicing and it is gratifying to note that the price is within the means of all.

Insulation of Electrical Apparatus

D. F. Miner. 452 pp. 275 figs. Appendix of Tables (McGraw Hill, 15/- net.)

A greater portion of this book is devoted to the insulation of heavy electrical machinery and apparatus, but there is much to interest the electronic engineer.

The opening chapters cover dielectric phenomena, theories of dielectric behaviour, and a general survey of insulating materials and their properties. The particular applications of insulation to industrial motors and generators, transformers and circuit breakers are then described fully with sections on H.V. insulators, lightning arrestors and heavy duty capacitors.

The book concludes with notes on insulation testing and high tension apparatus, and appendices on the properties of insulating materials. A useful table of common trade names of American plastics is also included.

Although dealing with American practice as regards testing, this does not detract from the value of the book to British engineers and it is undoubtedly a valuable work of reference which should be acquired by all laboratory and works' libraries.

Radio Simply Explained

Clarricoats. 44 pp. 24 figs. (Pitman 6d. net.)

The problem of how to explain radio to the average non-technical person has been successfully solved—spend sixpence and present him with a copy of Mr. Clarricoats' booklet. Only the densest of readers could fail to grasp the principles which are so clearly set out, and in addition to radio reception and wave propagation the author gives simple theory and calculations in electrical circuits. It is noted that the author has a similar book in preparation which covers the ground in a more detailed manner and we wish it every success.

Several other reviews are unavoidably held over, and will appear in next month's issue.

Can Sound-on-film supplant the Record? *(Concluded from p. 710)*

A final point is the loss of sound quality due to dirty film. Notwithstanding the use of noiseless recording, scrupulous cleanliness of the film is a necessity. Thus it would be desirable for the reproducer to be totally enclosed in operation, and for provision to be made for the automatic threading of the film, in order to minimise handling and abrasion of the surface. Automatic rewinding would also be advantageous, although less necessary if the film carried an even number of tracks.

Conclusions

To summarise: it would in the author's opinion be perfectly feasible to produce an apparatus capable of a really excellent quality of sound reproduction, using a sound track considerably narrower than at present, and running at a lower speed. Thus it would be possible for 3 or 4 tracks to be placed on a film say 8 mm. in width; although for the stages of recording and editing, and possibly also for some reproducing applications, a single track would be preferred.

Nevertheless, such an apparatus would be of no commercial value unless it were capable of first-class reproduction, entailing arduous and costly experimental work. Such work must include:

1. The choice of suitable photographic materials.
2. Possibly the discovery of some less costly film base than cellulose acetate.
3. The computation of optical components capable of the necessary standard of definition.
4. The perfection of mechanical devices for the recording, printing, and reproduction of the film.

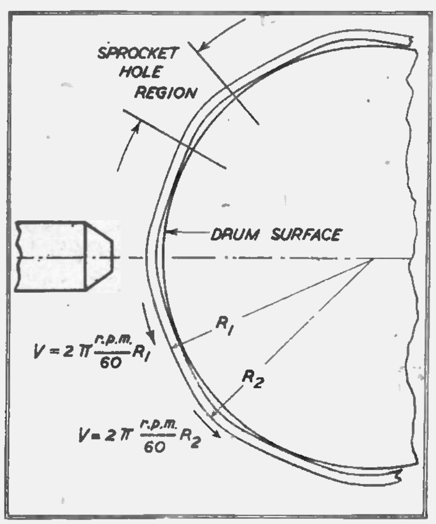


Fig. 6. Polygoning of a Film when flexed around a Drum.

The acoustic and electrical part of the equipment need present no difficulties. One commercial handicap is the complications of the patent situation, which would have a bearing upon many aspects of the problem, notably film drives, the use of ultra-violet for recording and printing, and the use of noise-reduction and volume-contraction and expansion devices.

References

1 "Stereophonic Sound-Film System—General Theory." H. Fletcher, *S.M.P.E. Journal*, October, 1941, p. 331.

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9 "Analysis of Sound-Film Drives." W. J. Albersheim and D. MacKenzie, *S.M.P.E. Journal*, November, 1941, p. 452.

10 "New and Old Aspects of the Origins of 96-cycle Distortion." J. O. Baker and R. O. Drew, *S.M.P.E. Journal*, September, 1941, p. 227.

11 "The Transport of Sound Film in Recording and Reproduction." J. J. C. Hardenberg, *Philips Technical Review*, March, 1940, p. 74.

A Novel D.C. Amplifier

Utilising a Photo-cell and Thyratron

This amplifier, which is the subject of Pat. No. 537784, was described in a recent paper before the Meter and Instrument Section of the I.E.E. by D. C. GALL (Messrs. H. Tinsley and Co.)

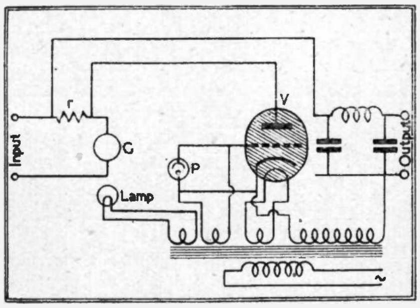


Fig. 1. Circuit diagram.

