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Editorial

The Bridged-*T* Method of Measuring the Constants of a Coil

IN the Editorial of *The Wireless Engineer* of last June we discussed the so-called bridged *T* method of measuring high resistance at high frequencies. The same method can be employed to determine the inductance and effective resistance of a coil. As shown in Fig. 1 the coil to be tested replaces the resistance that formed the upright element of the *T*, the horizontal elements consisting as before of two similar variable condensers mechanically coupled so that they always have equal capacitances. These condensers are bridged as before by a resistance R_s. G is the A.C. generator and D the detector; the condensers are adjusted until the indication on the detector is zero or a minimum. As we pointed out in the other case, the determination of the conditions for a balance is simplified by using the mesh-star transformation and replacing the three mesh-connected impedances Z_1, Z_2, Z_3 of Fig. 1 by the three star-connected impedances z_1, z_2, z_3 of Fig. 2, where $z_3 = Z_1Z_2/(Z_1+Z_2+Z_3)$ with similar expressions for z_1 and z_2. We are not very much interested in the latter, however, since z_1 forms a part of the detector circuit and z_2 a part of the generator circuit, and consequently neither of them affects the conditions of balance. The generator produces a current through z_2z_3 and the coil in series, and adjustment is made until the P.D. across z_3 and the coil is a minimum, that is, until z_3 and the coil are in series resonance. The fact that, apart from secondary effects, the P.D. can be reduced to zero is due to z_3 introducing a negative resistance

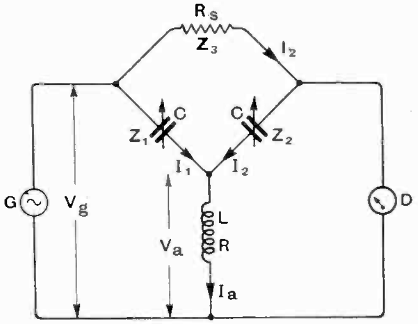

Fig. 1.

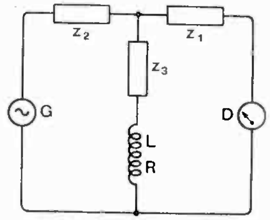

Fig. 2.

which compensates for the effective resistance of the coil.

Putting $Z_1 = Z_2 = 1/j\omega C$ and $Z_3 = R_s$ we get

$$z_3 = -\frac{R_s + j2/\omega C}{4 + \omega^2 C^2 R_s^2}$$

and the joint impedance of the coil and z_3 is

$$\left(R - \frac{R_s}{4 + \omega^2 C^2 R_s^2}\right) + j\left(\omega L - \frac{2/\omega C}{4 + \omega^2 C^2 R_s^2}\right)$$

For this to be zero we must have

$$R = \frac{R_s}{4 + \omega^2 C^2 R_s^2} \text{ and } \omega L = \frac{2/\omega C}{4 + \omega^2 C^2 R_s^2}$$

Hence, when balanced, we have

$$Q = \omega L/R = 2/\omega C R_s$$

If $\omega^2 C^2 R_s^2 \ll 4$, which will be the case for a high value of Q, the above formulæ give

$$R = R_s/4 \text{ and } L = 1/2\omega^2 C.$$

Returning now to the actual circuit arrangement of Fig. 1 let us consider the relations between the various voltages and currents. These are shown in Fig. 3. Across the coil there is a voltage V_a producing in the coil a current I_a lagging behind it by an angle ϕ approaching a right-angle. Since, when balanced, there is no P.D. across the detector, the voltage across Z_2 must be $-V_a$ producing in Z_2 the current I_2 (OA in Fig. 3) 90° ahead of $-V_a$. Since there is no current through the detector, the same current I_2 must flow through R_s, across which the voltage is that of the generator, viz. V_g. Hence V_g is in phase with I_2 and equal to $I_2 R_s$. V_g is also the resultant of V_a and the voltage V_1 across Z_1, as shown in Fig. 3, and the current I_1 must be 90° ahead of V_1. The coil current I_a is the resultant of I_1 and I_2. Now $I_2 = V_a \omega C$ and $AB = I_1 \cos\beta = V_1 \omega C \times V_a/V_1 = V_a \omega C$. Hence we have the interesting result that $OA = AB$, that is, the point A bisects the wattless component of the coil current, and therefore $\tan\beta = 2 \operatorname{cotan}\phi$. Since $\tan\beta = V_g/V_a = \dfrac{I_2 R_s}{I_2/\omega C} = \omega C R_s$ and $\operatorname{cotan}\phi = R/\omega L$, it follows that $\dfrac{\omega L}{R} = \dfrac{2}{\omega C R_s}$, as found above by the other method.

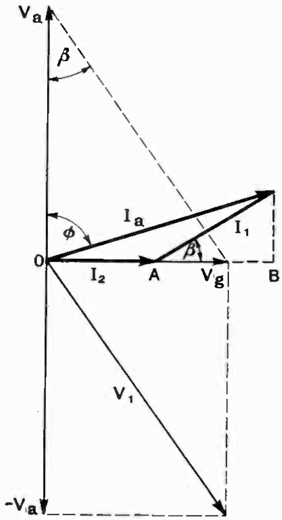

Fig. 3.

In the coil we have $R = \dfrac{V_a}{I_a}\cos\phi$, and putting $V_a = I_2/\omega C$, $I_a^2 = (2I_2)^2 + I_1^2 \sin^2\beta$, and $\cos\phi = I_1 \sin\beta/I_a$, and noting that, since $I_1 = \omega C V_1$ and $I_2 R_s = V_g$,

$$\frac{I_1^2}{I_2^2}\sin^2\beta = \frac{I_1^2 V_g^2}{I_2^2 V_1^2} = \omega^2 C^2 R_s^2$$

we find as before that

$$R = \frac{R_s}{4 + \omega^2 C^2 R_s^2}$$

Similarly from the formula $\omega L = \dfrac{V_a}{I_a}\sin\phi$ we find as before that

$$\omega L = \frac{2/\omega C}{4 + \omega^2 C^2 R_s^2}$$

It can easily be seen from Fig. 3 that if ϕ is very nearly 90°,

$$R = \frac{V_a}{I_a}\cdot(90^\circ - \phi) = \frac{V_a}{I_a}\cdot{}_2 = \frac{V_g}{2I_a}\cdot$$

$$= \frac{V_g}{4I_2} = \frac{R_s}{4}$$

and similarly

$$\omega L = \frac{V_a}{I_a}\sin\phi = \frac{V_a}{I_a} = \frac{V_1}{2I_1} = \frac{1}{2\omega C}$$

to a close approximation.

G. W. O. H.

Receiver Aerial Coupling Circuits*

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SUMMARY.—In the design of receiver aerial circuits it is necessary to produce the highest transfer voltage ratio (the ratio of the voltage across the first tuned circuit to the aerial open circuit voltage) with minimum reduction of selectivity and minimum mistuning. An analysis is made of mutual inductance coupling with special reference to these three factors and ratio terms are suggested for indicating the effect of the aerial coupling on selectivity and mistuning. The results obtained for mutual inductance coupling are used as a basis for generalised formulae applicable to any type of coupling and the terms in these formulae are tabulated for selected forms of coupling by inductance, capacitance and combinations of both. The general trend of transfer voltage, selectivity and mistune ratios over a range of frequencies and the effect of aerial terminal impedance are discussed.

Experimental work, which substantiates the theoretical formulae, is described and conclusions are drawn on the relative merits of different types of coupling.

Introduction

WHEN an aerial is coupled to the first tuned circuit of a receiver, three important factors must be taken into consideration: (1) Transfer voltage ratio, i.e., the ratio of the output voltage developed across the tuned circuit to the aerial generated voltage. (2) Selectivity; the coupling reflects a resistance component from the aerial into the tuned circuit so reducing its selectivity, and (3) mistuning, a reactance component is also reflected from the aerial thus requiring the tuning capacitance setting to be changed if mistuning is to be avoided. In aerial circuit design the problem is chiefly one of obtaining the highest transfer ratio with minimum reduction of selectivity and, more important still, minimum mistuning. A method of calculating these three factors is set out in this paper, which deals with the more usual types of aerial coupling circuits. There are two main sections; the first, which is theoretical, analyses mutual inductance coupling and uses this as a basis for generalised formulae applicable to any type of coupling. The values of the terms in the generalised formulae are tabulated for different forms of coupling by inductance, capacitance or combinations of both and the general trend of the three factors over a tuning range and the effect of variation of aerial terminal impedance are discussed. The second section describes experiments which substantiate the formulae derived theoretically and also gives an indication of the variation in the three factors, mentioned above, over the medium wave band. As a result of these experiments conclusions are drawn regarding the relative merits of different types of coupling.

1. Theory.

1.1.—*Mutual Inductance Coupling*

Coupling between the aerial and first tuned circuit of a receiver is quite commonly effected by mutual inductance between a primary coil to which the aerial is connected, and a secondary coil, which is the inductance element of the first tuned circuit. This form of coupling, shown in Figs. 1 (a) and (b), provides a convenient starting point for the analysis, which must, however, be preceded by a statement of the conventions followed and of the meanings attached to certain terms, including the three factors mentioned in the introduction.

The aerial is considered as a generator of voltage E_1, having an internal impedance

$$Z_{a0} = R_{a0} + jX_{a0}$$

equal to its terminal impedance, i.e., it is the impedance which would be measured between the aerial and earth looking into the aerial from the aerial terminal of the receiver.

The series impedance of the aerial and coupling coil is designated as

$$Z_{a1} = R_{a1} + jX_{a1} = R_{a0} + R_1 + j\,(X_{a0} + \omega L_1)$$

where R_1 and L_1 are the resistance and inductance of the primary coil. Hence Z_{a1}

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is the impedance which would be measured looking from the aerial input voltage E_1 with the tuning coil on open circuit.

The series impedance of the tuned secondary circuit with the aerial disconnected is designated as

$$Z_2 = R_2 + jX_2 = R_2 + j\left(\omega L_2 - \frac{1}{\omega C_2}\right).$$

Transfer voltage ratio T_R is the ratio of the voltage (E_2) developed across the tuning capacitance C_2 to the aerial input voltage (E_1).

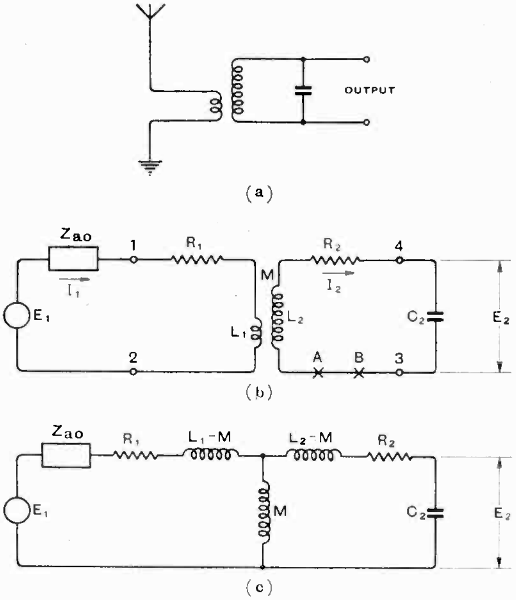


Fig. 1 (*a*) *Mutual inductance aerial coupling.* (*b*) *Mutual inductance aerial coupling, showing the aerial as a generator.* (*c*) *Equivalent T section for mutual inductance aerial coupling.*

To express selectivity a term, called the selectivity ratio, is employed and it is defined as

$$\text{Selectivity Ratio } (S_R) = \frac{R_2}{R_2 + R_c + R_{ar}}$$

$$= \frac{1}{1 + \dfrac{R_c + R_{ar}}{R_2}}$$

where R_2 = resistance of the secondary coil

R_c = resistance component (if any) of the coupling element.

R_{ar} = resistance reflected into the secondary circuit from the aerial.

It is the ratio of the Q value of the secondary circuit, with the aerial connected, to that of the secondary coil alone. The exclusion of the resistance component of the coupling element (it is zero for mutual inductance but not necessarily for other forms of coupling) from the numerator is justifiable since it may be assumed that the coupling element would not be included unless the aerial connection was required. The maximum value of selectivity ratio is 1, when the selectivity is that of the tuned circuit alone, and for all forms of coupling it will be less than 1.

Mistuning can be defined either as the change of tuning capacitance ΔC_2 from the initial setting $C_{20}\left(C_{20} = \frac{1}{\omega^2 L_2}\right)$ to maintain resonance of the secondary circuit when the aerial is coupled to it or in the ratio form $\frac{\Delta C_2}{C_{20}}$ and both are given in this paper. The former definition, which will be called the capacitance correction, is helpful in indicating the possibilities of adjustment by the trimmer across the tuning capacitance, whilst the latter, called the mistune ratio M_R, gives an indication of the frequency error, which occurs if the coupling and reflected aerial reactance is not corrected. If ΔC_2 is small compared with C_{20}, the frequency error ($\Delta f = f_2 - f_1$) is very nearly $\frac{\Delta C_2 f_1}{C_{20}\;2} = \frac{M_R f_1}{2}$, where f_1 is the resonant frequency of the uncoupled secondary circuit and f_2 is the resonant frequency with the aerial coupled.

The sign of mutual inductance is given with reference to the common limb of the equivalent T network in Fig. 1 (c). Thus $+M$ gives $(L_1 - M)$ and $(L_2 - M)$ whilst $-M$ gives $(L_1 + M)$ and $(L_2 + M)$ as the series arms. Referring to Fig. 1 (b), it means that M is positive if by joining 2 and 3 a measurement of total inductance across 1 and 4 gives $L_T = L_1 + L_2 - 2M$. Actually the sign of M is only important when additional coupling, e.g. by capacitance, is employed.

The current and voltage relationships from 1 (b), the actual circuit, are

$$E_1 = I_1(Z_{ao} + R_1 + j\omega L_1) + I_2 j\omega M$$

$$O = I_1(j\omega M) + I_2\left(R_2 + j\omega L_2 + \frac{1}{j\omega C_2}\right)$$

$$E_2 = \frac{I_2}{j\omega C_2}$$

Solving for the transfer voltage ratio

$$\frac{E_2}{E_1} = \frac{\frac{M}{C_2}}{Z_{a1}\,Z_2 + \omega^2\,M^2} =$$

$$\frac{\frac{M}{C_2}}{(R_{a1}R_2 - X_{a1}X_2 + \omega^2 M^2) + j(X_2 R_{a1} + X_{a1}R_2)} \quad \ldots \quad (1)$$

Assuming L_1 to be fixed there are two possible variables in (1), C_2 and M. In most practical circuits M is a preset component but C_2 is continuously variable. In the absence of ganging requirements C_2 would be adjusted for maximum $\frac{E_2}{E_1}$ and this occurs when the total series reactance of the secondary circuit, including the reflected reactance from the aerial, is zero, i.e., when the secondary is in the resonant condition. If M is also variable a maximum maximum value of $\frac{E_2}{E_1}$, called the optimum value in succeeding sections, is found.

To determine the resonant condition of the secondary circuit, the total series impedance (Z_{2T}) must be calculated by short circuiting E_1 and open circuiting the secondary at suitable points such as AB in Fig. 1 (b). The ratio of an applied voltage E (of any value) across these points to the current I it produces in the secondary circuit gives Z_{2T}.

$$\text{Thus } Z_{2T} = \frac{E}{I} = R_2 + j\omega L_2 + \frac{1}{j\omega C_2} + \frac{\omega^2 M^2}{Z_{a1}}$$

$$= R_2 + \frac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2} + j\left[X_2 - \frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2}\right] \quad (2)$$

The resistance and reactance reflected from the aerial are $\frac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2}$ and $-j\,\frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2}$ respectively.

For secondary circuit resonance

$$X_2 = \frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2} \quad \ldots \quad (3)$$

Replacing X_2 in (1) by this value

$$\frac{E_2}{E_1}(\max) = \frac{\frac{M}{C_2}}{\left[R_{a1}R_2 - \frac{\omega^2 M^2 X_{a1}{}^2}{|Z_{a1}|^2} + \omega^2 M^2\right] + j\left[\frac{\omega^2 M^2 X_{a1} R_{a1}}{|Z_{a1}|^2} + X_{a1}\,R_2\right]}$$

$$= \frac{\frac{M}{C_2}}{Z_{a1}\left[R^2 + \frac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2}\right]} \quad \ldots \quad (4a)$$

For optimum $\frac{E_2}{E_1}$ expression (4a) must be differentiated with respect to M and equated to zero. This gives

$$\omega M = Z_{a1}\sqrt{\frac{R_2}{R_{a1}}} \quad \ldots \quad (5)$$

$$\text{and } \frac{E_2}{E_1}(\text{opt}) = \frac{M}{2C_2 Z_{a1} R_2} \quad \ldots \quad (4b)$$

$$= \frac{1}{2\omega C_2\sqrt{R_2 R_{a1}}} \quad \ldots \quad (4c)$$

$$\text{Selectivity Ratio } \left(\max \frac{E_2}{E_1}\right) = \frac{R_2}{R_2 + \frac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2}} \quad \ldots \quad (6a)$$

$$S_R \left(\text{opt. } \frac{E_2}{E_1}\right) = \frac{R_2}{R_2 + R_2} = \tfrac{1}{2} \quad \ldots \quad (6b)$$

Calculation of mistuning can be made from 3.

$$C_2 = \frac{1}{\omega^2 L_2\left[1 - \frac{\omega^2 M^2 X_{a1}}{\omega L_2 |Z_{a1}|^2}\right]} \quad \ldots \quad (7a)$$

$$= \frac{C_{20}}{1 - \frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2 \omega L_2}} \quad \ldots \quad (7b)$$

$$\Delta C_2 = C_2 - C_{20} = C_{20}\,\frac{\frac{\omega^2 M^2 X_{a1}}{\omega L_2 |Z_{a1}|^2}}{1 - \frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2 \omega L_2}} \quad (8a)$$

$$M_R = \frac{\Delta C_2}{C_{20}} = \frac{1}{\frac{\omega L_2 |Z_{a1}|^2}{X_{a1}\omega^2 M^2} - 1} \quad \ldots \quad (8b)$$

From the above expressions it is clear that when X_{a1} is inductive, C_2 is greater than

C_{20}, i.e., the reactance reflected into the secondary circuit from the aerial is equivalent to a negative inductance $-\dfrac{\omega M^2 X_{a1}}{|Z_{a1}|^2}$ in series with the secondary coil. The reverse is true when X_{a1} is capacitive for then the reflected reactance is equivalent to a positive inductance. Over the medium and long wave band, the aerial terminal impedance is generally capacitive, so that for X_{a1} to be inductive a large primary coil is required, i.e. ωL_1 must be greater than X_{ao}.

For optimum coupling

$$\Delta C_2 = \frac{C_{20}}{\dfrac{\omega L_2 R_{a1}}{X_{a1} R_2} - 1} \quad \cdot\,\cdot \quad \cdot\,\cdot \quad (8c)$$

Optimum coupling is rarely realised in practice because it requires M to be changed when the tuning frequency is changed $-\left[M_{opt} = \dfrac{Z_{a1}}{\omega}\sqrt{\dfrac{R_2}{R_{a1}}} \right]-$ unless Z_{a1} is proportional to ω and the ratio R_2/R_{a1} is constant. An added disadvantage of optimum coupling is that selectivity is halved and mistuning is very large. The important practical case is for a fixed value of M and the formulae in (4a), (6a) and (8a) and (b) are therefore the more useful.

These expressions may be rewritten in order more clearly to bring out their salient features. By combining (4a) and (7a)

$$\frac{E_2}{E_1} = \frac{\omega M \left[\omega L_2 - \dfrac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2} \right]}{Z_{a1}\left[R_2 + \dfrac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2} \right]} \quad \cdot\,\cdot \quad (9a)$$

$$= \frac{\omega M}{Z_{a1}} Q_{21} \quad \cdot\,\cdot \quad \cdot\,\cdot \quad (9b)$$

where Q_{21} = Magnification of the secondary circuit when the aerial is coupled to it.

$$= \frac{\text{coil reactance} + \text{reflected aerial reactance}}{\text{coil resistance} + \text{reflected aerial resistance.}}$$

A very useful approximate formula is obtained when the coupling is loose, i.e.,

$$M \ll \frac{Z_{a1}}{\omega}\sqrt{\frac{R_2}{R_{a1}}}$$

for then $Q_{21} \,\Omega\, Q_2 = \dfrac{\omega L_2}{R_2}$, the magnification of the uncoupled secondary coil.

and $\dfrac{E_2}{E_1} = \dfrac{\omega M}{Z_{a1}} \cdot Q_2$

$$= \frac{\text{coupling impedance}}{\text{aerial circuit impedance}} \cdot Q_2 \quad \cdot\,\cdot \quad (9c)$$

From (8a)

$$\Delta C_2 = C_{20} \cdot \frac{\text{Reflected aerial reactance}}{\text{coil reactance} + \text{reflected aerial reactance}} \quad \cdot\,\cdot \quad (10)$$

The mutual inductance coupling can be made more general if a resistance is included in the coupling limb of Fig. 1 (c), and this form of the circuit, though practically never employed in practice, will next be considered.

1.2.—*Combined Mutual Inductance and Resistance Coupling*

The coupling impedance is now $(R + j\omega M)$ and the equivalent circuit is that of Fig. 2. Equation (1) is modified to

$$\frac{E_2}{E_1} = \frac{\dfrac{R + j\omega M}{j\omega C_2}}{Z_{a1} Z_2 - (R + j\omega M)^2}$$

where $Z_{a1} = R_{ao} + R_1 + R + j(X_{ao} + \omega L_1)$

$$= R_{a1} + jX_{a1}$$

and $\quad Z_2 = R_2 + R + j(\omega L_2 - \dfrac{1}{\omega C_2})$.

i.e., $j\omega M$ is replaced by $(R + j\omega M)$. The impedance reflected from the aerial into the tuned circuit becomes

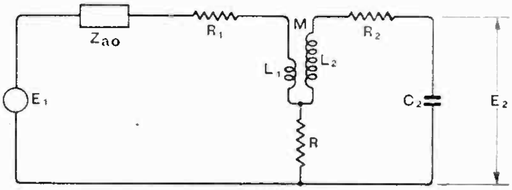


Fig. 2.—*Combined mutual inductance and resistance coupling.*

$$\frac{-(R + j\omega M)^2}{Z_{a1}} = \frac{-(R + j\omega M)^2 (R_{a1} - jX_{a1})}{|Z_{a1}|^2}$$

$$= \frac{(\omega^2 M^2 - R^2 - 2j\omega MR)(R_{a1} - jX_{a1})}{|Z_{a1}|^2}$$

$$= \frac{(\omega^2 M^2 - R^2) R_{a1} - 2R\omega M X_{a1}}{|Z_{a1}|^2}$$

$$-j\left[\frac{X_{a1}(\omega^2 M^2 - R^2) + 2\omega M R R_{a1}}{|Z_{a1}|^2} \right]$$

Generally $\omega M \gg R$ and $X_{a1}\omega M \gg 2R R_{a1}$ so that the reflected aerial impedance is

$$Z_{ar} = \frac{\omega^2 M^2 R_{a1} - 2R\omega M X_{a1}}{|Z_{a1}|^2} - j\,\frac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2}$$

The reflected resistance from the aerial circuit is appreciably increased but the reflected reactance is practically unchanged. Hence both transfer voltage ratio and selectivity factor are reduced by the inclusion of positive resistance in the coupling impedance. The former is

$$\frac{E_2}{E_1} = \frac{R + j\omega M}{j\omega C_2 Z_{a1}\left[R_2 + R + \dfrac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2} - \dfrac{2R\omega M X_{a1}}{|Z_{a1}|^2}\right]} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

and Selectivity Ratio

$$= \frac{R_2}{R_2 + R + \dfrac{\omega^2 M^2 R_{a1}}{|Z_{a1}|^2} - \dfrac{2R\omega M X_{a1}}{|Z_{a1}|^2}} \quad \ldots \quad (12)$$

Mistune ratio is practically unchanged from the value obtained in expression (8b).

1.3.—*Generalised Formulae for* $\dfrac{E_2}{E_1}$, *Selectivity Ratio and Mistune Ratio*

The analysis of Section 1.2 may be used as a basis for developing generalised formulae applicable to any type of coupling which exists as, or is convertible into, a T section network. For example, the generalised form of Fig. 2 is the network of Fig. 3, and the two figures are identical when

$$Z_\alpha + Z_\beta = Z_{a1} = R_{ao} + R_1 + R + j(X_{ao} + \omega L_1)$$

$$Z_\beta = R + j\omega M$$

$$Z_\Delta = R_2 + j\omega(L_2 - M)$$

$$Z_\lambda = \frac{-j}{\omega C_2}$$

By assuming that $Z_\alpha = R_\alpha + jX_\alpha$, etc., and using expression (11), the generalised formula for transfer voltage ratio is

$$\frac{E_2}{E_1} = \frac{Z_\beta Z_\lambda}{(Z_\alpha + Z_\beta)\left[R_\beta + R_\Delta + R_\lambda + \dfrac{X_\beta^2(R_\alpha + R_\beta)}{|Z_\alpha + Z_\beta|^2} - \dfrac{2R_\beta X_\beta(X_\alpha + X_\beta)}{|Z_\alpha + Z_\beta|^2}\right]} \quad \ldots \quad \ldots \quad (13a)$$

where $|Z_\alpha + Z_\beta|^2 = (R_\alpha + R_\beta)^2 + (X_\alpha + X_\beta)^2$

The generalised formula for Selectivity Ratio

$$S_R = \frac{R_2}{\left[R_\beta + R_\Delta + R_\lambda + \dfrac{X_\beta^2(R_\alpha + R_\beta)}{|Z_\alpha + Z_\beta|^2} - \dfrac{2R_\beta X_\beta(X_\alpha + X_\beta)}{|Z_\alpha + Z_\beta|^2}\right]} \quad \ldots \quad \ldots \quad (14a)$$

To obtain the generalised formula for mistune ratio it is necessary to start with the fundamental equation (7a) for C_2.

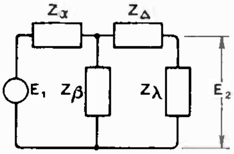


Fig. 3.—*Generalised T section network.*

$$C_2 = \frac{1}{\omega\left[\omega L_2 - \dfrac{\omega^2 M^2 X_{a1}}{|Z_{a1}|^2}\right]}$$

$$= \frac{1}{\omega\left[X_\beta + X_\Delta - \dfrac{X_\beta^2(X_\alpha + X_\beta)}{|Z_\alpha + Z_\beta|^2}\right]}$$

But $\dfrac{1}{\omega} = \omega L^2 C_{20}$

$$\therefore C_2 = C_{20}\left[\frac{\omega L_2}{X_\beta + X_\Delta - \dfrac{X_\beta^2(X_\alpha + X_\beta)}{|Z_\alpha + Z_\beta|^2}}\right]$$

and $\Delta C_2 = C_2 - C_{20}$

$$= C_{20}\left[\frac{\omega L_2}{X_\beta + X_\Delta - \dfrac{X_\beta^2(X_\alpha + X_\beta)}{(Z_\alpha + Z_\beta)^2}} - 1\right] \quad (15)$$

Mistune Ratio, $M_R = \dfrac{\Delta C_2}{C_{20}}$

$$= \left[\frac{\omega L_2}{X_\beta + X_\Delta - \dfrac{X_\beta^2(X_\alpha + X_\beta)}{|Z_\alpha + Z_\beta|^2}} - 1\right] \quad (16a)$$

Expressions (14a) and (16a) may be written more simply by combining some of the terms into a single term

Let $R_{a1} = R_\alpha + R_\beta$, the series resistance of the aerial and coupling circuit with the secondary coil disconnected.

$X_{a1} = X_\alpha + X_\beta$, the series reactance of the same circuit

$R_{21} = R_\beta + R_\Delta + R_\lambda$, the series resistance of the secondary and coupling circuit with the aerial disconnected.

$X_{21} + X_\lambda = X_\beta + X_\Delta + X_\lambda$, the series reactance of the same circuit.

$$x = \frac{X}{|Z_a + Z_\beta|} = \frac{X_\beta}{|Z_{a1}|}.$$

then

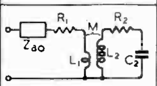
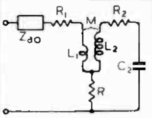
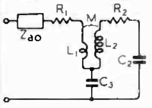
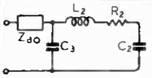
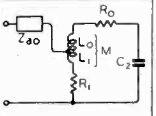
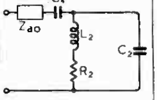
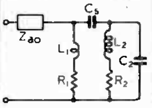
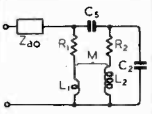
$$S_R = \frac{1}{\dfrac{R_{21}}{R_2} + \dfrac{x^2\left[R_{a1} - \dfrac{2R_\beta X_{a1}}{X_\beta}\right]}{R_2}} \qquad (14b)$$

and

$$M_R = \frac{\omega L_2}{X_{21} - x^2 X_{a1}} - 1 = \frac{1}{\dfrac{\omega L_2}{\omega L_2 - X_{21} + x^2 X_{a1}} - 1} \qquad (16b)$$

TABLE I. AERIAL COUPLING FORMULAE. $R_{a1} = R_a + R_\beta$; $R_{21} = R_\beta + R_\Delta + R_\lambda$;

* For these expressions

FORM OF COUPLING	CIRCUIT	R_α	X_α	R_β	X_β	R_Δ	X_Δ	R_{a1}	X_{a1}
1 MUTUAL INDUCTANCE		$R_{ao}+R_1$	$X_{ao}+\omega(L_1-M)$	0	ωM	R_2	$\omega(L_2-M)$	$R_{ao}+R_1$	$X_{ao}+\omega L_1$
2 MUTUAL INDUCTANCE AND SHUNT RESISTANCE		$R_{ao}+R_1$	$X_{ao}+\omega(L_1-M)$	R	ωM	R_2	$\omega(L_2-M)$	$R_{ao}+R_1+R$	$X_{ao}+\omega L_1$
3 MUTUAL INDUCTANCE AND SHUNT CAPACITANCE (a)+M (b)−M		(a) $R_{ao}+R_1$ (b) $R_{ao}+R_1$	$X_{ao}+\omega(L_1-M)$ $X_{ao}+\omega(L_1+M)$	0 0	$\omega M-\frac{1}{\omega C_3}$ $-\omega M-\frac{1}{\omega C_3}$	R_2 R_2	$\omega(L_2-M)$ $\omega(L_2+M)$	$R_{ao}+R_1$ $R_{ao}+R_1$	$X_{ao}+\omega L_1-\frac{1}{\omega C_3}$ $X_{ao}+\omega L_1-\frac{1}{\omega C_3}$
4 SHUNT CAPACITANCE		R_{ao}	X_{ao}	0	$-\frac{1}{\omega C_3}$	R_2	ωL_2	R_{ao}	$X_{ao}-\frac{1}{\omega C_3}$
5 TAPPED TUNED COIL $R_1+R_o=R_2$ $L_1+L_o+2M=L_2$		R_{ao}	$X_{ao}-\omega M$	R_1	$\omega(L_1+M)$	R_o	$\omega(L_o+M)$	$R_{ao}+R_1$	$X_{ao}+\omega L_1$
6 SERIES CAPACITANCE		R_{ao}	$X_{ao}-\frac{1}{\omega C_4}$	R_2	ωL_2	0	0	$R_{ao}+R_2$	$X_{ao}+\omega L_2-\frac{1}{\omega C_4}$
7 SERIES CAPACITANCE AND SHUNT INDUCTANCE $A=\frac{1}{B\omega C_5}$; $B=\frac{1}{\omega C_5}-\omega(L_1+L_2)$		$R_{ao}+A\left[R_1+\frac{(R_1+R_2)\omega L_1}{B}\right]$	$X_{ao}+A\omega L_1$	$-\frac{\omega^2L_1L_2}{B^2}(R_1+R_2)$	$-\frac{\omega^2L_1L_2}{B}$	$A\left[R_2+\frac{(R_1+R_2)\omega L_2}{B}\right]$	$A\omega L_2$	$R_{ao}+AR_1+A\left[\frac{(R_1-R_2)}{B}\left(1-\frac{\omega L_2}{AB}\right)\omega L_1\right]$	$X_{ao}+A\omega L_1-\frac{\omega^2L_1L_2}{B}$
8 MUTUAL INDUCTANCE AND SERIES CAPACITANCE $A_1=\frac{1}{B_1\omega C_5}$ (a)+M (b)−M (a) $B_1=\frac{1}{\omega C_5}-\omega(L_1+L_2-2M)$ (b) $B_1=\frac{1}{\omega C_5}-\omega(L_1+L_2+2M)$		$R_{ao}+AR_1$ (a) $+\frac{A_1}{B_1}(R_1+R_2)\omega(L_1-M)$ (b) $+\frac{A_1}{B_1}(R_1+R_2)\omega(L_1+M)$	X_{ao} $+A_1\omega(L_1-M)$ $+A_1\omega(L_1+M)$	$R_{\beta+}$ $R_{\beta-}$	$\omega M-\frac{\omega^2(L_1-M)(L_2-M)}{B_1}$ $-\omega M-\frac{\omega^2(L_1+M)(L_2+M)}{B_1}$	$A_1R_2+\frac{A_1(R_1+R_2)\,\omega(L_2-M)}{B_1}$ $A_1R_2+\frac{A_1(R_1+R_2)\,\omega(L_2+M)}{B_1}$	$A_1\omega(L_2-M)$ $A_1\omega(L_2+M)$	$R_\alpha+R_{\beta+}$ $R_\alpha+R_{\beta-}$	$X_{ao}+A_1\omega L_1+(1-A_1)\omega M-\frac{\omega^2(L_1-M)(L_2-M)}{B_1}$ $X_{ao}+A_1\omega L_1+(A_1-1)\omega M-\frac{\omega^2(L_1+M)(L_2+M)}{B_1}$

$$R_{\beta+} = -\left[\frac{R_2\,\omega(L_1-M)+R_1\,\omega(L_2-M)}{B_1} + \frac{\omega^2(L_1-M)(L_2-M)(R_1+R_2)}{B_1{}^2}\right]$$

If $R_{a1} \ll X_{a1}$, a further simplification is possible for $x = \frac{X_\beta}{X_{a1}}$ and

$$S_R = \frac{1}{\frac{R_{21}}{R_2} + \frac{x^2 R_{a1}}{R_2} - \frac{2xR_\beta}{R_2}} \quad \dots \quad \dots \quad (14c)$$

$$M_R = \frac{1}{\frac{\omega L_2}{\omega L_2 - X_{21} + xX_\beta} - 1} \quad \dots \quad (16c)$$

If coupling is by mutual inductance $X_{21} = \omega L_2$ and

$$M_R = \frac{1}{\frac{\omega L_2}{xX_\beta} - 1} \quad \dots \quad \dots \quad \dots \quad (16d)$$

and generally for other forms of shunt coupling $X_{21} = \omega L_2 + X_\beta$, hence

$$M_R = \frac{1}{-\frac{\omega L_2}{X_\beta(1 - x)} - 1} \quad \dots \quad \dots \quad (16e)$$

$X_{a1} = X_a + X_\beta$; $X_{21} = X_\beta + X_\Delta$; $Z_{a1} = R_{a1} + jX_{a1}$; $R_\lambda = 0$; $X_\lambda = \frac{1}{\omega C_2}$