THE need for a direct-current amplifier, suitable for industrial conditions, has been realised and a suitable design has been developed. It is entirely mains-operated and the accuracy is independent of mains fluctuations or change in valve characteristics. The amplifier is capable of an output of 3 watts and has a power gain of about 10^{10}. It can be used either as a voltage amplifier or as a current amplifier and is extremely stable. It has been applied to high-speed temperature-recording for the measurement of liquid steel, and also to the metering of heat transport in large hot-water plants. It has also been applied to optical pyrometry, measurements of illumination by barrier-layer-type photocells, to the polarograph and to many other problems in which very small e.m.f's are available as a function of the quantity to be measured. The theory of the amplifier has been worked out in sufficient detail to meet practical design requirements. The departure from linearity of response is of the order of only a few parts in 10,000, and voltages of a few microvolts and currents as low as 0.01 micro-amp. can be amplified, and thus used to operate recorders and controllers.

The schematic arrangement of the circuit is shown in Fig. 1. Although it is a d.c. amplifier, the whole of the internal circuit operates on alternating current supplied from the mains. It will be seen that the applied voltage which is to be amplified is taken to a circuit consisting of a reflecting galvanometer g in series with a resistance r. The light from the galvanometer falls on a photocell p which in turn controls the magnitude and phase of the voltage upon the grid of a thyratron valve v in such a way that this grid voltage shifts in proportion to the degree of illumination of the photocell. The effect of this grid voltage is to make the thyratron conducting between its anode and filament circuit for part of the positive half-wave, as shown in Fig. 2. The thyratron current starts when the grid has reached a certain positive value and stops when the anode voltage passes through zero. Thus, as the phase of the grid advances, the duration of the conducting period increases giving a larger effective rectifier current output. That is, the effective current output of the thyratron is governed by the degree of illumination of the photocell, or by the deflection of the galvanometer. This output current is fed back through the resistance r in such a direction that the voltage drop opposes the applied voltage. Thus when an applied input voltage causes the galvanometer to deflect, the voltage drop on the resistance r rises until the input voltage is balanced. The output current is therefore proportional to the input voltage, since it is the output current which produced the opposing voltage drop, which is held in equilibrium by the galvanometer.

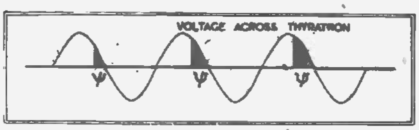


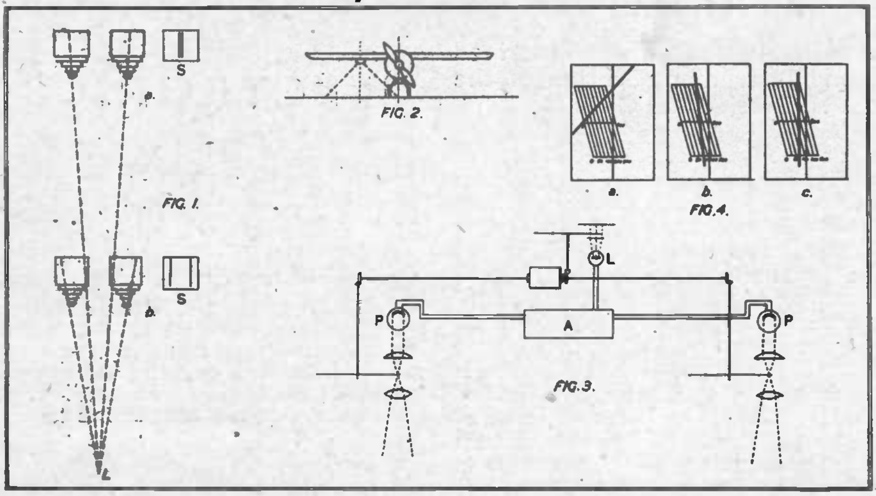
Fig. 2. Current pulses of different magnitude due to change of phase in grid voltage.

The current through the thyratron is controlled chiefly by the phase of the voltage of its grid. This grid voltage is in turn controlled by the photocell. The grid control circuit comprises the photocell in series with a small condenser of a few micromicrofarads and is supplied from a tapping on the mains transformer at about 50 volts. The grid is connected to the common point between the photocell and condenser. When the photocell is illuminated its resistance is reduced, with the effect that the voltage between the grid and the cathode changes in phase, the locus of the voltage vector following a semicircle.

The thyratron "fires" if the grid voltage is sufficiently high and positive during the positive half-wave of the plate voltage, but extinguishes itself as the plate voltage passes through zero.

The overall sensitivity of this combination of light on the photocell to output in the thyratron circuit is of the order of 300 mA per lumen. In practice the lamp illuminating the galvanometer is very much under-run in order to give a very long life. In spite of this the sensitivity is high and the ratio of the out- in the industrial instrument is 1.4 A per radian.