X is assumed to be $\frac{X_\beta}{X_{a1}}$

R_{21}	X_{21}	x	SELECTIVITY RATIO	MISTUNE RATIO	APPROXIMATE * SELECTIVITY RATIO	APPROXIMATE * MISTUNE RATIO
R_2	ωL_2	$\frac{\omega M}{Z_{a1}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}}$	$\frac{1}{\frac{\omega L_2}{x^2X_{a1}}-1}$		$\frac{1}{\frac{L_2}{Mx}-1}$
R_2+R	ωL_2	$\frac{\omega M}{Z_{a1}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R}{R_2}-\frac{2x^2X_{a1}R}{R_2X_\beta}}$	AS FOR I	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R}{R_2}(1-2x)}$	AS FOR I
R_2 R_2	$\omega L_2-\frac{1}{\omega C_3}$ $\omega L_2-\frac{1}{\omega C_3}$	$\frac{\omega M-\frac{1}{\omega C_3}}{Z_{a1}}$ $\frac{-\omega M-\frac{1}{\omega C_3}}{Z_{a1}}$	AS FOR I	$\frac{1}{\frac{\omega L_2}{x^2X_{a1}+\frac{1}{\omega C_3}}-1}$		$\frac{1}{\frac{L_2}{Mx+\frac{1}{\omega^2C_3}(1-x)}-1}$ $\frac{1}{\frac{L_2}{-Mx+\frac{1}{\omega^2C_3}(1-x)}-1}$
R_2	$\omega L_2-\frac{1}{\omega C_3}$	$\frac{-\frac{1}{\omega C_3}}{Z_{a1}}$	$\frac{1}{1+\frac{x^2R_{a0}}{R_2}}$	$\frac{1}{\frac{\omega L_2}{x^2X_{a1}+\frac{1}{\omega C_3}}-1}$		$\frac{1}{\frac{\omega^2L_2C_3}{(1-x)}-1}$
R_2	ωL_2	$\frac{\omega(L_1+M)}{Z_{a0}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_1}{R_2}\left(1-\frac{2x^2X_{a1}}{X_\beta}\right)}$	$\frac{1}{\frac{\omega L_2}{x^2X_{a1}}-1}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_1}{R_2}(1-2x)}$	$\frac{1}{\frac{L_2}{(L_1+M)x}-1}$
R_2	ωL_2	$\frac{\omega L_2}{Z_{a1}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}-\frac{2x^2X_{a1}}{X_\beta}}$	$\frac{1}{\frac{\omega L_2}{x^2X_{a1}}-1}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}-2x}$	$\frac{1}{\frac{1}{x}-1}$
$AR_2+\frac{A(R_1-R_2)}{B}\omega L_2\left(1-\frac{\omega L_1}{AB}\right)$	$A\omega L_2-\frac{\omega L_1L_2}{B}$	$\frac{-\omega^2L_1L_2}{BZ_{a1}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_\beta}{R_2}\left(1-\frac{2x^2X_{a1}}{X_\beta}\right)}$	$\frac{1}{\frac{\omega L_2}{(1-A)\omega L_2+\frac{\omega^2L_1L_2}{B}+x^2X_{a1}}-1}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_\beta}{R_2}(1-2x)}$	$\frac{1}{\frac{1}{(1-A)+\frac{\omega L_1}{B}(1-x)}-1}$
$R_{\beta+}+R_\Delta$ $R_{\beta-}+R_\Delta$	$A_1\omega L_2+(1-A_1)\omega M-\frac{\omega^2(L_1-M)(L_2-M)}{B_1}$ $A_1\omega L_2+(A_1-1)\omega M-\frac{\omega^2(L_1+M)(L_2+M)}{B_1}$	$\frac{-\omega M}{Z_{a1}}-\frac{\omega^2(L_1-M)(L_2-M)}{B_1Z_{a1}}$ $\frac{-\omega M}{Z_{a1}}-\frac{\omega^2(L_1+M)(L_2+M)}{B_1Z_{a1}}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_\beta}{R_2}\left[1-\frac{2x^2X_{a1}}{X_\beta}\right]}$	$\frac{1}{\frac{\omega L_2}{(1-A_1)\omega(L_2-M)+\frac{\omega^2(L_1-M)(L_2-M)}{B_1}+x^2X_{a1}}-1}$ $\frac{1}{\frac{\omega L_2}{(1-A_1)\omega(L_2+M)+\frac{\omega^2(L_1+M)(L_2+M)}{B_1}+x^2X_{a1}}-1}$	$\frac{1}{1+\frac{x^2R_{a1}}{R_2}+\frac{R_\beta}{R_2}(1-2x)}$	$\frac{1}{\frac{1}{\frac{(1-A)(L_2-M)}{L_2}+\frac{\omega(L_1-M)(L_2-M)(1-x)}{B_1L_2}+\frac{Mx}{L_2}}-1}$ $\frac{1}{\frac{1}{\frac{(1-A_1)(L_2+M)}{L_2}+\frac{\omega(L_1+M)(L_2+M)(1-x)}{B_1L_2}+\frac{Mx}{L_2}}-1}$

$$R_{\beta-} = -\left[\frac{R_2\,\omega(L_1+M)+R_1\omega(L_2+M)}{B_1} + \frac{\omega^2(L_1+M)(L_2+M)(R_1+R_2)}{B_1^2}\right]$$

as a rule $R_\beta \ll X_\beta$ and the transfer voltage ratio may be written,

$$T_R = \frac{xZ_\lambda S_R}{R_2}$$

R_λ is usually very small so that

$$Z_\lambda = X_\lambda = -\frac{1}{\omega C_2} = -\frac{1}{\omega C_{20}\left(1 + \frac{\Delta C_2}{C_{20}}\right)}$$

$$= -\frac{1}{\omega C_{20}(1 + M_R)}$$

$$\text{and } T_R = \frac{x S_R}{\omega C_{20} R_2 (1 + M_R)} = \frac{x Q_2 S_R}{(1 + M_R)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (13b)$$

$$\simeq x Q_2 \quad \ldots \quad \ldots \quad \ldots \quad (13c)$$

when x is much less than its optimum value $\sqrt{\frac{R_2}{R_{a1}}}$ (see expression 5). For $x = 0.4$ and $0.7\sqrt{\frac{R_2}{R_{a1}}}$ the approximate value of T_R is about 10 per cent. and 25 per cent. high respectively. The identity between (13c) and (9c) may be noted. The values of R_a, X_a, etc. together with those for R_{a1}, X_{a1}, etc. are given in Table I for various types of coupling.

TABLE 2

S_R	M_R	T_R	
$\dfrac{1}{1 + \dfrac{x^2 R_{a1}}{R_2} - \dfrac{2x^2 X_{a1}}{X_\beta}}$	$\dfrac{1}{\dfrac{\omega L_2}{x^2 X_{a1}} - 1}$	$\dfrac{x Q_2 S_R}{(1 + M_R)}$	$x = \dfrac{\omega L_2}{\lvert Z_{a1}\rvert}$ $X_{a1} = X_{a0} + \omega L_2 - \dfrac{1}{\omega C_4}$ $R_{a1} = R_{a0} + R_2$ $Z_{a1} = R_{a1} + jX_{a1}$
$\dfrac{1}{1 + \dfrac{R_{a0}\omega L_2 Q_2}{\lvert Z'_{a1}\rvert^2}}$	$\dfrac{X'_{a1}}{\omega C_{20}\lvert Z'_{a1}\rvert^2}$	$\dfrac{1}{\dfrac{R_{a0}}{\lvert Z'_{a1}\rvert} + \dfrac{\lvert Z'_{a1}\rvert}{\omega L_2 Q_2}}$	Colebrook Analysis $X'_{a1} = X_{a0} - \dfrac{1}{\omega C_4}$ $Z'_{a1} = R_{a0} + jX'_{a1}$

Amended formulae for S_R and M_R are also included; T_R is not listed because expression (13b) shows its direct connection with M_R and S_R. The terms used to designate the couplings are those which are applied to network analysis, *i.e.* an impedance joining the top or any tapping point on the secondary coil is called a series coupling (see 6 in Table I) and an impedance common to both aerial and secondary circuits is called a shunt coupling (see 3 and 4). The effect of the sign of the mutual inductance when combined with additional reactance coupling can be noted in 3 and 8. The equivalent T section networks for the tapped tuned circuit (5) and the combined couplings of 7 and 8 are developed in appendices 1, 2a and b.

Colebrook has made a comprehensive analysis of series capacitance coupling* and his expressions for T_R, S_R and M_R are listed in Table 2 with those obtained from the above analysis. Though expressed in a slightly different form they give the same results in any numerical example.

The approximate expressions, (14c), (16d), (16e) and (13c), for the selectivity, mistune and transfer voltage ratios are very useful for estimating the trend of these ratios over a given tuning range.

1.4.—*Variation of Selectivity Ratio with Frequency*

The variation of the resistance components over a given tuning range can be ignored since S_R is expressed as a ratio of these components and the tendency is for numerator and denominator to vary together as the tuning frequency is increased from the low to the high end of the range.

When X_β and X_{a1} are the same type of reactance, viz., both inductive or both capacitive, x is independent of frequency and so is selectivity ratio.

If X_β is inductive and X_{a1} capacitive, x is proportional to $-f^2$; hence S_R decreases as the tuning frequency is increased. The reverse is true for X_β capacitive and X_{a1} inductive; x is proportional to $-\frac{1}{f^2}$ and

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* The Balance of Power in Aerial Tuning Circuits, *Wireless Engineer*, March, 1930.

S_R increases as the tuning frequency is increased.

1.5.—*Variation of Mistune Ratio with Frequency*

For an inductive X_β and X_{a1}, x and $\frac{\omega L_2}{X_\beta}$ in expression (16e) are positive constants; hence mistune ratio is negative and independent of frequency. When X_β and X_{a1} are capacitive, x is a positive constant but $\frac{\omega L_2}{X_\beta}$ is negative and proportional to $-f^2$. Since X_β is generally $\ll \omega L_2$ and $x \ll 1$, $\frac{\omega L_2}{-X_\beta(1-x)} > 1$, and M_R is positive, increasing as the tuning frequency is increased.

If X_β is capacitive and X_{a1} is inductive $\left(x \propto -\frac{1}{f^2}\right)$, $\frac{\omega L_2}{X_\beta}$ is negative and proportional to $-f^2$.

$$M_R = \frac{1}{\dfrac{Kf^2}{1+\dfrac{K_1}{f^2}} - 1}$$

$\frac{\omega L_2}{-X_\beta(1-x)} > 1 > x$ and M_R is therefore positive, decreasing as the tuning frequency is increased.

The modified expression (16d) for mutual inductance coupling gives for X_{a1} capacitive $(x \propto -f^2)$

$$M_R = \frac{1}{-\dfrac{K}{f^2} - 1}$$

Hence M_R is negative and it increases as f is increased. When X_{a1} is inductive M_R is positive $\left(\frac{L_2}{Mx} > 1\right)$ and constant.

1.6.—*Variation of Transfer Voltage Ratio with Frequency*

Expression 13c shows T_R to be proportional to x.

For convenience these conclusions are tabulated below. The trends of the capacitance correction ΔC_2 and of the frequency error, if the secondary circuit is not retuned, are also indicated in Table 3.

1.7.—*Aerial Terminal Impedance and S_R, M_R, and T_R*

It is important next to consider the effect on S_R, M_R, and T_R, of varying the aerial terminal impedance. Taking first increasing R_{a0}; with a high value of X_{a1}, R_{a1} is increased but Z_{a1} and x are almost unchanged.

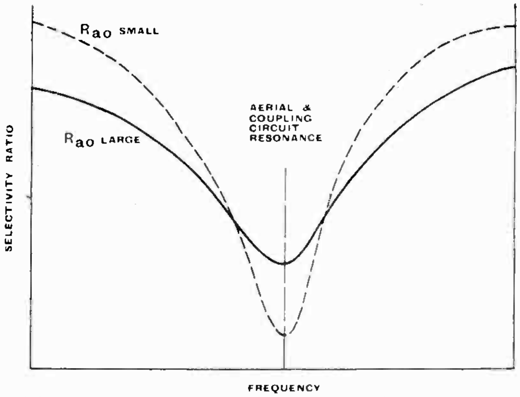

Fig. 4.—*Selectivity ratio for two values of R_{a0} over a frequency range including resonance of the aerial and coupling circuit.*

TABLE 3

TUNING FREQUENCY INCREASING

X_β	X_{a1}	x	S_R	M_R	ΔC_2	T_R	Frequency Error
Inductive	Inductive	Constant	Constant	Constant	Decreases −	Constant	Increases −
Capacitive	Capacitive	Constant	Constant	Decreases +	Decreases +	Constant	Decreases +
Inductive	Capacitive	$-Kf^2$	Decreases	Increases −	Almost constant −	Increases	Increases −
Capacitive	Inductive	$-K/f^2$	Increases	Decreases +	Decreases +	Decreases	Almost constant +
Mutual Inductance	Inductive	Constant	Constant	Constant +	Decreases +	Constant	Almost constant +
Mutual Inductance	Capacitive	$-Kf^2$	Decreases	Increases −	Slight increase −	Increases	Increases −

Hence mistune ratio (16b) is unchanged, S_R is decreased because the second term in (14c) is increased and consequently T_R is decreased (see expression 13b). If in the tuning range aerial and coupling circuit resonance is approached, i.e. $X_{a1} \rightarrow 0$, M_R is still almost unchanged but the second term in (14c) approaches $\frac{X_{\beta}^2}{R_{a1}R_2}$ and so S_R tends to increase. The general shape of the selectivity ratio curve over a tuning range in which $X_{a1} = 0$ is shown in Fig. 4. The condition rarely occurs in practice and increase of R_{a0} normally decreases S_R. The trend of T_R is always to decrease with increasing R_{a0}.

Increase of aerial terminal reactance X_{a0} provided it has the same sign as X_{a1}, increases Z_{a1} and decreases x. Hence T_R is decreased and S_R increased. The statement needs qualification if the coupling reactance is initially greater than its optimum value, $Z_{a1}\sqrt{\frac{R_2}{R_{a1}}}$, for increase of Z_{a1} then causes the optimum coupling to be approached and so T_R increases. The normal decrease follows when optimum coupling is passed.

From (16b) mistune ratio is decreased if X_{a1} is negative (capacitive) and increased if X_{a1} is positive (inductive).

The results are set out in Tables 4a and b.

TABLE 4*a*. R_{a0} INCREASING

X_{a1}	x	S_R	M_R	T_R
Very large	Little affected	Decreased	Little affected	Decreased
Small and comparable with R_{a0}	Decreased	Increased	Little affected	Decreased

TABLE 4*b*. X_{a1} INCREASING

X_{a1}	x	S_R	M_R	T_R
Same sign as X_{a0}	Decreased	Increased	Decreased	Decreased if initial coupling $<$ optimum, increased if $>$ optimum.
Opposite sign to X_{a0}	Increased	Decreased	Increased	Increased if initial coupling $<$ optimum, decreased if $>$ optimum

(*To be concluded.*)

Further Notes on

Ganging Superheterodyne Receivers[*]

By Dr. Ing. Martin Wald

IN a previous paper[†] it was pointed out that the best padding curve—that with the smallest fault factor $\Delta f_{\max}$—is obtained if the four extreme values of the ganging fault Δf are made equal to each other (see equations 8 on page 107). Furthermore, approximate formulae were deduced (see equations 13 on page 108) for determining the adjusting points, that is, the frequencies at which Δf is zero. In the present article formulae are deduced for calculating directly the circuit components L_0, C_p, C_T, and the fault factor $\Delta f_{\max}$ and curves are given from which the quantities of interest in the designing and ganging of oscillator circuits can be read directly.

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[*] M.S. accepted by the Editor, November, 1940.

[†] *Wireless Engineer*, March, 1940, page 105.