A Proposed Device for
Landing Aircraft in Darkness
by S. BROD.



IT is possible to enable an aeroplane to land in darkness without illuminating the aerodrome runway if infra-red radiation is used. This, as is well-known, is invisible to the eye, but can be detected by photo-electric cells.

One method of utilising infra-red radiation to guide aircraft on landing is to equip the runway with a line of infra-red sources producing vertical beams along the line of travel of the aeroplane. The line indicating the runway to be used is then made visible to the pilot by a simple form of television scanner in the plane. Such an instrument can also be used to indicate ground clearance.

The operation of such a device can be understood with reference to Fig. 1, which shows two cameras, one installed in the wing and the other in the fuselage. The view of both cameras is seen on one screen (shown at S in the diagram). When the aeroplane is at a high altitude the images of the line L will approximately coincide on the screen, but from a lower altitude (Fig. 1b) the position of the lines will be different and the separation will be proportional to the height above ground.

If, therefore, two transmitting cameras are arranged so that both pictures are visible on the same television screen in the receiver, the lines will coincide when the aeroplane is at an altitude greater than 500 ft., say, and will gradually draw apart as the plane descends, indicating the height on a calibrated scale. (Fig. 4c).

The spacing of the transmitters would be determined by the accuracy of height indication required, but 10 ft. would be satisfactory in most cases. The angle of vision of the cameras is determined by the spacing and by the minimum height which the device has to indicate when the aeroplane is on the ground. As it is necessary to keep the image from the transmitter in the fuselage near the centre of the screen, the angle of vision must be such that it will intersect the perpendicular from the centre camera when the plane is on the ground (Fig. 2).

The transmitters and receiver can be of a simple type using a scanning disk, as in Fig. 3, a motor driving all three disks in synchronism to give a 60-line picture. The output of the caseium photo-cells PP is combined in the amplifier A and applied to the crater lamp or light valve L.

The infra-red light can be supplied by tungsten filament lamps sunk below the surface of the aerodrome and fitted with suitable filters for the visible spectrum. Such an arrangement of lamps spaced, say, 20 ft. apart will form a line along the runway and can be extended to the boundary of the aerodrome. A short line at right angles to the main line could be used to indicate the boundary.

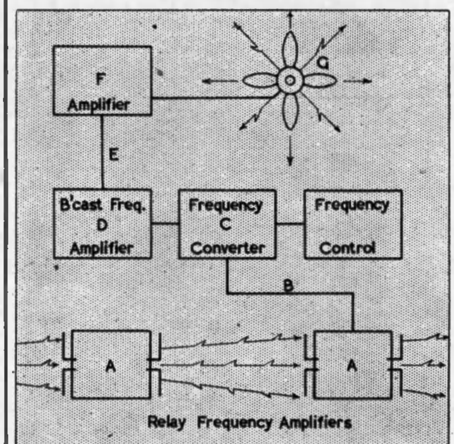
As soon as the sources are picked up by the transmitting cameras the position of the aircraft will be indicated on the screen, which has a calibrated scale similar to that shown in Fig. 4. The zero line corresponds to the height of the plane on the ground (10 ft. approx.). The line formed by the fuselage transmitter is made longer than the line formed by the other transmitter in order to distinguish them, the longer line indicating the position of the aeroplane and the shorter the height.

When the aircraft approaches the landing ground it flies until the line of infra-red lights appear on the screen. The pilot then knows the position of the landing ground and will steer to approach it from one end. (Fig. 4a). When above the runway the plane is manœuvred to bring the indicating line parallel to and near the centre line of the screen. (Fig. 4c).

With the descent of the aircraft the lines will draw apart, indicating the height, while the longer line will be kept near the centre of the screen. The pilot thus has an accurate indication of height and position on the runway.

A Television Relay System

WHEN relaying television over a considerable distance it is convenient to make use of frequencies as high as several hundred megacycles; such frequencies are, of course, outside the range of the usual television broadcast receiver, which is usually adapted to deal with signals of the order of 50 Mc/s. To meet this position it has been proposed to heterodyne the signal down to normal television broadcast frequencies at points along the chain where it is desired to provide reception.



In the block diagram of Fig. 1 are shown a number of relay stations along a chain. Each of these consists essentially of a directional receiving aerial and similar transmitting aerial, the two connected by an amplifier adapted to handle a frequency modulated u.h.f. signal. Assuming television reception is to be provided in an area in the neighbourhood of relay station A, a transmission line B is connected to the relay amplifier, and feeds signals to the frequency converter C; this may be a frequency-controlled oscillator of any convenient type, e.g., a crystal oscillator. The signal at the desired frequency is amplified at D and passed via transmission line E to power amplifier F, whence it is applied to the broadcasting aerial G in the usual way. If, as may sometimes happen, it is desired to reduce the frequency modulation percentage of the broadcast signal below that of the relay signal, this can conveniently be done by passing a portion of the signal from the transmission line B through a demodulator before being applied to the frequency converter, in an opposing manner to degenerate the frequency swing.