Fig. 1 shows the usual diagram of an oscillator circuit and Fig. 2 the best padding curve with the four extreme values of Δf equal to each other. f_1 and f_4 are the ends of the frequency range in question. α_1, α_2 and α_3 the three adjusting frequencies, f_2 and f_3 the two frequencies where Δf reaches a maximum. Although f_1, f_4 and the intermediate frequency f_i are given, we introduce f_2 and f_3 as independent variables instead of f_1 and f_4, since in this way the calculation is considerably simplified. At the points f_2 and f_3 $\dfrac{d\Delta f}{df}$ becomes zero and thus at these points we have the relations

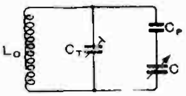


FIG. 1.—*Diagram of the oscillator circuit.*

$$\frac{d\Delta f}{df} = \frac{d(f_0 - f - f_i)}{df} = 0$$

$$\text{or} \quad \left(\frac{df_0}{df}\right) = 1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

On the other hand, for the oscillator frequency f_0, equation 18 in the paper referred to, gives

$$f_0^2 = \frac{x_2}{x_1}\,\frac{f^2 + x_3}{f^2 + x_2 + x_3} = \frac{x_2}{x_1} - \frac{x_2^2}{x_1} \cdot \frac{1}{f^2 + x_2 + x_3} \quad \ldots \quad \ldots \quad (2)$$

where

$$x_1 = \frac{L_0}{L}; \; x_2 = \frac{1}{4\pi^2 L C_T} \text{ and } x_3 = \frac{1}{4\pi^2 L C_p}$$

L being the inductance of the input circuit. From (2) it follows that

$$\frac{f_0}{f} \cdot \frac{df_0}{df} = \frac{x_2^2}{x_1} \cdot \frac{1}{(f^2 + x_2 + x_3)^2} \quad \ldots \quad (3)$$

From (1) and (3) we obtain

$$f_2^2 + x_2 + x_3 = \frac{x_2}{\sqrt{x_1}}\sqrt{\frac{f_2}{f_{02}}} \quad \ldots \quad (4)$$

$$\text{and } f_3^2 + x_2 + x_3 = \frac{x_2}{\sqrt{x_1}}\sqrt{\frac{f_3}{f_{03}}} \quad \ldots \quad (5)$$

which, substituted in (2), give

$$f_{02}^2 = \frac{x_2}{x_1} - \frac{x_2}{\sqrt{x_1}}\sqrt{\frac{f_{02}}{f_2}} \quad \ldots \quad \ldots \quad (6)$$

$$\text{and } f_{03}^2 = \frac{x_2}{x_1} - \frac{x_2}{\sqrt{x_1}}\sqrt{\frac{f_{03}}{f_3}} \quad \ldots \quad \ldots \quad (7)$$

where for f_{02} and f_{03} we can write from Fig. 2.

$$f_{02} = f_2 + f_i - \Delta f_{\max} \quad \ldots \quad \ldots \quad (8)$$

$$\text{and } f_{03} = f_3 + f_i + \Delta f_{\max} \quad \ldots \quad \ldots \quad (9)$$

From equations (4), (5), (6) and (7) we now calculate the four unknowns x_1, x_2, x_3 and $\Delta f_{\max}$. Subtracting (4) from (5) and (6) from (7) gives

$$f_3^2 - f_2^2 = \frac{x_2}{\sqrt{x_1}}\left(\sqrt{\frac{f_3}{f_{03}}} - \sqrt{\frac{f_2}{f_{02}}}\right) \quad \ldots \quad (10)$$

$$\text{and } f_{03}^2 - f_{02}^2 = \frac{x_2}{\sqrt{x_1}}\left(\sqrt{\frac{f_{03}}{f_3}} - \sqrt{\frac{f_{02}}{f_2}}\right) \quad (11)$$

On dividing (10) by (11) we obtain

$$\frac{f_3^2 - f_2^2}{f_{03}^2 - f_{02}^2} = \frac{\sqrt{f_2 f_3}}{\sqrt{f_{02} f_{03}}}$$

Since $(f_{03} + f_{02})^2 - (f_{03} - f_{02})^2 = 4 f_{03} f_{02}$

and $(f_3 + f_2)^2 - (f_3 - f_2)^2 = 4 f_3 f_2$

$$\frac{1}{(f_{03} - f_{02})^2} = \frac{1}{(f_3 - f_2)^2} - \frac{1}{(f_3 + f_2)^2} + \frac{1}{(f_{03} + f_{02})^2} \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

With regard to (8) and (9) we have further

$$\frac{1}{f_3 - f_2 + 2\Delta f_{\max}} = \frac{1}{f_3 - f_2} \times \sqrt{1 + \frac{(f_3 - f_2)^2}{(f_3 + f_2 + 2f_i)^2} - \frac{(f_3 - f_2)^2}{(f_3 + f_2)^2}} \quad (13)$$

We use the approximation $\sqrt{1 - \epsilon} \cong 1 - \dfrac{\epsilon}{2}$ for $\epsilon \ll 1$, which applies in all practical cases for the expression under the square root and obtain

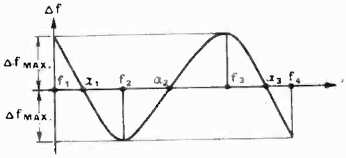


FIG 2.—*The best padding curve with the four extreme values of Δf equal to each other.*

$$\Delta f_{\max} \doteq \left(\frac{f_3 - f_2}{f_3 + f_2}\right)^3 f_i \, \frac{1 + \dfrac{f_i}{f_3 + f_2}}{\left(1 + \dfrac{2f_i}{f_3 + f_2}\right)^2} \quad (14)$$

Dividing equation (6) by (7) gives

$$\frac{f_{02}^2}{f_{03}^2} = \frac{\dfrac{1}{\sqrt{x_1}} - \sqrt{\dfrac{f_{02}}{f_2}}}{\dfrac{1}{\sqrt{x_1}} - \sqrt{\dfrac{f_{03}}{f_3}}}$$

$$\text{or } \sqrt{x_1} = \frac{1 - \dfrac{f_{02}{}^2}{f_{03}{}^2}}{\sqrt{\dfrac{f_{02}}{f_2}} - \sqrt{\dfrac{f_{03}{}^1}{f_3} \cdot \dfrac{f_{02}{}^2}{f_{03}{}^2}}} \quad \ldots \quad (15)$$

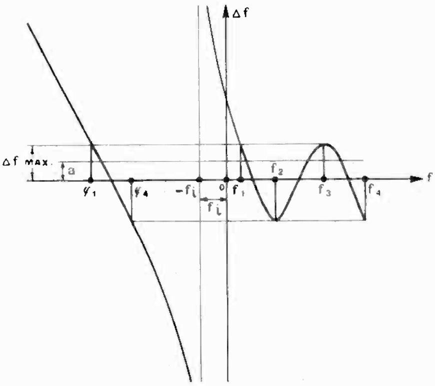


FIG. 3.—*The function* $\Delta f = \psi(f)$.

From (10)

$$\frac{x_2}{\sqrt{x_1}} = \frac{f_3{}^2 - f_2{}^2}{\sqrt{\dfrac{f_3}{f_{03}}} - \sqrt{\dfrac{f_2}{f_{02}}}} \quad \ldots \quad \ldots \quad (16)$$

and from (4), (5) and (15)

$$\frac{x_3}{f_3{}^2} = \frac{1 - \left(\sqrt{\dfrac{f_2 \cdot f_{03}}{f_3 \cdot f_{02}}}\right)^3}{\left(\dfrac{f_3}{f_2}\right)^2\left(\sqrt{\dfrac{f_2 \cdot f_{03}}{f_3 \cdot f_{02}}}\right)^3 - 1} \quad \ldots \quad (17)$$

The formulae (14), (15), (16) and (17) give the fault factor $\Delta f_{\max}$ and the circuit components L_0, C_T, C_p as functions of f_2, f_3 and f_i. We also have to express f_1 and f_4 as functions of f_2, f_3 and f_i. For this purpose we start from formula (20) of the earlier article (see *Wireless Engineer*, 1940, page 108.)

$$\Delta f = \frac{(f + f_i)^2(f^2 + x_2 + x_3) - \dfrac{x_2}{x_1}(f^2 + x_3)}{[-2(f + f_i) - \Delta f](f^2 + x_2 + x_3)}$$
$$= \Psi(f) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

The shape of this function is shown in Fig. 3. It will be seen that any horizontal line $\Delta f = a$ where a is a constant, lying between $-\Delta f_{\max}$ and $+\Delta f_{\max}$, gives four intersections with the curve Δf corresponding to the four roots of the equation of the fourth degree resulting from (18). For the limiting case $a = +\Delta f_{\max}$ or $a = -\Delta f_{\max}$ two of the intersections will coincide, which means that f_2 and f_3 are double roots of equation (18). If (18) be arranged according to the powers of f, we obtain

$$f^4 + f^3(2f_i + 2\Delta f)$$
$$+ f^2\left[x_2 + x_3 - \frac{x_2}{x_1} + (f_i + \Delta f)^2\right]$$
$$+ f(x_2 + x_3)(2f_i + 2\Delta f) + (x_2 + x_3)(f_i + \Delta f)^2$$
$$- \frac{x_2}{x_1}x_3 = \theta \quad \ldots \quad \ldots \quad \ldots \quad (19)$$

For $\Delta f = +\Delta f_{\max}$ the roots of equations (19) are, according to Fig. 3, f_3, f_3, f_1 and ϕ_1. Thus we can write

$$(f - f_3)(f - f_3)(f - f_1)(f - \phi_1) = \theta \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (20)$$

The expressions (19) and (20) are identical for all values of f, and therefore the coefficients of the same power of f must be

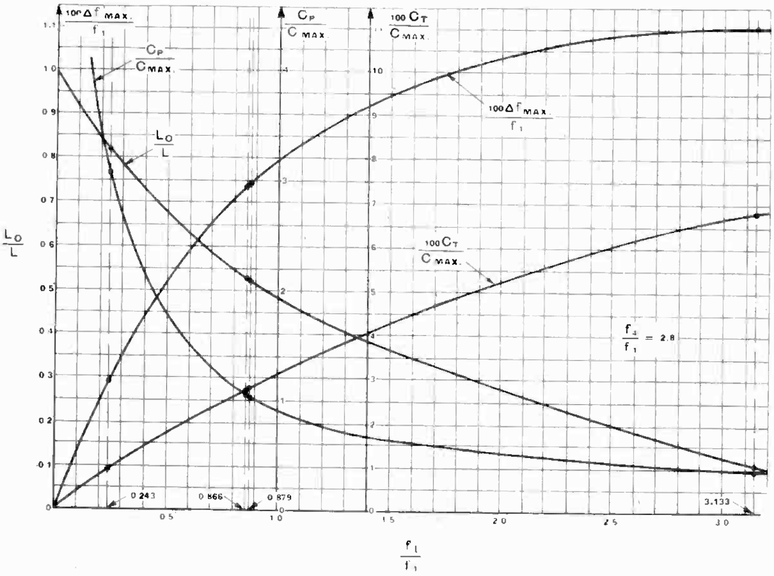


FIG. 4.—*Circuit components and fault factor for the case* $f_4/f_1 = 2.8$.

equal in both expressions. Writing these down for the 1st and 3rd power of f we obtain

$$(x_2 + x_3)(2f_i + 2\Delta f) = -2f_3 f_1 \phi_1 - f_3^2(\phi_1 + f_1) \quad \ldots \quad \ldots \quad (21)$$

$$2f_i + 2\Delta f = -\phi_1 - f_1 - 2f_3 \quad \ldots \quad (22)$$

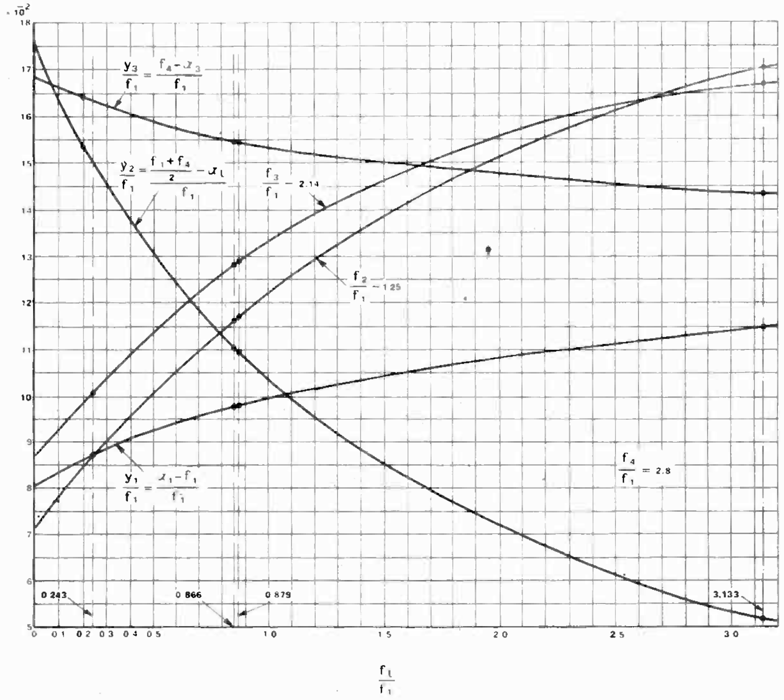


FIG. 5.—*Characteristic points of the padding curve for the case* $f_4/f_1 = 2{\cdot}8$.

Eliminating ϕ_1 from (21) and (22) gives an equation of 2nd degree in f_1 the solution of which gives

$$f_1 = -f_{03} + \sqrt{f_{03}^2 - f_3 f_{03} + (x_2 + x_3)\frac{f_i + \Delta f}{f_3}} \quad \ldots \quad \ldots \quad \ldots \quad (23)$$

For $\Delta f = -\Delta f_{\max}$ the roots of equation (19) are, according to Fig. 3, f_2, f_2, f_4 and ϕ_4. By similar considerations we obtain for f_4 the relation

$$f_4 = -f_{02} + \sqrt{f_{02}^2 - f_2 f_{02} + (x_2 + x_3)\frac{f_i - \Delta f}{f_2}} \quad \ldots \quad \ldots \quad \ldots \quad (24)$$

By substituting for x_2 and x_3 from (16) and (17) we obtain

$$f_i = -f_{03} + \sqrt{(f_i + \Delta f)\left[f_i + \Delta f + f_3 \frac{1 - (f_2/f_3)^2}{1 - \sqrt{\frac{f_2}{f_{02}} \cdot \frac{f_{03}}{f_3}}}\right]} \quad \ldots \quad \ldots \quad \ldots \quad (25)$$

$$f_4 = -f_{02} + \sqrt{(f_i - \Delta f)\left[f_i - \Delta f + f_2 \frac{1 - (f_3/f_2)^2}{1 - \sqrt{\frac{f_{02}}{f_2} \cdot \frac{f_3}{f_{03}}}}\right]} \quad \ldots \quad . \quad (26)$$

In Figs. 4 and 5 we give a graphical representation of the formulae deduced above for the practically important case $\frac{f_4}{f_1} = 2{\cdot}8$. As independent variable we have on the horizontal axis the ratio of the intermediate frequency f_i to the lowest input frequency f_1 of the frequency range in question. In Fig. 4 we have plotted against $\frac{f_i}{f_1}$ the following quantities:

$$x_1 = \frac{L_0}{L} = \frac{\text{Inductance of the oscillator circuit}}{\text{Inductance of the input circuit}}$$

$$\frac{f_1^2}{x_3} = \frac{C_p}{C_{\max}} = \frac{\text{Capacitance of the padding condenser}}{\text{Capacitance of the input circuit at the lowest frequency } f_1}$$

$$\frac{100 f_1^2}{x_2} = \frac{100\, C_T}{C_{\max}} = \frac{\text{100-times the capacitance of the trimmer condenser}}{\text{Capacitance of the input circuit at the lowest frequency } f_1}$$

$$\frac{100\Delta f_{\max}}{f_1} = \frac{\text{100-times the maximum ganging fault}}{\text{the lowest input frequency}}$$

In Fig. 5 are represented $\frac{f_2}{f_1}$ and $\frac{f_3}{f_1}$ resulting from equations (25) and (26), furthermore the values of $\frac{y_1}{f_1}$, $\frac{y_2}{f_1}$, and $\frac{y_3}{f_1}$ resulting from the approximate formulae (13) of the earlier article (page 108).

As a practically important application we will determine the circuit components for $f_i = 470$ kc/s and $f_i = 130$ kc/s respectively, both for the medium- and long-wave ranges.

With the intermediate frequency $f_i = 130$ kc/s, $\frac{f_i}{f_1} = \frac{130}{535} = 0.243$ for the medium frequency range. This gives from Figs. 4 and 5 :

L_0/L	$\frac{C_p}{C_{max}}$	$\frac{100 C_T}{C_{max}}$	Δf_{max} kc/s	α_1 kc/s	α_2 kc/s	α_3 kc/s	f_2 kc/s	f_3 kc/s
0·82	3·12	0·94	1·6	581·5	936	1412	715·5	1199

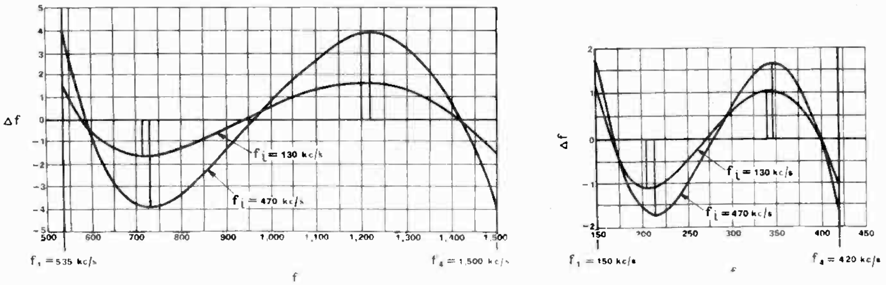


FIG. 6.—*The best padding curves for medium and long waves, with the intermediate frequency $f_i = 470$ kc/s and $f_i = 130$ kc/s respectively.*

For medium waves and the intermediate frequency $f_i = 470$ kc/s we have :

$$f_4 = 1500 \text{ kc/s}, f_1 = \frac{f_4}{2{\cdot}8} = 535 \text{ kc/s},$$

$$\frac{f_i}{f_1} = \frac{470}{535} = 0.879.$$

For $\frac{f_i}{f_1} = 0.879$ we read directly from Fig. 4 and Fig. 5 :

L_0/L	$\frac{C_p}{C_{max}}$	$\frac{100 C_T}{C_{max}}$	Δf_{max} kc/s	α_1 kc/s	α_2 kc/s	α_3 kc/s	f_2 kc/s	f_3 kc/s
0·52	1·04	2·8	3·96	587·5	959	1416	731	1215

For long waves and the intermediate frequency $f_i = 470$ kc/s we obtain :

$$f_1 = 150 \text{ kc/s}, f_4 = 2{\cdot}8, f_1 = 420 \text{ kc/s},$$

$$\frac{f_i}{f_1} = \frac{470}{150} = 3{\cdot}133.$$

For $\frac{f_i}{f_1} = 3{\cdot}133$ we obtain from Figs. 4 and 5 :

L_0/L	$\frac{C_p}{C_{max}}$	$\frac{100 C_T}{C_{max}}$	Δf_{max} kc/s	α_1 kc/s	α_2 kc/s	α_3 kc/s	f_2 kc/s	f_3 kc/s
0·098	0·36	6·85	1·65	167	277	398·5	213	346·5

For the long-wave range and $f_i = 130$ kc/s, $\frac{f_i}{f_1} = \frac{130}{150} = 0.886$. This gives from Figs. 4 and 5 :

L_0/L	$\frac{C_p}{C_{max}}$	$\frac{100 C_T}{C_{max}}$	Δf_{max} kc/s	α_1 kc/s	α_2 kc/s	α_3 kc/s	f_2 kc/s	f_3 kc/s
0·525	1·05	2·75	1·1	165	268·5	397	205	340·5

Fig. 6 shows the shape of the four padding curves in question. All the curves represented in Figs. 4 and 5 are available for frequency ranges, the ends of which give the ratio $\frac{f_4}{f_1} = 2{\cdot}8$. From the formulae above deduced, similar curves can be computed for any other value of the parameter $\frac{f_4}{f_1}$. The writer intends to publish in form of charts a complete representation allowing the quantities in question to be read directly for any value of the parameter $\frac{f_4}{f_1}$.

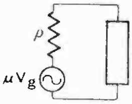
Equivalent Circuits of the Feedback Amplifier*

By Alan Fairweather, M.Sc., Grad. I.E.E.

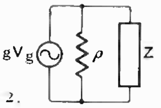
TABLE OF CONTENTS

1. Introduction

THE "constant voltage" and "constant current" equivalent circuits of the simple amplifier, which were described, it is believed, for the first time by H. W. Nichols[1] and H. F. Mayer[2] respectively, are well known. They have been employed by many workers, and, at various times, their utility has been made the subject of special mention, e.g. by N. R. Bligh[3], by B. J. Thompson[4] and by L. H. Bedford[5].



(*Left*) Fig. 1.



(*Right*) Fig. 2.

The object of this note is to demonstrate the existence of similar equivalent circuits for the feedback amplifier which may, in some cases, facilitate calculation. The artifice consists, essentially, of replacing the forward and feedback paths of the feedback amplifier by an equivalent forward path utilising an hypothetical valve whose constants are simply related to those of the valve employed in the actual forward path.

As an example of its use the cathode-coupled amplifier is briefly discussed.

2. The Equivalent Circuits

Let:

μ' and β' be the (complex) amplification factors of the forward and feedback paths.

μ, g and ρ be the valve constants, denoting the amplification factor, mutual conductance and internal resistance respectively.

μ_1, g_1 and ρ_1 refer to the valve in the equivalent forward path.

μ_2, g_2 and ρ_2 refer to the valve in the actual forward path.

Z be the load impedance.

The effective amplification factor, m say, of the simple valve amplifier is given by:

$$m = \mu Z/(Z + \rho) \quad .. \quad .. \quad .. \quad (1)$$

but: $\mu = g\rho \quad .. \quad .. \quad .. \quad .. \quad (2)$

and (1) may, therefore, be rewritten:

$$m = g/[(1/\rho) + (1/Z)] \quad .. \quad .. \quad (3)$$

From (1) and (3) the equivalent circuits of Figs. 1 and 2 follow immediately: here, V_g is the instantaneous grid voltage.

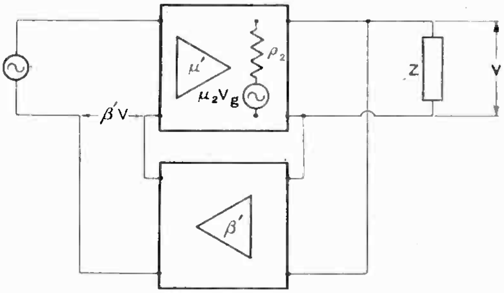


Fig. 3.

The familiar circuit of the feedback amplifier is shown in Fig. 3: following H. S. Black[6], the effective amplification factor of such a stage may be derived at once, for, referring to the figure:

$$\mu'(v + \beta'V) = V$$

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*MS. accepted by the Editor, November 1940.

[1] *Phys. Rev.*, Second Series, June 1919, Vol. 13, No. 6, p. 404.

[2] *Teleg.-u. Ferns.-Tech.*, November 1926, Vol. 15, No. 11, p. 335.

[3] *Experimental Wireless* (now *Wireless Engineer*), September 1930, Vol. 7, No. 84, p. 480.

[4] *Proc. Inst. Rad. Eng.*, March 1931, Vol. 19, No. 3, p. 434.

[5] *Journ. I.E.E.*, April 1934, Vol. 74, No. 448, p. 352.

[6] *Bell. S. Tech. Journ.*, January 1934, Vol. 13, p. 1.

So : $$V/v = \mu'/(1 - \mu'\beta') \quad \ldots \quad (4)$$

Also : $$\mu' = \mu_2 Z/(Z + \rho_2) \quad \ldots \quad (5)$$

which enables (4) to be written :

$$V/v = \frac{Z[\mu_2/(1 - \mu_2\beta')]}{Z + [\rho_2/(1 - \mu_2\beta')]} \quad \ldots \quad (6)$$

The form of this equation is identical with that of (1), and it follows, therefore, that the forward and feedback paths of the feedback amplifier may be replaced by a single forward path employing a valve whose constants are related to those of the valve in the original forward path by the following expressions :

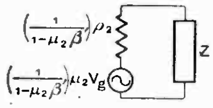


Fig. 4.

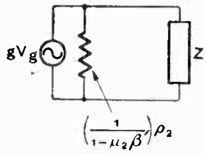


Fig. 5.

$$\mu_1 = \mu_2/(1 - \mu_2\beta') \quad \ldots \quad (7)$$

and : $$\rho_1 = \rho_2/(1 - \mu_2\beta') \quad \ldots \quad (8)$$

Now : $$\mu_2 = g_2\rho_2$$

and it is necessary that :

$$\mu_1 = g_1\rho_1$$

hence : $$g_1 = g_2 \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

With the aid of (7), (8), and (9), the equivalent circuits of Figs. 1 and 2 for the simple amplifier may be redrawn for the feedback amplifier : this has been done in Figs. 4 and 5. From these the effective amplification and output impedance are obvious by inspection.

3. Example : the Cathode-Coupled Amplifier

The circuit is shown in Fig. 6, and is seen to be a special case of the negative feedback amplifier where $\beta' = -1$ and $Z = R$. Positive grid bias is applied, but grid current flow is prevented by arranging that the "no signal" load voltage exceeds the grid bias, the grid thus being negative with respect to the cathode.

The definitions of the symbols which will be used are as follows, alternating quantities being specified by their instantaneous values :

i' = total anode current
I = "no signal" value of i'
i = alternating component of i'
e_g = grid-cathode voltage
E_g = grid-bias
V_g = grid drive
e_a = anode-cathode voltage
E_a = anode battery voltage
E_o = "no signal" load voltage
V_o = alternating component of load voltage

3.1 *Amplification*

The linear approximation to the valve characteristic may be written :

$$i' = g_2(e_g + e_a/\mu_2) \quad \ldots \quad \ldots \quad (10)$$

From the figure, ignoring the portion to the right of the dotted line :

$$E_o + V_o = R(I + i) \quad \ldots \quad \ldots \quad (11)$$

and when V_g is zero :

$$E_o = RI \quad \ldots \quad \ldots \quad \ldots \quad (12)$$

So : $$V_o = Ri \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

But :

$$i' = (I + i) \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

$$e_g = (E_g + V_g) - (E_o + V_o) \quad (15)$$

$$e_a = E_a - (E_o + V_o) \quad \ldots \quad (16)$$

$$V_o = Ri \quad \ldots \quad \ldots \quad \ldots \quad (17)$$

Substituting (14), (15), and (16) in (10) and reducing with the aid of (11) :

$$(I + i) = g_2\left\{\frac{(E_g + V_g) + E_a/\mu_2}{1 + g_2R(1 + 1/\mu_2)}\right\} \quad \ldots \quad (18)$$

When V_g is zero, i is zero, so :

$$I = g_2\left\{\frac{E_g + E_a/\mu_2}{1 + g_2R(1 + 1/\mu_2)}\right\} \ldots \quad (19)$$

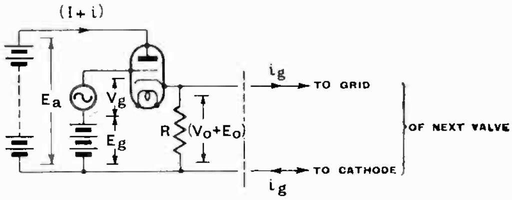


Fig. 6.

Subtracting (19) from (18) and substituting in (17) it follows that :

$$V_o/V_g = \mu_2R/(R + \rho_2 + \mu_2R) \quad \ldots \quad (20)$$

an expression which is self-evident from an inspection of Fig. 4 when β' and Z are replaced by -1 and R respectively.

3.2 *Output Impedance*

When grid current, i_g, flows in the following valve, it flows, conventionally, from grid to cathode. It therefore enters and leaves the drive stage as shown by the portion of Fig. 6 to the right of the dotted line. If the output impedance be R_e then :

$$R_e = \frac{d}{di_g}\left[-(E_o + V_o)\right] \quad \ldots \quad (21)$$

Rewriting (15), (16) and (17), so as to take account of i_g :

$$e_g = (E_g + V_g) - R(I + i - i_g) \quad (22)$$

$$e_a = E_a - R(I + i - i_g) \quad \ldots \quad (23)$$

$$(E_o + V_o) = R(I + i - i_g) \quad \ldots \quad \ldots \quad (24)$$

Substituting for $(E_o + V_o)$ in (21) from (24), and again for $(I + i)$ from (10), (14), (22) and (23), there results, after some reduction :

$$R_e = \frac{R[\rho_2/(1 + \mu_2)]}{R + [\rho_2/(1 + \mu_2)]} \quad \ldots \quad (25)$$

and this expression is again immediately apparent from Fig. 5 with the same substitutions as before.

3.3 *General*

In passing, it may be of interest to point out the salient features of the cathode-coupled amplifier. From (20) it appears that, if g_2R and μ_2 are both large, $V_o = V_g$ (approx.), and the stage has an amplification factor of unity. If g_2 is about 4 mA/V, this condition obtains if R exceeds say 1000 ohms. Further, the value of the effective impedance, given in (25), is clearly less than the corresponding expression for the simple amplifier, i.e. $R\rho_2/(R + \rho_2)$. Taking the same value of g as before, and a value of ρ_2 of 2000, R_e is found to be of the order of 200 ohms. The utility of the arrangement as a low impedance drive stage for Class B amplifiers is obvious.

4. Acknowledgment

This note was written during the course of some work carried out partly in the Signalling Apparatus Laboratory of the Post Office Engineering Research Station, and partly in the Electrotechnics Department of the Victoria University of Manchester, during January 1937. The author's thanks are due, therefore, both to Captain B. S. Cohen, O.B.E., F.Inst.P., M.I.E.E., and the late Professor R. Beattie, D.Sc., for the facilities provided, and to Dr. F. C. Williams, D.Sc., D.Phil., A.M.I.E.E., for assistance and helpful discussion.

Correspondence

"A Theory of the Practical Triode"

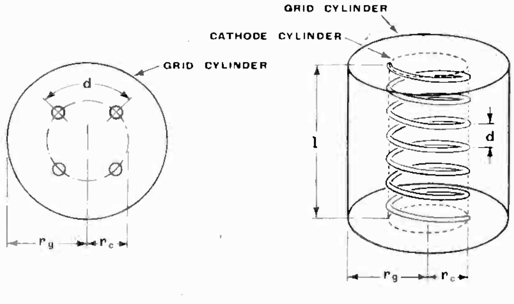
To the Editor, "The Wireless Engineer."

SIR,—In connection with my article under the above heading in the February issue of *The Wireless Engineer*, I wish to call attention to two points.

The first is a correction to the notation on page 52 where, in equ. 33, in the two preceding equations, in equ. 35 and those following, and in the one preceding 34, b_2' should of course be replaced by b_1' $(= b_2' - b_2)$. Also, $q^{3/4} = b_2'/b_1'$. It is regretted that this error, which occurred in the transcription from the original calculation to the manuscript, should have been undetected until now.

Also, in equ. 28 on page 51, $\lambda_1\lambda'$ should read λ_1/λ'.

Secondly, the theory is readily extended to cylindrical electrode systems of the type used in large transmitting triodes.



(a) (b)

Thus with the filament arranged either as one or two loops (approximating to two or four parallel wires arranged as a cylinder as in Fig. a) or as a spiral (Fig. b), the equation corresponding to 8 runs :

$$k = 14.6 \times 10^{-6}\,\frac{l}{r_g\beta^2}\cdot\frac{4\,(r_g - r_c)}{d}\cdot f$$

with $d/(r_g - r_c)$ replacing d/b_1 of Fig. 3, and β is Langmuir's constant.

$$\beta = \log\frac{r_g}{r_c} - \frac{2}{5}\left(\log\frac{r_g}{r_c}\right)^2 + \text{etc.}$$

The results of sections III and IV in the expressions for V_d are modified by the transformation

$$b_1 \rightarrow r_g \log\,(r_g/r_c'),\; b_2 \rightarrow r_g \log\,(r_a/r_g),$$

where r_a is the radius of the anode cylinder and r_c' is $r_c + \frac{1}{4}\,(r_g - r_c)$, the space-charge corrected form of r_c. The transformation is strictly true only in so far as the valves are ideal, but this limitation is of little consequence in practice since the cylindrical triode is usually more nearly ideal than the plane triode.

The grid supports have a more marked effect on μ_0, and the constants β, β' in equs. 22 and 23 are no longer negligible, but have as a mean value: $\beta = \beta' = 2 \log 2 = 1.39$. [Not to be confused with Langmuir's β.] On neglecting $(\beta/4\pi)^2$ in comparison with $\beta/4\pi$, equation 27 becomes

$$\mu_0 = (\mu + \mu') \cdot \left(1 + 0.11 \frac{a + a'}{\gamma + \gamma'}\right)$$

This result is interesting, since it has always been found in transmitting triodes that the amplification factor is greater than the sum of that of the spiral alone and that of the supports alone. Also, for a square mesh grid ($a = a'$), the theory confirms the old assumption of an equivalent single grid of "half the pitch" of the square mesh.

In calculating μ', a' is to be measured *around* the cylinder through the centres of the supports.

It is worth noting, also, that the above transformation from planar to cylindrical systems leads to the well-known expressions:

$$\mu = \frac{2\pi r_g \log (r_a/r_g)}{a \log (a/2\pi\rho)} \text{ and } A = \frac{\log (r_a/r_c')}{\log (r_g/r_c')}$$

I. A. HARRIS.

Chippenham, Wilts.

Calculating Conductance

To the Editor, The Wireless Engineer.

SIR,—With reference to the calculation of the conductance due to a beam of electrons traversing an alternating transverse deflecting field given in my letter published in the February issue of *The Wireless Engineer*, I regret that there was an error in evaluating that part of the displacement, at emergence, which is in phase with the applied alternating voltage. If this is denoted by $\hat{y}$ for unit alternating deflecting voltage between the plates, then the "end-effect" conductance

$$= \frac{-\hat{y}}{\alpha} I_B.$$

The amended expression for conductance is:—

$$\sigma = \frac{I_B}{V_B}\left(\frac{l}{d}\right)^2 \frac{\sin \omega\tau \left[\tan\left(\frac{\omega\tau}{2}\right) - \left(\frac{\omega\tau}{2}\right)\right]}{(\omega\tau)^2}.$$

I find that the method I have employed, which gives zero conductance for ω equal to zero, is precisely that of Recknagel (*Zeitsch. f. tech. Phys.*, Vol. 3, 1938, p. 74.)

S. RODDA.

New Barnet,
Herts.

Wireless Patents

A Summary of Recently Accepted Specifications

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

AERIALS AND AERIAL SYSTEMS

529 522.—Aerial arrangement for radiating horizontally-polarised short waves with substantially equal field strength in all directions.

Marconi's W.T. Co. (assignees of G. H. Brown). Convention date (U.S.A.) 28th May, 1938.

530 114.—Assembly and mounting of a short-wave aerial and reflector as used for television.

Bullers and J. E. McKless. Application date 3rd June, 1939.

530 220.—Anti-static arrangement in which an aerial is coupled to a transmission line through one "phantom" and two physical circuits.

Philips Lamps and J. B. Kaye. Application date 30th June, 1939.

530 406.—V-type antenna array, giving a wide frequency response, for transmitting and receiving television signals.

Marconi's W.T. Co. (assignees of P. S. Carter). Convention date (U.S.A.) 28th July, 1938.

DIRECTIONAL WIRELESS

529 542.—Preventing disturbances due to reflected signal waves in a direction finder using a radiogoniometer with a continuously rotated search coil.

Telefunken Co. Convention date (Germany) 4th June, 1938.

529 712.—Direction-finding system in which the position of a number of different wireless transmitters is simultaneously shown on the fluorescent screen of a cathode-ray tube. (Addition to 525 393.)

M. Wallace. Convention date (U.S.A.) 17th March, 1938.

530 550.—Monitoring arrangement for a blind-landing radio beacon of the equi-signal type. (Addition to 524 526.)

Standard Telephones and Cables and L. J. Heaton-Armstrong. Application date 27th June, 1939.

RECEIVING CIRCUITS AND APPARATUS

(See also under Television)

529 590.—Valve amplifier circuit in which the rectifier used for automatic volume control is made to vary in efficiency with the strength of the received signals.

A. H. Cooper. Application dates 19th May, 1939, and 15th March, 1940.

529 595.—Amplifier circuit with a negative feedback designed to show a desired variation according to the frequency that it handles.

Electrical Research Products and S. H. W. Browning. Application date 19th May, 1939.

529 755.—Compound "crystal" construction of galenite or carborundum and carbon for limiting the

effect of static interference in an ordinary wireless receiver.

A. Spitz. Application date 7th June, 1939.

529 798.—Wireless set with tuning means designed to receive automatically predetermined broadcast programmes at different selected times.

The British Thomson-Houston Co. Convention date (U.S.A.) 7th June, 1938.

529 862.—Means for preventing frequency drift in a superheterodyne receiver.

The General Electric Co.; N. R. Bligh; and A. Bloch. Application date 9th June, 1939.

529 964.—Circuit in which the internal resistance of a valve is varied to control the reactance or tuning of an associated electrical circuit, particularly for stabilising frequency, or for automatic frequency control.

Philips Lamps (communicated by G. Schotel). Application date 13th June, 1939.