This proposal originated with the Radio Corporation of America.

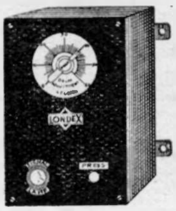

PRE-EMINENT
IN PEACE
T.C.C.
INDISPENSABLE
IN WAR

NOTES FROM THE INDUSTRY

Another Londex Product

Leaflet 97 describes a new synchronous time delay relay, developed by Messrs. Londex, Ltd., of Anerley Road, S.E.20. The instrument, as the illustration shows, is compactly mounted in an iron case with front knob controlling the time delay. Six models cover a range of 2 sec. to 28 days and the switching capacity is 500 VA. Larger currents can be dealt with by using a Mercury Type Relay (LQA) in conjunction with the time delay.

A variety of timing actions is available, for example: Make on impulse with switch off after a given time interval; break on impulse with switch on after given interval; secondary circuit made on a pre-determined time after the primary, with simultaneous switching off of primary and secondary.



Non-standard switching arrangements can be provided to suit special requirements, and the company will gladly advise on any specific problem of switching, however, intricate. (Tel.: Syd. 6258).

We regret that owing to a typographical error the name of Messrs. Londex was printed as "Lodnex" in their announcement in the March issue. Readers who have noted the regularly appearing advertisements of this company will, of course, have had no difficulty in recognising the true name.

Aquadag Coatings

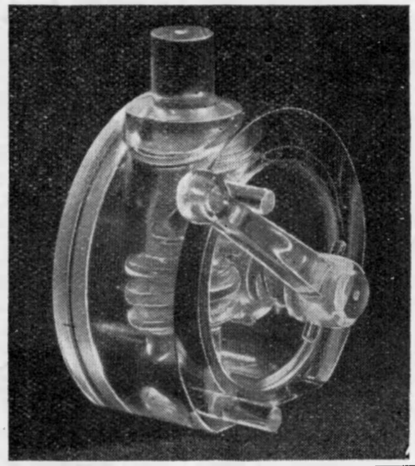
Since the application of colloidal graphite ("Aquadag") to the production of conducting coatings on glass and other materials, Messrs. E. G. Acheson have received many inquiries for methods of screening apparatus and equipment with graphite coating, possibly on account of the shortage of metal foil.

They have accordingly sent us the following note on screening:

"Aquadag" colloidal graphite in water is diluted with two or more parts of distilled water and applied by means of a brush, or by other suitable method, to the surfaces requiring to be treated. The latter, however, should be cleaned and degreased before the solution is applied and the graphite coating formed can then be dried in a warm atmosphere or by heating.

As the electrical conductivity of a graphite coating formed in this way varies with the thickness, a good conducting path can be provided by brushing on successive coatings of a more dilute dispersion of "Aquadag." A coating, however, should be dried before a successive one is applied.

Owing to the extreme fineness of the particles of graphite in the colloidal dispersion, they are able to arrange themselves, when applied to surfaces, so that they lie flat on the latter. In doing so,



they ensure maximum electrical conductivity, freedom from internal arcing and a uniform texture and appearance. Light polishing improves still further the orientation of the particles with respect to the surface on which they lie and so increases the conductivity.

Technical information may be obtained on request to E. G. Acheson, Ltd., 9 Gayfere Street, Westminster, S.W.1.

Instrument Dials

Messrs. Muirhead have just issued a well-printed catalogue of dials, knobs and dial plates for precision instruments which will be of particular interest to research laboratories constructing special apparatus and firms specialising in high quality test gear.

All dials have silvered lacquered scales, generally covering an arc of 180°, and can be fitted with vernier scale for accurate reading. Drive is either direct or by slow motion, giving 9:1, 50:1 or other ratios. Among the miscellaneous items listed are dial lenses, flexible couplings, and a clamp for locking the dial in any position. Copies of the booklet can be obtained by bona fide manufacturers on application to the company's offices at Elmers End, Beckenham, Kent.

Transparent Plastics

An interesting application of cast resin plastics is in the production of transparent working models from which the interior construction can be seen and the working of hidden parts studied if required.

Messrs. Runcolite, Ltd., of Vere Street, W.1, have sent us photographs of full-size models made in cast resin, of which one is shown in the illustration. They point out that it is well-known that components produced from expensive tools often do not work according to plan and that by the use of a full-scale specimen from the tools any defects can be seen in working and remedied with the minimum of delay.

Transparent models, unless exceptionally complicated, can be produced in a few days to manufacturers requirements and full details of this service can be obtained from the company. (Tel.: Mayfair 9501).