530 256.—Circuit for balancing-out static interference from a wireless receiver.

W. E. Zuccarello. Convention date (U.S.A.) 15th November, 1938.

530 407.—Balancing-out interference, both as regards amplitude and phase, in a wireless receiver.

Marconi's W.T. Co. (assignees of W. van B. Roberts). Convention date (U.S.A.) 30th July, 1938.

TELEVISION CIRCUITS AND APPARATUS

For Transmission and Reception

529 319.—Television receiver in which an automatic gain-control voltage is derived from the " edge " or " slope " of the synchronising impulses.

Hazeltine Corporation (assignees of C. J. Wilson). Convention date (U.S.A.) 21st June, 1938.

529 320.—Television system in which a carrier wave is amplitude modulated by the picture signals and frequency modulated by the synchronising impulses.

Hazeltine Corporation (assignees of A. V. Loughren). Convention date (U.S.A.) 9th June, 1938.

529 383.—Circuit comprising a primary valve and a second or " follower " valve for generating substantially-linear saw-toothed oscillations, suitable for scanning.

E. L. C. White. Application date 15th May, 1939.

529 410.—Cathode-ray television tube in which the photo-electric cathode is in the same plane as, though separated from, the mosaic screen.

Marconi's W.T. Co. (assignees of H. A. Iams. Convention date (U.S.A.) 31st May, 1938.

529 411.—Cathode-ray television transmitter in which means are provided to cause the mosaic electrode to increase the normal signal output.

Marconi's W.T. Co. (assignees of W. H. Hickok). Convention date (U.S.A.) 31st May, 1938.

529 523.—Cathode-ray tube in which the deflecting plates are specially shaped and designed to prevent " trapezium " or " barrel " distortion of the scanning area.

A. C. Cossor and E. E. Shelton. Application date 26th May, 1939.

529 560.—Deflecting system for a micro-oscillograph used in combination with a photographic film and a focusing system giving a scanning spot a thousandth of a millimetre in cross-section.

M. von Ardenne. Convention date (Germany) 3rd June, 1938.

529 777.—Construction and use of the mosaic screen in a cathode-ray television transmitter.

Marconi's W.T. Co. (assignees of L. E. Flory and G. A. Morton). Convention date (U.S.A.) 15th June, 1938.

529 790.—Valve with a secondary-emitting electrode for deriving both the line and frame synchronising impulses used in television.

Kolster-Brandes and C. N. Smyth. Application date 26th May, 1939.

530 095.—Arrangement of a television receiver cabinet designed to facilitate access to the component parts, for servicing purposes.

Standard Telephones and Cables and D. S. B. Shannon. Application date 16th June, 1939.

530 115.—Frequency-changing circuit, with means for preventing oscillator and tuning drift, particularly for a television receiver.

Kolster-Brandes; D. S. B. Shannon; and P. K. Chatterjea. Application date 3rd June, 1939.

530 227.—Synchronising means designed to ensure a precisely interlaced relation between successive scanning periods in television.

Hazeltine Corporation (assignees of H. M. Lewis). Convention date (U.S.A.) 10th August, 1938.

530 263.—Electro-magnetic deflection means designed to apply a uniformly-distributed field to control the electron stream in a cathode-ray tube.

Standard Telephones and Cables and C. N. Smyth. Application date 6th June, 1939.

530 319.—Wide-band amplifier for television signals, with automatic control of the frequency response over the signal band.

A. A. Thornton (communicated by Philco Radio and Television Corporation). Application date 8th June, 1939.

530 378.—Saw-toothed oscillation generator of the grid-controlled gas-discharge type for handling synchronising impulses in television.

A. A. Thornton (communicated by Philco Radio and Television Corporation). Application date 5th June, 1939.

530 409.—Television transmitter tube adapted for scanning with a low-velocity electron stream.

Marconi's W.T. Co. (assignees of A. Rose). Convention date (U.S.A.) 30th July, 1938.

530 426.—Television receiver with means for automatically controlling the background and level of light modulation.

Hazeltine Corporation (assignees of H. M. Lewis). Convention date (U.S.A.) 27th July, 1938.

530 519.—Controllable delay circuit in which the electron stream of a cathode-ray tube is used to correct " lag effects " in a television transmitter.

Marconi's W.T. Co. and D. L. Plaistowe. Application date 9th June, 1939.

530 523.—Magnetic deflection coils arranged to prevent " coma " and " astigmatism " in a cathode-ray television tube.

Telefunken Co. Convention date (Germany) 11th June, 1938.

TRANSMITTING CIRCUITS AND APPARATUS

(*See also under Television*)

529 648.—Method of deriving signal pulsations by bombarding an electron target located behind an apertured screen. (Addition to 523 575.)

Kolster-Brandes and W. A. Beatty. Application date 24th May, 1939.

529 652.—Means for generating a time-modulated impulse train for signalling. (Addition to 524 671.)

Kolster-Brandes and W. A. Beatty. Application date 24*th May*, 1939.

529 771.—Generating ultra-high-frequency oscillations by controlling the flow of an electron stream through hollow "resonator" chambers.

The Board of Trustees of The Leland Stanford Junior University. Convention date (*U.S.A.*) 1*st March*, 1938.

530 024.—Modulating circuit arranged to maintain the working characteristics of the various valves substantially the same for different loads.

Telefunken Co. Convention date (*Germany*) 14*th June*, 1938.

530 109.—Valve generators, particularly of the split-anode magnetron type, for producing ultra-short waves at a high level of power.

Marconi's W.T. Co. (*assignees of E. G. Linder*). *Convention dates* (*U.S.A.*) 29*th April and* 31*st May*, 1938.

CONSTRUCTION OF ELECTRONIC-DISCHARGE DEVICES

529 433.—Electron-multiplier tube provided with a magnetic control field which diverts any abnormally fast-moving electrons away from the secondary target electrodes.

Philips Lamps. Convention date (*Germany*) 3rd *June*, 1938.

529 599.—Construction of valve designed to feed sharply-defined current impulses to a transmitting aerial. (Addition to 518 665.)

G. Jobst. Convention date (*Germany*) 2*nd June*, 1938.

529 837.—Secondary-emission discharge tube of the so-called double-beam type, in which the same sensitive surface is subjected to the action of two electron streams of different velocity.

Kolster-Brandes ; D. S. B. Shannon ; and P. K. Chatterjea. Application date 22*nd April*, 1939.

529 864.—Preventing variation of anode current in an amplifier due to changes of cathode temperature.

The General Electric Co. ; H. C. Turner ; and G. M. Tomlin. Application date 9*th June*, 1939.

529 881.—Arrangement and assembly of the electrodes of a pentode valve, particularly to prevent overheating of the cathode springs during the process of "pumping."

Marconi's W.T. Co. and A. J. Young. Application date 9*th June*, 1939.

529 882.—Arrangement of the electrodes of a pentode valve designed to prevent the suppressor grid from being driven into a region of negative resistance.

Marconi's W.T. Co. and A. J. Young. Application date 9*th June*, 1939.

530 138.—Electrode arrangement for effecting a conical dispersion of the electron stream in a cathode-ray tube used for generating high-frequency oscillations.

Marconi's W.T. Co. (*assignees of D. W. Power*). *Convention date* (*U.S.A.*) 21*st June*, 1938.

530 260.—Electron multiplier in which the electron stream is first formed into a velocity-spectrum and thereafter into a stream of uniform velocity, so as to ensure straight-line amplification.

Baird Television and G. E. G. Graham. Application date 6*th June*, 1939.

530 300.—Construction and support for the indirectly-heated cathode of a thermionic valve.

Standard Telephones and Cables and R. R. N. Murphy. Application date 28*th July*, 1939.

530 408.—Electron multiplier designed to develop a high and constant gain, irrespective of variations in the line or operating voltage.

Marconi's W.T. Co. (*assignees of R. L. Snyder, Jr.*). *Convention date* (*U.S.A.*) 30*th July*, 1938.

530 551.—Electrode arrangement and assembly of a power valve of the external-anode type.

Standard Telephones and Cables (*assignees of J. E. Clark and V. L. Ronci*). *Convention date* (*U.S.A.*) 11*th August*, 1938.

SUBSIDIARY APPARATUS AND MATERIALS

529 290.—Device for coupling a "dielectric guide" for the transmission of centimetre waves to a transmission line of the coaxial type.

Marconi's W.T. Co. (*assignees of I. Wolf*). *Convention date* (*U.S.A.*) 28*th May*, 1938.

529 291.—Thermionic valve circuit with a closed feed-back loop arranged to produce a stable phase-shift of 90° at a common predetermined frequency.

Standard Telephones and Cables (*assignees of G. H. Stevenson*). *Convention date* (*U.S.A.*) 28*th June*, 1938.

529 441.—Circuit in which a pair of valve amplifiers with a common cathode resistance are arranged to give a balanced output even from an unbalanced input.

B. M. Hadfield. Application date 17*th April*, 1939.

529 480.—Means for increasing the maximum resolving power of an electron microscope.

M. von Ardenne. Convention date (*Germany*) 1st *June*, 1938.

529 525.—Balanced-bridge arrangement designed to give a direct reading both of inductance and resistance values.

H. W. Sullivan and W. H. F. Griffiths. Application date 2*nd June*, 1939.

530 032.—Means for safeguarding the "foils" used for mounting the objects to be scrutinised in an electron microscope.

"Fides" G.m.b.h. Convention date (*Germany*) 14*th June*, 1938.

530 105.—Thermionic valve control circuit for passing a predetermined amount of energy (say for spot welding) in accurately determined periods of time.

The British Thomson-Houston Co. (*communicated by General Electric Co.*). *Application date* 31*st March*, 1939.

Abstracts and References

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For the information of new readers it is pointed out that the length of an abstract is generally no indication of the importance of the work concerned. An important paper in English, in a journal likely to be readily accessible, may be dealt with by a square-bracketed addition to the title, while a paper of similar importance in German or Russian may be given a long abstract. In addition to these factors of difficulty of language and accessibility, the nature of the work has, of course, a great influence on the useful length of its abstract.

PROPAGATION OF WAVES

1002. SIGNAL RANGE OF ULTRA-HIGH-FREQUENCY BROADCAST STATIONS [F.C.C. Diagram].—(*See* 1217, below.)

1003. THE ANGLE OF ARRIVAL OF SHORT-WAVE RADIATION IN TRANSOCEANIC COMMUNICATION [Investigation of Reception on Two Rhombic Aerials, in Germany, from U.S.A.].—E. Schüttlöffel & G. Vogt. (*Hochf:tech. u. Elek:akus.*, Oct. 1940, Vol. 56, No. 4, pp. 123–125.)

Long summary of a *VDE-Fachberichte* paper. Each of the two aerials (arranged one behind the other, with their major axes directed towards the distant station) is so dimensioned that its vertical characteristic has a maximum at about 20°, and each is capacitively coupled to its short-wave receiver, the two receivers having a common heterodyne oscillator so that the phase relation between the input voltages may be maintained in the i.f. circuit. The two aerials can be switched off and replaced by a signal generator acting on both receivers.

The voltage-addition of the two signals is carried out in the i.f. stages, so that the whole equipment, apart from the first stages, is independent of the signal frequency, and any station which falls within the reception range of the receiver can have its angle of arrival measured. The i.f. current of the first receiver is taken to a phase adjuster, consisting of a goniometer with crossed-field stator and motor-driven rotor: the field coils are fed with i.f. currents displaced in phase by 90°, over a resistance-capacity circuit, so that a rotating field is produced. If the phases at the output of both receivers remain constant during a rotation of the moving coil, the phase displacement of the voltage induced in the latter with respect to the voltage from the second receiver will cover the range up to 360° during one revolution. The i.f. voltage in the rotor is taken inductively from its coil and combined, in a "vector-addition" stage, with that coming directly from the second receiver: the vectorially added voltages are then amplified, rectified, and applied to one pair of plates of a cathode-ray oscillograph, the other pair being given a deflecting voltage. The combined effect of the two receivers gives a maximum at phase equality and a minimum at 180° phase difference. "On account of its better readability the minimum is used for the observations. A control condenser of a relaxation-oscillator is mounted on the axle of the rotor so that an oscillation is produced at each 360° revolution. The speed is 1500 r.p.m. so that unflickering stationary image may be given on the screen of the tube. The position of the minimum on the screen is a measure of the phase differences of the waves arriving at the two aerials." As a preliminary, the position of the minimum must be determined for in-phase signal voltages: this is done by reception from a small auxiliary transmitter during the calibration of the whole equipment.

The final form of apparatus actually used for measurements on Bound Brook and Schenectady was rather more complicated: in particular it had second oscillograph and a second goniometer, "which allowed the voltages from the two aerials, one acting on the horizontal plates and the other on the vertical plates of the second tube, to be added together with a phase displacement of 0° or 180°. In the first case there appears on the screen a straight line inclined at 45° to the horizontal, in the second case one inclined at 135°" (*see* below). The phase displacement for horizontal incidence was measured for various wavelengths by reception from the auxiliary transmitter "at a distance of 4 km from the end points of the two aerials": as a check, a measurement from 10 km was also made.

The photographed traces from the two American stations named above show that in certain conditions several transmission paths (actually up to 5 were found) occur alternately or simultaneously, with different arrival-angles: Fig. 3 shows a single-path case, Fig. 4 a double one. Fig. 5 gives Bound Brook results for three runs (winter evening and night): each "dash" represents several measurements. The most frequent arrival-angle lies between 22.4 and 23.8 (these angles throughout the paper are with the horizontal) but two others occur occasionally, 10–12° and 7.4–10°. The large angles gave signals almost as strong as those from a European broadcasting station, the small angles gave weak reception. Schenectady yielded very similar results, with the most frequent angle at 25.4–26°, then 14.6–16° and 11.2–12.6°, and finally 8.4–10.4°. "For both stations the high arrival angles were practically always present, in the later day hours by themselves: the smaller angles occurred only occasionally, and never by themselves."

The use of the second goniometer mentioned above allowed the voltages from the two aerials to be adjusted so as to be in phase (trace at 45° on the second screen). This gave distinctly better reception than that from a single aerial; in particular, a decrease in the otherwise frequent rapid fades. No doubt the correct addition of phases so oriented the vertical characteristic of the installation that only those waves which came by the most favourable paths were received, the weaker waves, which came by inferior paths and which would only disturb reception, being suppressed.

1004. The Practical Importance of Ionospheric Research for Wireless Services [Comparative Table of Fading and Echo Records: the Types of Fading, and Their Causes].—Beckmann, Menzel, & Vilbig. (*E.T.Z.*, 7th Nov. 1940, Vol. 61, No. 45, p. 1016.)

Summary of a paper in *T.F.T.*, April 1940, Vol. 29, pp. 106–116. Fading may be divided into two main classes, the first of which consists in a more or less rapid change of field strength without an actual breakdown of communication (fading), while the second involves a complete interruption of the service (fade-out). Fading in the first class may have various different characteristics: thus there is quick fading and slow; regular, almost periodic fading, and very irregular fading; and fading with smooth and with "stepped" fading curves. The regular, almost periodic type is due to fluctuations in the major axis of the elliptically polarised reflected wave formed from the two magneto-ionic components: this type of fading ceases when, towards mid-day, one component is absorbed and only circularly polarised waves are present, as echo observations show. But fading can still occur, either by interference between several rays travelling by different paths (this type is characterised by a "stepped" curve) or by absorption (slow and quite irregular fading). Thus the first class is divided into fading of three types—polarisation, interference (multi-path), and absorption fading.

The second class, fade-outs, may set in either with a steep decrease of field strength to zero (and a correspondingly steep final recovery) or with a gradual (with correspondingly gradual recovery). Echo observations show that the former type is due to a decrease in ionisation, the rays penetrating the layer. The longer interruptions, with their slower onset and recovery, are shown by echo observations to be caused by absorption due to marked increase of ionisation. Thus the second class of phenomenon is divided into critical-ionisation fading and total-absorption fading. Auroral disturbances may produce both types: echo measurements show that such disturbances are accompanied by a decrease in F-region ionisation (critical-ionisation fading) and by the formation of very badly reflecting layers (total-absorption fading). "The Mögel-Dellinger effect is a suddenly occurring, strong absorption fading. A damping layer is formed below the E layer."

Scattering phenomena, due to ion clouds in the E region (as echo observations also show) produce an effect of their own on the field-strength recordings. They may maintain quite good communication even after a critical-ionisation fade-out has set in. Scattering has a certain connection with auroral disturbances.

Critical-ionisation and absorption fade-outs can be avoided by the correct choice of wavelength. Thanks to the relation between the cause of the disturbance and geophysical and astrophysical processes, prediction is possible to a certain extent.

1005. On the Intensity Variations of the Downcoming Wireless Waves from the Ionosphere [Observations on 370.4 m Waves from Calcutta at Dacca at Night, with Ground-Wave Suppression: Good Agreement with Rayleigh's Formula for Random Scattering: Determination of Ratio of Amplitudes of Downcoming & Ground Waves].—S. R. Khastgir & A. K. Ray. (*Indian Journ. of Phys.*, Aug. 1940, Vol. 14, Part 4, pp. 283–293.)

Thus confirming the conclusions of Appleton & Ratcliffe (1927 Abstracts, p. 571) and of Ratcliffe & Pawsey (1313 of 1935 and back reference). The paper includes descriptions of the receiving aerial with ground-wave suppression (similar to that used by Ratcliffe & Pawsey), its theory and testing; and of the receiver and its calibration (using a current-attenuating unit with Hull cylinder).

1006. Short-Period Fluctuations in the Characteristics of Wireless Echoes from the Ionosphere [Directional & Polarisation Measurements].—Eckersley & Farmer. (*See* 1086.)