Radio Corporation of America

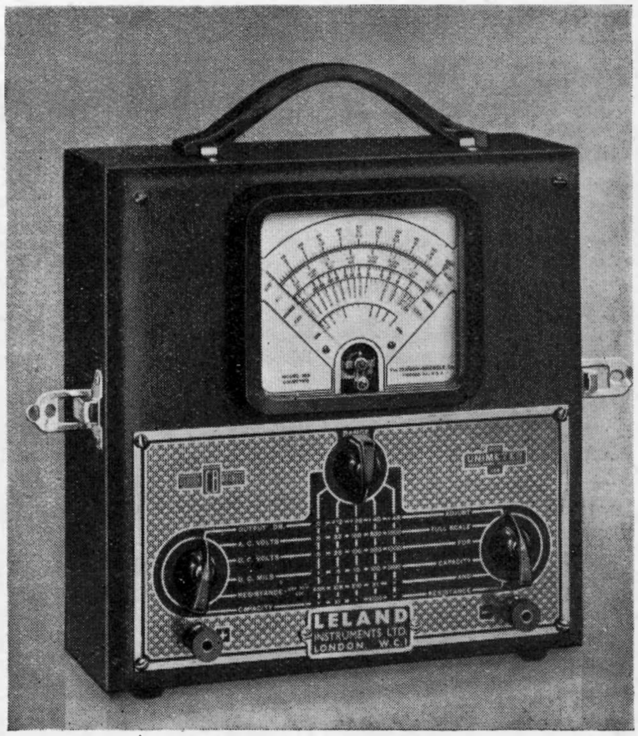
Plans for the erection of a new large radio valve factory at Manheim Township, Lancaster, Pa., are in hand by the R.C.A. Ground for the main building, which will occupy 326,000 sq. ft. of space, will be broken by the time this appears in print and the factory will be completed by September. It will employ nearly 2,000 workers and will probably be devoted to the manufacture of special valves and thermionic devices. Air conditioning will be installed throughout.

The R.C.A. have also produced a new quarterly dealing with their activities, *Radio Age*, published by the Dept. of Information, R.C.A. Building, N.Y. The second number contains an interesting review of the development of the gramophone and traces its decline in popularity (1925) and rapid recovery only to drop again in the slump of 1929. In 1936 the Philadelphia Orchestra boosted the sales of recorded music and the industry flourished until in 1941 more than 110,000,000 records were sold in America. It is expected that the 1942 figures will exceed these, although no mention is made of shortage of raw materials.

The Clough-Brengle "Unimeter"

Model 185B 2,000Ω/V.

A Leland Instrument



The Clough-Brengle "Unimeter," marketed in this country by Messrs. Leland Instruments, is a high quality universal test meter with an accuracy of 2% on the D.C. ranges. It is contained in a welded steel case with removable cover and carrying handle and weighs only 10 lbs.

The ranges available are as follows :

- D.C. Volts : 0–5–20–100–500–1,000 (2,000 ohms/volt).
- D.C. Amps : 0–5–20.
- D.C. Milliamps : 0–5–10–100.
- A.C. Volts : 0–8–32–160–800–1,600 (1,250 ohms/volt).
- Decibels : —15 to +59 db. (6 mW.) 500 ohm reference level.
- Resistance : 0–4000 and 0–40,000 ohms. Reading can be extended to 4.0 megohms with external battery.
- Capacity : .0005 — 0.1 mfd. and .05 —10 mfd.

Description

As will be seen from the illustration the meter is of the square flush type with a dead-beat movement. Below the meter are the range-setting knobs and the control resistance for adjusting zero on the resistance scales (right-hand knob).

The range setting controls are ingeniously arranged to select the range by pointing to the "co-ordinates" marked on the centre of the engraved panel. As a safety precaution it is recommended that the range switch is always set to maximum D.C. voltage range when the instrument is left out of use.

A novel feature is the inclusion of capacity ranges, operated from A.C. supply mains by means of a flexible connexion provided.

The cover to the case contains complete instructions for operation fixed inside together with a pocket for the test prods and leads. Another novel point is the provision of a small hinged foot at the back of the case which enables the instrument to be tilted for ease in reading.

Due to the characteristics of the metal rectifier, the A.C. ranges differ from the D.C. voltage ranges, but this possible source of confusion is allowed for by printing the A.C. scale in green, and in practice no difficulty is experienced in taking readings quickly.

Full details are available from Messrs. Leland Instruments, 43a, Mecklenburgh Square, W.1, and delivery can be made in a reasonable time for Government approved orders.

ABSTRACTS OF ELECTRONIC LITERATURE

INDUSTRY

Photo-electric Control of Sludge

(H. H. Slawson)

In the coal washing and cleaning plant the coal, when raised, is dumped into a trough of water which is agitated by the gentle, pulsating action of compressed air.

The refuse, meanwhile, sinks to the bottom of the trough where it makes contact with a sensitive, free-moving float. Attached to the float is an aluminium stem. On the upper tip of this stem is a vane which intercepts the beam of a photo-electric cell. As the refuse in the trough piles up, the float rises higher, until the vane no longer intercepts the light beam. This latter, falling on the photo-cell, actuates relays which set in motion a mechanism controlling a rotary gate.

Through this gate continuous and automatic discharge of refuse is thus maintained. Through a second photo-cell provision is made for increasing motor speed if the discharge gate cannot handle the accumulating refuse fast enough after it is opened.

—*Electronics,* Vol. 14, No. 9, 1941, page 72.

Styrene and its Insulating Potentialities

(Scott)

Following his review of 1937, in which the author discussed polystyrene as an insulating material, he states that in the intervening four years styrene has found such a marked use in the electrical field that it seemed desirable once again to review the general situation. Articles made from bonded styrenated paper are illustrated. Combinations of fibrous insulating materials and the styrenes are discussed, and the desirability or otherwise for plasticisation of polystyrene in its application as an electrical insulator is considered.

—*El. Engg.,* October, 1941, page 478.*

Surface Hardening by Induction

(Osborn)

The article is a shortened form of a paper on surface hardening by high frequency induction presented before the April, 1941, meeting of the American Electro-chemical Society. According to the author, induction hardening equipment can be used to harden only the requisite portion of almost any steel object; to harden parts of intricate design which cannot feasibly be treated in any other way; to eliminate expensive pre-treatment such as copper plating and carburising, and costly subsequent straightening and cleaning operations; and to harden a fully machined item without the necessity of any finishing operation. After discussing the principles of operation of a typical heating and quenching unit, various commercial equipments and their respective characteristics are mentioned.

—*Mech. Engg.,* August, 1941, page 602.*

Design Chart for R.F. Heat Treatment Generators

(E. Mittleman)

Many heat treatment generators using capacitive electrodes do not produce expected power output because of improper coupling to the load and because the designer usually does not have sufficient information about the load impedance. A reference sheet is given and the power absorbed can be quickly determined for normal operating conditions.

—*Electronics,* Vol. 14, No. 9, 1941, page 68.

An Electrical Engine Indicator

(Martin, Grinstead and Frawley)

The paper presents the design of a condenser type indicator and associated electrical equipment, together with the technique of measuring pressures in internal combustion engines. Important requirements of an ideal engine indicator and its associated amplifying and recording equipment, and the types of electrical pressure indicator which have been developed are first considered. The principle of operation of the equipment described, the mechanical design of the indicator, the electrical equipment, oscillograph amplifier, recording equipment, indicator calibration and other applications of condenser-plate indicator equipment are then discussed.

—*A.I.E.E., Trans.,* June, 1941, pp. 513-23.*

An Automatic Recorder of Spectral Sensitivity of Photoelectric surfaces

(J. R. Tykociner and L. R. Bloom)

A method of recording automatically spectral sensitivity of photoelectric surfaces has been developed. It consists of a Hardy spectrophotometer supplied with attachments for 60 modulation of two glow discharge lamps. One of the lamps serving as light intensity reference source, is supplied with an iris whose aperture is controlled mechanically by the analyser cam. The other lamp is controlled photoelectrically so that its light intensity is proportional to the relative spectral sensitivity of the investigated photoelectric surface. Light emitted by both lamps is received by the detector photocell which by means of thyratrons controls the recording mechanism.

—*Journ. Opt. Soc. Am.,* Vol. 31, No. 11 (1941), page 689.

CIRCUITS

The Development of a Frequency Modulated Police Receiver for Ultra-High-Frequency Use

(H. E. Thomas)

This paper first describes the general considerations bearing upon design of a frequency-modulated mobile police receiver for use in the 30 to 40 megacycle band where the channel width is restricted to 40 kilocycles. Details of developing the various circuits around these considerations then proceeds with a discussion of overall performance and field testing. Comparative and quantitative results show very favourable performance using a double-superheterodyne circuit with automatic-frequency control of the second oscillator.

—*R.C.A. Review,* Vol. 6, No. 2, page 222 (1941).

ELECTRO-MEDICAL

Short-Wave Diathermy Apparatus

(Gieringer)

Short-wave diathermy apparatus such as applicators and the generator are briefly referred to, following which the author discusses patient-circuit impedance, interference with radio communications, frequency stability, maximum frequency deviation for fixed maximum output power, maximum frequency deviation for output current limited, and tank-circuit efficiency.

—*A.I.E.E. Trans.,* June, 1941, pp. 459-63.*

Integration of Action Potentials

(S. S. Stevens)

A voltage integrator is now being used in a medical research laboratory to measure the total amount of action potentials produced by the muscles of various patients. The action potentials are amplified and fed to a 5 μf condenser which is discharged through an 884 valve whenever the voltage on the condenser reaches 110 volts. The discharge activates a micro-switch relay which in turn activates a marker on a moving tape. The total number of marks within a given period provides a measure of the muscular activity. The rectifier network of this instrument was adjusted until the frequency with which the condenser discharged was directly proportional to the applied voltage. Linearity was achieved over a range of from 0.5 to 20 volts. The condenser discharges once per second for an input of 5.6 volts r.m.s. The integrator has a frequency response which is flat to within 0.5 db. from 0 to 15,000 cps. Its input impedance is 3,800 ohms at 100 cps. 2,700 ohms at 1,000 cps. and 900 ohms at 10,000 cps. It is fed through a 250 ohms transformer.

—*Electronics,* Vol. 15, No. 1 (1942) page 40.