1007. Polarisation Measurements in the Medium Wave Band.—Grosskopf & Vogt. (*See* 1087—long abstract.)

1008. The Solar-Half-Day Period of the Cosmic Radiation at the Equator.—Rau. (*See* 1026.)

1009. Notes on the Time Relation between Solar Emission and Terrestrial Disturbances [Velocity required if Particles are to encounter Earth, and Number of Days after Sunspot's Passage of Central Meridian when Encounter would occur, are Both dictated by Position of Sunspot with respect to Central Meridian and by Angle of Emission: Transit Times may range from 1–2 Days to 3 Months: Explanation of Apparent Occurrence of Disturbances without Sunspots and Sunspots without Disturbances].—C. N. Anderson. (*Proc. I.R.E.*, Nov. 1940, Vol. 28, No. 11, pp. 503–511.)

1010. Measuring Sun's Effect in causing Terrestrial Magnetic Disturbances [" K-Index," from Data obtained by Seven American-Operated Observatories, published weekly by Science Service].—(*Sci. News Letter*, 21st Dec. 1940, Vol. 38, No. 25, pp. 394–395.)

1011. Preparations in Soviet Russia for the Observation of the Solar Eclipse of 21st Sept. 1941.—(*Science*, 20th Dec. 1940, Vol. 92, Supp. p. 10.)

1012. An Apparent Influence of the Earth on Solar Prominences [Conflicting Results of Previous Investigations: a New Method giving Evidence of an Enhancing Influence with Observed Effects varying Inversely as Some Power of Distance between 3rd & 4th: Effect of Variations of Solar Activity on Prominence Data: Behaviour of Hydrogen Absorption Markings in relation to Earth Effect: etc.].—A. K. Das & B. G. Narayan. (*Indian Journ. of Phys.*, Aug. 1940, Vol. 14, No. 4, pp. 311–323.)

1013. Analysis of the Ionosphere.—G. W. O. H.: Darrow. (*Wireless Engineer*, Feb. 1941, Vol. 18, No. 209, pp. 43–45.) Editorial on Darrow's survey referred to in 3729 of 1940. One or two typographical errors are pointed out.

1014. Recombination and Electron Attachment in the F Layers of the Ionosphere.—F. L. Mohler. (*Journ. of Res. of Nat. Bur. of Stds.*, Nov. 1940, Vol. 25, No. 5, pp. 507–518.)

A summary was dealt with in 3293 of 1940. " There is little doubt that the rate of recombination decreases rapidly with decreasing pressure above F_1, and a necessary consequence of this is that the max. number of electrons is far above the level where the rate of production is a maximum. . . . . Several independent lines of evidence indicate that the max. rate of production must be near the F_1 level so that one absorption process can account for both F layers. This avoids the assumption that the temperature above F_1 is extremely high and subject to enormous seasonal variations. A complication in the theory is that the height of F_2 and the electron concentration depend on the ratio of electrons to negative ions, which is extremely sensitive to temperature. . . . It is possible that this can explain the apparently erratic variations in ionisation that are characteristic of the F_2 layer.

" One consequence of the theory is that the variation of ionisation with time and height will depend on the absolute intensity of the ionising radiation, which varies over a wide range during a sunspot cycle." The implications of this are discussed and compared with observed increases in F_1 and F_2 ionisation from 1934 to 1938.

1015. On a Connection between the Light of the Night Sky and the Ionosphere.—R. Hechtel. (*Hochf:tech. u. Elek:akus.*, Nov. 1940, Vol. 56, No. 5, pp. 129–136.)

" The experimental exploration of the ionosphere is based exclusively on the reflecting power for electromagnetic waves. One of the few other phenomena capable of yielding deductions about the upper atmospheric layers is the light of the night sky. The idea of a connection between the changes in the ionosphere and the changes in the light of the night sky would seem to have been first put forward by Martin & Pulley [3677 of 1936]. They pointed out that the electron concentration in the F_2 layer and the intensity of the green auroral line in the light of the night sky showed the same daily and yearly course, basing their statement on the results of Appleton, Naismith, Schafer, Goodall, and Gilliland for the ionosphere and of Lord Rayleigh and McLennan for the light of the night sky (abbreviated in what follows to N.H.L.—" Nachthimmellicht "). It is now known that the midnight maximum of electron concentration in F_2, to which Martyn & Pulley referred, by no means always occurs [and as regards the yearly variation, " the relations are not so simple as Martin & Pulley saw them, since the two maxima of F_2 concentration in October and February only apply to the mid-day values: the course of night electron concentration, shown in Fig. 15, is quite different." However, the results obtained by the writer on the N.H.L. variation over the year are too limited, and those furnished by other workers too contradictory, to enable any conclusion to be drawn as to a yearly correlation]. On the other hand the observations on the nightly intensity variation of the N.H.L., drawn from various sources, are contradictory. It was therefore desirable to carry out a more complete investigation of the problem by means of simultaneous observations of the ionosphere and the N.H.L."

The records of the effective height of the ionospheric layer as a function of frequency were made at the Herzogstand (Bavarian Alps) ionospheric station, where once an hour the frequency spectrum from 1 to 10 Mc/s was run through in 3½ minutes. The technique was similar to that described in 2508 of 1940 (Netzer's work on abnormal E ionisation, etc.), and a specimen run is seen in Fig. 7. The simultaneous night-sky observations were made close to the same station: owing to the low intensity of the light the process was divided into two parts, the spectral composition being investigated with a spectrograph, while the variations with time of the intensities in the various regions of the spectrum were recorded by photographic photometry, using colour filters, an automatic camera, and a photoelectric device for interpreting the resulting films. Meanwhile an indication of the amount of cloud veiling the sky was also recorded photographically on the principle of Pickering's " polar star recorder " (Fig. 5 and adjacent text).

In Figs. 10, 11, 13, & 14 the upper curves, marked F_2, show the night variation of 2 log f', representing the max. electron concentration in the F_2 layer: the triple sets of lower curves represent, on an arbitrary logarithmic scale, the intensities T (total visible), R (red region of spectrum), and G (green region). " The fact that in the course of a long time all possible types of intensity characteristic present themselves accounts for the partial contradictions between the observations of different writers."

The writer admits that the agreement between the curves is not particularly convincing, and he therefore works out the correlation coefficients. Table 3 gives the results for measurements on perfectly clear nights. The calculations were carried out on the logarithmic values used in the curves: this plan has the advantage that the dispersions can be compared among themselves directly. A coefficient of zero ($r = 0$) implies that there is no correlation: if $r = \pm 1$, the two phenomena are completely linked together, with a positive or negative correlation. If line No. 34 is neglected because of the aurora which occurred in North Germany on that night, the ratio of the number of positive cases to negative is 9 : 3 for *T* and 8 : 4 for *G* and *R*. The magnitudes of the coefficients are just about the same as those relating to similar geophysical correlations, such as the connection between magnetic activity and ionospheric disturbances, or the barometer effect of cosmic radiation. The highest average coefficient is given in the red region, namely 0.33, or neglecting No. 34, 0.50: this superiority also applies to the night-to-night variation (Fig. 12).

The writer considers that the correlation established leads to the conclusion that an important fraction of the N.H.L. is emitted in the F_2 layer (a similar correlation with the abnormal E layer is not thought to have been established, though certain indications of it have been found: in any case, if it exists it is certainly far less well marked than that for the F_2 layer). The spectral composition indicates the presence of atomic oxygen and molecular nitrogen. Most theories of the excitation of N.H.L. neglect the presence of an ionised layer and the processes occurring in it, and can therefore be put aside. The one which comes closest to the truth is probably Chapman's, in which a nitrogen molecule or oxygen atom is thought to be excited to luminosity by a complex two-stage recombination process. " It seems that no one in the literature of the N.H.L. has yet pointed out that the simple process of recombination between an ionised atom and an electron can be accompanied by the emission of light " [de Groot and Penning]. This process gives the simplest explanation of the relation between electron concentration and N.H.L. intensity; the recombination equation is $dN/dt = -\alpha . N^2$, and the quantity $\alpha . N^2$ would thus be (on certain assumptions) a measure of the N.H.L. intensity.

But the changes in the F_2 max. electron concentration are about 2.4 times as great as the N.H.L. intensity changes. The writer suggests that this is due to two causes: (i) the determining factor in the light generation is not the max. electron concentration but the total number of electrons: if the electron concentration falls off from the maximum on both sides, the ratio of total electron number to max. electron concentration does not (for normal recombination, without other processes) remain constant: and (ii) the amplitude of the N.H.L. intensity variations is further reduced by the starlight which forms a constant component, estimated by Cerniajew and his co-workers at 22–33%.

1016. Determination and Interpretation of the Layer Limits of the Sodium Fluorescence Radiation at Twilight.—G. Cario & U. Stille. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 122–136.)

The yellow radiation in the light of the night sky, whose identity with the sodium *D* line has been established, was found by Bernard to display a marked fall in intensity (to about 1% of its original value) in the course of a few minutes as twilight faded into night. This twilight effect can be explained by supposing the excitation of the *D* line during twilight and at night to be produced by two different processes: the first being an optical resonance-fluorescence due to the still present yellow sunlight and photoluminescence due to ultraviolet rays (with simultaneous dissociation of NaCl if much of the sodium exists in this form), while the second, when the zone in question is in the earth's shadow, is a process of excitation by collision: *see* also 31 of 1940. Thus the sudden fall in Bernard's measured curve represents the entry of the sodium-containing layer into the earth's shadow, and in this way Bernard estimated the height of this layer as 60 km. This estimate has been criticised by Götz and others (*see* for instance Vegard, 2520 of 1940).

The object of the present paper is to show that even while adhering to Bernard's optical resonance-fluorescence mechanism the estimate would only represent a minimum value for the upper limit of the layer, because Bernard based his calculations on an ideally transparent troposphere, whereas the troposphere is actually far from being transparent to grazing rays of sunlight. Taking this action of the troposphere into consideration, the writers arrive at a height of about 78 km for the upper limit of the layer, a height of about 69 km for the lower limit, and thus a layer thickness of about 9 km. They conclude that the upper limit is sharply defined as a result of a temperature inversion in the atmosphere at a height of 80–85 km, so that above that height the temperature rises sharply with increasing height. It is at about 82 km that the luminous night clouds have been shown to occur, and it is thought that the same temperature inversion is responsible both for these and for the upper limit of the sodium layer. The lower limit of the latter is probably less well defined, being due to the extinction of the resonance-fluorescence and a lowering of the sodium partial pressure as a result of molecule formation with oxygen. Further investigations are proceeding; later, it is hoped, in conjunction with radio echo measurements.

1017. On the Ionisation Potential of the Nitrogen Molecule [Rejection of Rydpal & Vegard's New Reduced Value of 13.3 Volts in Favour of the Established Value of 15.51 Volts].—U. Stille. (*Zeitschr. f. Phys.*, No. 3/4, Vol. 116, 1940, pp. 144–152.) *See* 3298 of 1940.

1018. Recent Technical Developments in Wireless and Broadcasting in Great Britain.—Rakshit. (*Sci. & Culture*, Calcutta, Dec. 1940, Vol. 6, No. 6, pp. 314–326.) Concluded from 919 of March.

1019. The Influence of Reflection on the Action of Doubly Refracting Plates.—F. Gabler & P. Sokob. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 47–55.)

" The reflections occurring at the surfaces of separation of a doubly refracting plate have, as will be shown, an important influence on the polarisation condition of a wave of light traversing this plate. Equations are derived for the phase displacement and for the intensity which is allowed through an analyser following the lens, and the results are generalised for an assembly composed of *k* plates." It is shown that the taking into account of the reflections does not alter the known law according to which, for parallel or crossed orientation of *k* plates, the over-all phase displacement is equal to the sum of the individual displacements.

1020. New Investigations on Magnetic Rotation in Doubly Refracting Media.—Gabler. (*See* 1229.)

1021. A General Interferential Method [Derivation of General Intensity Equation (yielding Expressions for Resolving Power, Dispersion, etc.) directly applicable to All Optical Interferometry Arrangements].—L. Sturkey & B. P. Ramsay. (*Phil. Mag.*, Jan. 1941, Vol. 31, No. 204, pp. 13–23.)

ATMOSPHERICS AND ATMOSPHERIC ELECTRICITY

1022. Some Studies in High-Frequency Atmospheric Noise at Dacca by the Warbler Method [Atmospherics just masked by Adjustable Artificial Noise (Rotating Condenser): Curves of Field Strength as Function of Frequency (250–1 500 kc/s) for Near & Distant Origins: Diurnal Variation—Sunrise & Sunset Effects: Comparison with Results of Other Workers].—S. R. Khastgir & M. K. Rao. (*Proc. I.R.E.*, Nov. 1940, Vol. 28, No. 11, pp. 511–513.)

1023. Anticipatory Triggering Devices for Lightning and Static Investigations [actuated by Stepped Leader Process through Its Radio-Wave Pulses: with Discrimination between These Pulses and Pulses from Main Disturbances (Man-Made Static and Certain Forms of Lightning Origin) Not preceded by Stepped Leader].—B. F. J. Schonland & J. S. Elder. (*Journ. Franklin Inst.*, Jan. 1941, Vol. 231, No. 1, pp. 39–47.)

1024. On the Origin and Distribution of Cloud Charges [Possibility of Formation of Positively Polarised Clouds even by Simpson Mechanism (Effect of Traces of Hydrogen Peroxide already detected in Rain, and in Moist Air exposed to Ultra-Violet Radiation): etc.].—T. R. J. Raman. (*Current Science*, Bangalore, Oct. 1940, Vol. 9, No. 10, pp. 467–468.)

1025. On the Auxiliary Electrons due to Photoelectric Effect in a Non-Spontaneous Gaseous Discharge in Air.—H. Costa. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 508–514.)

1026. The Solar-Half-Day Period of the Cosmic Radiation at the Equator [Hoerlin's Peru Observations confirm the Writer's Bodensee Results: "No More Doubt as to Existence of Double Daily Period of Hard Component": Amplitude about ± 0.8%: Phase Agreement at the Two Places].—W. Rau. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 105–114.)

1027. The Seasonal Variations of Cosmic-Ray Intensity and Temperature of the Atmosphere [Cosmic-Ray Variations more closely correlated with Mean Temperature up to 16 km than with Temperature near Ground (Support to Blackett's Mesotron-Instability Theory): etc.].—A. Duperier. (*Proc. Roy. Soc.*, Ser. A, 10th Jan. 1941, Vol. 177, No. 969, pp. 204–216.)

PROPERTIES OF CIRCUITS

1028. "Relaxation Methods in Engineering Science: a Treatise on Approximate Computation" [Book Review].—R. V. Southwell. (*Journ. of Scient. Instr.*, Feb. 1941, Vol. 18, No. 2, p. 29.)

The method developed, that of "systematic relaxation of constraints," has been described as "one of the most powerful methods of computation in mathematical physics and engineering." The greater part of the treatise deals with problems in the theory of elasticity (modes and natural frequencies of vibrating systems, etc.) but the determination of currents and potentials in electrical networks also receives detailed consideration. *Cf.* 3246 of 1940.

1029. Circuits with Double Linkages [*e.g.* String of Suspension Insulators with Capacitance to Ground and to High-Voltage Line, Transformer Winding with Capacitance to Core and to Neighbouring High-Voltage Winding: Determination of Voltage Distribution].—E. A. Walker. (*Phil. Mag.*, Feb. 1941, Vol. 31, No. 205, pp. 169–176.)

1030. An Experimental Investigation of Subharmonic Currents [in Series Circuit of Resistance, Capacitance, & Non-Linear Inductance, on Application of Sine-Wave Voltage].—J. D. McCrumm. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 34: preview, copy obtainable.)

1031. Vario-Losser Circuits [Compressers & Expanders, etc.].—Bennett & Doba. (*See* 1101.)

1032. On a Wide Band-Pass Effect in Crystals associated with Negative-Impedance Elements, and the Development of Wide-Band Low-Loss Crystal Band-Pass Filters [Limitations of Existing Crystal Band-Pass Filters: the New Filters with Negative-Impedance Element in Series: in Parallel: De-tuned: Tuned: Applications to Television & Multi-Channel Radio-Telephony].—S. P. Chakravarti & N. L. Dutt. (*Indian Journ. of Phys.*, Aug. 1940, Vol. 14, Part 4, pp. 295–310.) Further development of the work dealt with in 3495 of 1938 and 51 of January.

1033. A Narrow Band Filter using Crystal Resonators [Analysis: Design Restrictions imposed by Use of Quartz Resonators (Stray Capacitances, Restricted Characteristic Impedance, etc.): Example of Performance in Practice (Filter for Pass Band 63.936–64.064 kc/s): Close Agreement between Computed & Measured Attenuations].—H. Stanesby & E. R. Broad. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 176–182.)

1034. A Resistance-Compensated Band-Stop Filter: Erratum.—H. Stanesby. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, p. 196.) *See* 3357 of 1940. For Stanesby's letter, prompted by the summarised version referred to in 719 of March, see *E. & Television & S-W.W.*, Jan. 1941, p. 32.

1035. Canonical Network Circuits for Reactance Quadripoles with Predetermined Characteristics.—H. Piloty. (*T.F.T.*, Oct. 1940, Vol. 29, No. 10, pp. 279–290: to be concluded.) Continued from a previous issue. For earlier work *see* 959 (and 958) of 1940.

1036. Transformation and Driving Point Impedances of Energy of Linear Modulation Vectorial Four-Terminal Network.—M. Akiyama. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, p. 61: summary only.) Further development of the work dealt with in 4227/8 of 1940.

1037. Computation of Band-Pass Filters [with Nomogram].—J. G. Lang. (*Funktech. Monatshefte*, Oct. 1940, No. 10, pp. 156–157.)

1038. An A.C.-Operated D.C. Amplifier with Large Current Output [primarily for operating String Oscillograph (from Frequency Meter with 7 Volts Output): Linear Output up to 160 mA: D.C. Phase Inverter with Cathode In-Phase Degeneration, driving Push-Pull Output Stage].—S. N. Treviño & F. Offner. (*Review Scient. Instr.*, Dec. 1940, Vol. 11, No. 12, pp. 412–415.)