* Supplied by the courtesy of Metropolitan-Vickers Elec. Co., Ltd., Trafford Park, Manchester.

PATENTS RECORD

The information and illustrations on this page are given with the permission of the Controller of H.M. Stationery Office. Complete copies of the Specifications can be obtained from the Patent Office, 25, Southampton Buildings, London, W.C.2, price 1s. each.

Thermionic Valve Apparatus

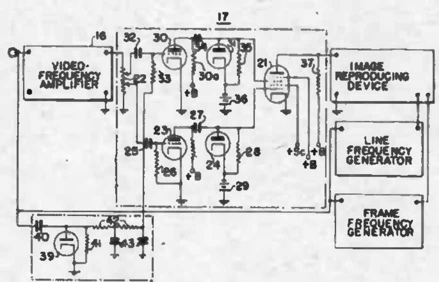
The system concerned includes a valve in which, in addition to the usual electrodes, an accelerator grid is connected to a positive voltage through a potentiometer and a secondary emitting electrode polarised that the number of electrons emitted is on the whole greater than the number striking it.

This electrode is polarised through a resistance of suitable value, the terminal remote from the electrode being connected to the zero potential point through a condenser of negligible current impedance. The alternating potential is applied to control the electron stream at a point where the electron velocity is low, thereby producing a positive feedback which increases the effective mutual conductance of the valve. The amount of feedback is limited by suitably proportioning the resistance in series with the secondary emitting electron electrode so that it is insufficient to cause oscillations to take place.

The method by which the desired result is obtained consists in locating the secondary emission electrode itself at a suitable point of low electron velocity in the stream or by locating it near the control grid where the electron velocity is low.

The auxiliary control grid may be located on either side of the control grid or in the same plane. Likewise the secondary emitting electrode may be placed on either side of the accelerator grid with the secondary emission electrode placed between the two.
Standard Telephones and Cables and B. B .Jacobsen. Patent No. 538,381.

Improvements in Television Signal-Translating Systems



The video-frequency signal is supplied to the amplifier 17 from the output of the amplifier 16, and appears across the voltage-divider resistor 22 with such polarity that positively increasing signal voltage corresponds to increased illumination in the image represented. The valves 30 and 23 serve to amplify and reverse the polarities of the applied signal voltages, which are then applied by way of the reinserter diodes 24 and 31 to the first and third grids, respectively, of the valve 21. The resultant signals applied to the control grids of valve 21 include the fixed bias voltages and the unidirectional background illumination component as well as the video components, and they are so applied to their respective grids that a predetermined characteristic level (preferably the level corresponding approximately to black) corresponding to zero signal voltage on each of the control electrodes is obtained.

Valve 21 is, therefore, a self-modulating device and serves to distort the translated signal in accordance with its operating characteristic to effect a predetermined gamma change in the translated signal. *Hazeltine Corporation (Assignees of J. C. Wilson). Patent No.* 538,947.

Classified Announcements

The charge for miscellaneous advertisements on this page is 12 words or less 3/-, and 3d. for every additional word. Single-column inch rate displayed, £1. All advertisements must be accompanied by remittance. Cheques and Postal Orders should be made payable to Hulton Press, Ltd., and crossed, and should reach this office, 43, Shoe Lane, London, E.C.4, not later than the 15th of the month previous to date of issue.

COIL FORMERS

FORMO Ceramic ribbed 2" × ⅞" Coilformers, 3/- per doz., 30/- per gross. Formo Ceramic bases for above, 2⅛" × ⅞" × ⅛", 5-hole, without fittings, 1/6 per doz., 15/- per gross.—A.C.S. Radio, 44, Widmore Road, Bromley.

LOUDSPEAKERS

3,000 SPEAKERS P.M. and energised 4" to 14", including several Epoch 18". Sinclair Speakers, Pulteney Terrace, Copenhagen Street, N.1.

LOUDSPEAKER repairs, British, American, any make, 24-hour service; moderate prices.—Sinclair Speakers, Pulteney Terrace, Copenhagen Street, N.1.

MORSE EQUIPMENT

FULL range of Transmitting Keys, practice sets and other equipment for Morse training.—Webb's Radio, 14, Soho Street, London, W.1. Phone: GERard 2089.

RADIO MAP AND GLOBE

WEBB'S Radio Map of the World enables you to locate any station heard. Size 40" by 30" 2 colour heavy Art Paper, 4/6, post 6d. Limited supply on Linen, 10/6, post 6d.—Webb's Radio, 14, Soho Street, London, W.1. 'Phone: Gerrard 2089.

TELEVISION

GOOD selection of shop soiled Television sets by Baird, Cossor and Murphy. Details on request.—A.C.S. Radio, 44, Widmore Road, Bromley.

TUITION

PRACTICAL Radio Postal Courses, coaching for I.P.R.E., R.A.F. Location, and A.I.D. exams.; booklet free.—Secretary, I.P.R.E., Bush House, Walton Avenue, Henley-on-Thames.

WANTED

ALL TYPES of used Radio Sets, Radio and Electrical accessories. Bought for cash. University Radio, 22, Lisle Street, W.C.2. 'Phone: GER 4447.

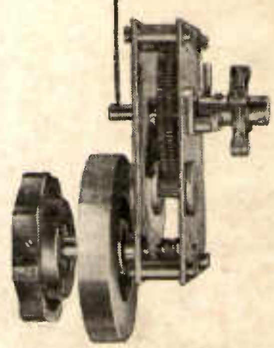
WE OFFER cash for good modern Communication and all-wave Receivers.—A.C.S. Radio, 44, Widmore Road, Bromley.

COLLEGE requires complete Speech Recording Equipment.—Full details to Box 647.

Bandspread superseded

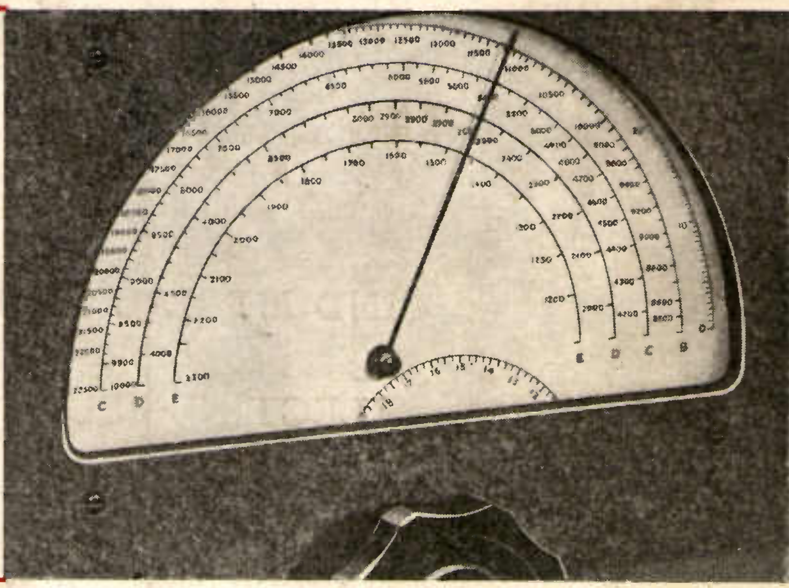
Amongst the many special features of the Eddystone "358" Communication Receiver the main tuning control is of special interest. Bandspread is superseded by a logging scale, the readings on which are amplified by a secondary vernier dial. This system gives all the advantages of bandspread, whilst making a return to any given position simple, as the main dial remains accurately calibrated. The fly wheel drive described alongside adds considerably to simplicity of control. These are but two of the many refinements indicative of the care and precision which Eddystone engineers have expended on both the "358" and its counterpart the Medium Frequency Model "400."

MAIN TUNING CONTROL
What is, in effect, mechanical Bandspread, is supplied by the fly wheel control and spring loaded Tufnol Gearing fitted to the main tuning control. Its mechanism is illustrated on the right. The gearing gives a ratio of 70-1 and makes possible minutely accurate logging. The progression of the pointer across the dial can be controlled to give hardly perceptible movement, and the action of the whole component is unbelievably smooth.

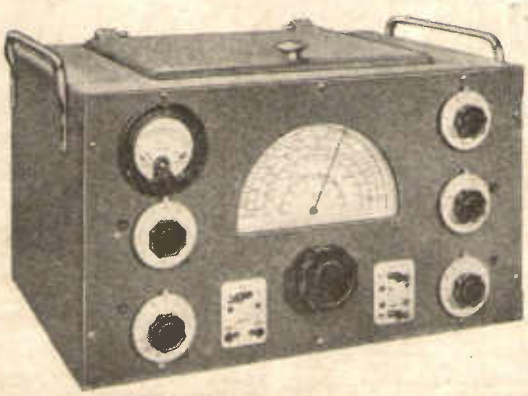


EDDYSTONE

'358'



EDDYSTONE "358" Communication Receiver. *Specification*: The receiver employs one stage of R.F. amplification, frequency changer, two I.F. amplifiers, a separate beat frequency oscillator, octal base Mullard or Osram 6.3 volt valves. Frequency range is continuous from 22 M/cs to 1.25 M/cs using four fully screened interchangeable coil units. *Five additional coil units extend the range to 31 M/cs, and 90 K/cs.* Illuminated dial is accurately calibrated with four standard coils. Additional coils supplied with separate graph. To simplify maintenance a metre and test switch is fitted. Main tuning control incorporates fly wheel drive and spring loaded Tufnol gearing (ratio 70-1). Logging scale supersedes the old type band spread control. Separate Power unit assures freedom from drift.



MEDIUM FREQUENCY MODEL "400." A highly sensitive receiver covering medium frequencies only. Similar to the "358" but is provided with four coils only covering frequency range from 130 K/cs to 2,200 K/cs. Optimum gain is secured with very high signal to noise ratio.

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Special Models of the Eddystone "358" and "400" are available with Band-pass Crystal Filters.

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