1039. Graphic Aid for the Design of Degenerative Amplifiers.—Hygrade Sylvania. (*Electronics*, Nov. 1939, Vol. 12, No. 11, p. 64.) Use of graphs based on fact that gain and distortion in presence of negative feedback are similarly related to gain and distortion in its absence.

1040. Equivalent Circuit of Multi-Stage Amplifier [Proposed Equivalent Circuit consisting of One High-Internal-Impedance Valve with Four-Pole Network of Constant-Current Type: etc.].—K. Yamamoto & S. Mochizuki. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, pp. 61–62: summary only.)

1041. On the Feedback Circuit of a Multi-Stage Amplifier and the Constant-Current Four-Pole Network [and the Question of Phase Compensation and Avoidance of Singing].—K. Yamamoto. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, p. 62: summary only.)

TRANSMISSION

1042. Resistance-Tuned Oscillator: Its Application to Automatic Frequency Control.—Foster. (*See* 1055.)

1043. Square Waves at High Frequencies [2 kc/s & 200 kc/s].—W. H. Fenn. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 67 and 68.) Summary of paper in *Review Scient. Instr.*, Nov. 1940. For previous summaries *see* 3793 of 1940.

1044. Correction to "The Design and Calculation of High-Power Transmitters."—H. Peschke. (*Funktech. Monatshefte*, Oct. 1940, No. 10, p. 152.) The error in the original paper (June 1940, No. 6) concerned the comparative sharpness of resonance in the two alternative wave-ranges.

1045. A Push-Button-Tuned 50-Kilowatt Broadcast Transmitter.—Rockwell & Lepple. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, Transactions pp. 1–3.) A summary was referred to in 352 of February.

1046. Spy's Transmitter: Details of the Gear used by Enemy Agents.—(*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 51–52.) "Some mild disappointment will be felt that the transmitter is not of especial technical interest. . ."

RECEPTION

1047. Inductive Tuning for Ultra-High Frequencies [Slide-Wire Unit with Tuning Ratio 6.8 : 1 instead of Usual 3 : 1 given by Capacitive Tuning: Specially Suitable for Aircraft (Insensitivity to Vibration, etc.)].—B. V. G. French: Ware. (Summary only: *see* 1244, below.) Development of Ware's work, 2739 of 1939 and back reference.

1048. A State-Wide Frequency-Modulation Police Network: Parts I and II.—Noble. (*See* 1220.)

1049. Papers on Frequency-Modulation Reception [Double-Superheterodyne Circuit to give Gain of 4 Million before Limiting and Demodulation: Two-Stage Cascade Limiter to combine Advantages of Short & Long Time-Constants: etc.].—Worcester, Carnahan, & others. (Summaries only: *see* 1244, below.) *See* also 1245, below.

1050. New 27–145 Mc/s Frequency-Modulation/Amplitude-Modulation Receiver [Hallicrafters].—S. G. Taylor. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 12–14 and 24.)

1051. Noise in Frequency-Modulated Transmissions: Field Tests confirm Advantages.—(*See* 1219.)

1052. The Diminution of Interference by Frequency Modulation.—F. C. Saic. (*Funktech. Monatshefte*, Oct. 1940, No. 10, pp. 157–160.) Based on the papers by Zuhrt (90 of 1940) and Plump (491 of 1939).

1053. Panoramic Reception applied to Aerial Navigation.—Wallace. (*See* 1088.)

1054. More High Quality Reception Needed [U.S. Public tending to listen only to News, changing to Gramophone Records for Entertainment].—M. B. Sleeper. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 71 : summary only.)

1055. Resistance-Tuned Oscillator : Its Application to Automatic Frequency Control [*e.g.* in Push-Button Receivers].—D. E. Foster. (*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 56–57.) For earlier work on resistance-tuning, including Cabot's paper, *see* 921 of 1938 and back reference : *also* 1840 of same year.

1056. Use of Johnsen-Rahbek Effect to convert Varying Voltage into Variation of Capacity [*e.g.* for Automatic Frequency Control in Receiver].—Marconi Company. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, p. 30.) Patent summary.

1057. Series or Parallel ? Alternative Feed Circuits for A.V.C. Systems [Parallel Method, though Not Widely Used, has Certain Advantages for Short-Wave & All-Wave Receivers].—W. T. Cocking. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 5–7.)

1058. Improving Quiescent-Push-Pull Quality : the Use of Negative Feedback.—S. W. Amos. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 11–12.)

1059. High-Tension Battery Economy [in Battery-Driven Receivers] : Some War-Time Expedients.—(*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 9–10.) *See* also Broadbent, 1193, below.

1060. Test Reports : Murphy Model AD94 [for War-Time Requirements : Short & Medium Wave Bands : DC/AC Supply] : Cossor Model 74A [Short, Medium, & Long : AC Mains].—(*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 24–25 : Feb. 1941, No. 2, pp. 54–55.)

1061. Short-Wave Portable : Light-Weight Headphone Set for Present Conditions.—W. H. Cazaly. (*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 49–50.)

1062. Miniature Receivers [Average Weight 4½ lb. : 100–180 Cubic Inches : Sensitivity about 250 μV/m for 15 mW Output : 67.5 V from Eveready MiniMax Battery : Large Sales].—(*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 17–19.) With illustrations and descriptions of the Fada, Philco, RCA Victor, and Emerson receivers.

1063. Size of Intermediate-Frequency Transformers Greatly Reduced by Use of Iron Powder moulded with Polystyrene, as Core and Shield : etc.—(In article dealt with in 1062, above.)

1064. A New Coaxial Tuning Condenser [with Vitreous-Enamel Dielectric : Strong & Small : Capacity variable from 5 $\mu\mu$F to 400 $\mu\mu$F : "Q" Value of 800 : Advantages over Mica Dielectric].—Robinson. (Summary only : *see* 1244, below.)

1065. A New Cellulose Ester Sheet Plastic replacing Paper in Small Tubular Condensers.—L. L. McGrady. (Summary only : *see* 1244, below.)

1066. The Calculation of the Filter Choke of a Mains Unit [with Economy in Material].—H. Pitsch. (*Funktech. Monatshefte*, Oct. 1940, No. 10, pp. 153–156.)

A paper by Käser (2330 of 1939) dealt with the design of a mains transformer without waste of material. The present paper extends this to the design of a smoothing choke, where the conditions are quite different on account of the large direct current passing. Beginning with the calculation of the minimum diameter of the wire, the writer continues by calculating the minimum core size (from the point of view of the heating) and then the inductance, from the number of turns and the core dimensions.

A numerical example is worked out, and an alternative method, starting from the desired inductance and ending with the calculation of the resistance, is given.

AERIALS AND AERIAL SYSTEMS

1067. Variation of Field Strength in the Vicinity of an Ultra-Short-Wave Horizontal Transmitting Aerial [Calculation, by Carter's Formula, of Electric Field Strengths at Distance of $3\lambda/4$ from Input End of Single Half-Wave Horizontal Aerial, in Various Directions with respect to the Latter : Comparison with Experimental Results on 6.1 m Wave received on Transported Aerial kept always Parallel to Transmitting Aerial].—S. S. Banerjee & Paramanand. (*Indian Journ. of Phys.*, Aug. 1940, Vol. 14, Part 4, pp. 325–332.)

1068. Ultra-High-Frequency Aerial Coupling Circuits [recommended by Police Department, for Receiving Aerials mounted on Transmitting Tower].—M. M. Lesensky. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 67 : summary only.)

1069. One Method of measuring High-Frequency Feeder Wire Constant.—K. Ogihara & J. Karasawa. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, pp. 63–64 : summary only.)

Various methods known in the past "have not been altogether what they should have been": thus the writers, in measuring the feeder cable of an aircraft beacon by the "open/short" method, found accurate results were impossible "owing to the electrical length of the cable happening to be a quarter of the frequency employed." They now describe a method free from such difficulties and giving accurate results : it involves connecting successively pure resistances of various known values to the far end. Examples are given.

1070. The Corner-Reflector Antenna [Analysis of Performance : Gain Curves (as Function of Aerial-to-Corner Spacing) for Different Corner Angles : Optimum Limits of Spacing : Measured & Calculated Directional Patterns : Applications].—J. D. Kraus. (*Proc. I.R.E.*, Nov. 1940, Vol. 28, No. 11, pp. 513–519.) *See* also 389 of February.

1071. On the Optimum Design of Two-Element Radiation-Coupled Directive Aerials [Theoretical Investigation].—H. J. Fausten. (*Arch. f. Elektrot.*, 15th Nov. 1940, Vol. 34, No. 11, pp. 653–668.)

Author's summary :—" In the first section the Hertzian solution for the electromagnetic field of a radiating dipole is first of all briefly derived up to the wave-equation $\Delta\vec{Z} = \epsilon_0\mu_0 \cdot \partial^2\vec{Z}/\partial t^2$. On the assumption that the vector $\vec{Z}$ is dependent only on the distance r of the external point and has the same direction everywhere in space, the wave-equation is solved and thus the field of the dipole determined through its components. To clarify the effect of the distance r, E_z and H [thus given by eqns. 6a and 6b] are divided into near, transitional, and distant fields, with the result that it can be seen how far from the radiator various simplifications are permissible.

" In the second section the electric field is used, with the assumption of a cosine-distributed current in the radiator, to determine the electromotive force induced in the reflector : here, as an approximation to the double integral representing the reflector voltage, both radiator and reflector are split up into five elementary dipoles each $\lambda/20$ long, and a summation carried out. This shows the occurrence of a phase displacement between reflector voltage and radiator current, which is represented as a function of the distance ratio r_0/λ. This phase is checked by comparison with the corresponding expressions calculated by Rücklin [1934 Abstracts, pp. 207–208] and Sammer [1930 Abstracts, p. 278], and it is found that the assumptions made by Rücklin are inadmissible for the near zone which alone is considered. Then, from the equations of line theory, the ratio of radiator current to reflector current is determined for the case of reflector resonance [section III].

" The further treatment of the most favourable dimensioning of a radiation-coupled directive system requires that a coupling factor should be calculated from the radiated output which, in analogy to the ratio mutual-inductance/self-inductance of a coupled system of two oscillatory circuits, is determined from the mutual radiation resistance [section IV]. The expression for this mutual radiation resistance is found to be : $R_{SR} = 2\pi c\mu_0(1/\lambda)^2 \cdot \cos\eta \cdot F(2\pi r_0/\lambda)$ ohms [where η is the phase difference between reflector and radiator currents, $\pi/2 - \Phi + \psi$ (section III) ; for F *see* p. 664. R_{SR} can serve as a measure of the coupling between radiator and reflector : $R^2{}_{SR} = k^2 R_S R_R$, and when $R_S = R_R$, $k = 3/2 \cdot \sqrt{\cos^2\eta F^2}$]. Using this coupling factor, the resulting coupling-frequencies are found.

" The last section devotes itself to the result of the preceding calculations, which provide a tool for determining the optimum spacing of the reflector from the radiator, if in the direction of minimum radiation the highest possible amount of screening is to be obtained. Account must be taken, in this determination, of the fact that the detuning of the reflector has an influence on the coupling, and that an optimum detuning of $\psi = 7°$ exists which results in an improvement of some 4% in the screening [p. 667]. In conclusion, two horizontal characteristics are shown [Fig. 13, calculated by eqn. 7] which are drawn for the optima of the curves $|\bar{E}|_0$ and $|\bar{E}|_1$". These curves " show unmistakably that $r_0/\lambda = 0.25$ and $\psi = 7.0°$ represent the optimum dimensioning of a radiation-coupled directive system."

1072. Directional Broadcasting [on Medium Waves : Reducing Wasted Radiation].—(*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 2–4.) Midland Regional and Start Point stations are given as examples.

1073. [Ice-] Storm Damage to the Main Aerial System at Rugby Radio Station.—(*P.O. Elec. Eng. Journ.*, Oct. 1940, Vol. 33, Part 3, pp. 134 and 135.)

1074. Earthing Resistance of Various Types of Soil.—O. Münger. (*Bull. Assoc. suisse des Élec.*, No. 23, Vol. 31, 1940, pp. 529–533 : in German.)

Author's summary :—" A report is made on investigations directed towards the determination of the resistance of various types of soil. It is found that the resistance depends chiefly on the quantity and resistance of the water contained in the pores. Discrepancies between results already published are explained. Finally, methods of measuring the soil resistance are discussed, and the technique of geological sounding (*e.g.* by the Wenner method) is outlined.

1075. Eight Miles of Earth Wires Ploughed under in Two Days [by Caterpillar Diesel Tractor at KFAR, Alaska].—(*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 26.)

1076. A Graphical Method [using Weir Nomogram] of Working Out the Bearing of a Distant Transmitter.—T. S. E. Thomas. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 7–8.) For corrected rules see *ibid.*, February issue, p. 39.

VALVES AND THERMIONICS

1077. The Impedance due to a Beam of Electrons traversing a Transverse Alternating Deflecting Field [Previous Expressions for Resistance & Capacity of Pair of Parallel Plates have neglected Change of Charge on Condenser Plates as Electrons leave the Field : " Profound Modification " in Results when Factor $(1 - \cos\omega\tau/2)$, allowing for This, is introduced].—S. Rodda. (*Wireless Engineer*, Feb. 1941, Vol. 18, No. 209, p. 64.)

1078. On the Characteristics of the Magnetron of a Symmetrical Type [with Central Cathode and Symmetrical End Plates & Split Anodes : Tests on Three Models].—S. Aoi. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, pp. 62–63 : summary only.)

1079. New Valves [including RCA-815 (Transmitting Push-Pull Beam Power Amplifier) and RCA-826 (Transmitting Triode), both for Ultra-High Frequencies].—R.C.A. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 31..33.) *See* also 767 of March.

1080. A Theory of the Practical Triode: Its Application to Valve Design [Deduction, by Approximate Methods, of Relations between Valve Geometry and the Characteristics of Actual Triode with Plane Anode & "W" Filament: Failure of Classical Equation to give Observed Mutual-Conductance Values traced to Effect of Grid Supports: a Modified Formula: Effect of Space Charge: Example of Application].—I. A. Harris. (*Wireless Engineer*, Feb. 1941, Vol. 18, No. 209, pp. 45–55.)

1081. New Metal Valve [Improvements and Simplifications: New Technique for Exhausting].—D. W. Jenks. (Summary only: *see* 1244, below.)

1082. Tubes Department Index [since Inception in Nov. 1939].—(*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 61–62.)

1083. The Measurement of Electrode Temperatures of Valves during Exhaust and Operation.—A. D. Power. (Summary only: *see* 1244, below.)

1084. Activation Phenomena in Thoriated Tungsten and Thoriated Molybdenum.—H. Nelting. (*Zeitschr. f. tech. Phys.*, May 1940, Vol. 21, No. 5, pp. 103–110.) *See* also 4287 of 1940.

1085. Contributions to the Electronics at Natural Cleavage Surfaces of Metallic Single Crystals: I.—Kluge & Steyskal. (*See* 1133.)

DIRECTIONAL WIRELESS

1086. Short-Period Fluctuations in the Characteristics of Wireless Echoes from the Ionosphere [Directional & Polarisation Measurements on Two Spaced Aerials, using Photographic Recording (at 1/25th Sec. Intervals) of Cathode-Ray-Tube Ellipses: Single Pulse of Echo Pattern selected by Desensitising Device].—T. L. Eckersley & F. T. Farmer. (*Proc. Roy. Soc.*, Ser. A, 10th Jan. 1941, Vol. 177, No. 969, p. S 82.)

"The results show that for normal E and F reflections the relative e.m.f. in the two aerials, and in consequence the directions and polarisations, remain constant over many seconds. Reflections from scattering clouds are however entirely different. The apparent ray directions and the polarisations only remain constant over a fraction of a second (between 1/25th and ½ sec.) and the difficulty of balancing by manual methods the electric force in one frame against that in another is entirely explained. The results show that the abnormal E region is also irregular in time and space."

1087. Polarisation Measurements in the Medium-Wave Band.—J. Grosskopf & K. Vogt. (*T.F.T.*, Oct. 1940, Vol. 29, No. 10, pp. 291–296.)

Although the classic tests (on medium waves) in England and Australia confirmed the predictions of Appleton's magneto-ionic theory, and although it can be assumed from the theory that in the northern hemisphere the predominant polarisation will be left-handed whatever the direction of propagation may be, in the tests mentioned the propagation was in the direction of the Pole in both cases, and (say the writers) "there have been only few investigations on the polarisation of space waves in the medium-wave band." In connection with direction-finding research the present writers found it necessary to obtain an exact knowledge of the polarisation of such waves for propagation in any direction: "since we have developed a simply working apparatus for the polarisation measurement, we will here describe this and report on the first results obtained with it."

The lay-out of this crossed-loop equipment is seen in Fig. 1: each loop has its own receiver, but there is a common heterodyne whose frequency, "for the correct reproduction of the h.f. phase, as regards magnitude and sign, at the l.f. end," must be smaller than the signal frequency. The l.f. voltages are taken to a phase-measuring unit whose output actuates a continuously working triple ink-writer. This records the amplitude curves for the two loops, and the phase curve. The application of eqns. 5 and 6 is simplest when γ (the angle between loop 1 and the plane normal to the direction of transmission) is made 0° or 90°, with a check reading at 45°. The sense of the polarisation is determined by an oscilloscope which is so connected, during calibration of the equipment, that a right-handed rotation of the polarisation plane, or rather the corresponding left-handed rotation of the crossed loops about their vertical axis, produces a right-handed rotation of the trace: the sense of rotation is easily observed by connecting a pulse generator (giving a pulse frequency a few cycles below the note frequency) in the lead to one pair of plates. However, this arrangement was found inconvenient for the investigation of the rapid phase fluctuations (during the transition period between day and night conditions) in the later tests when the ground wave was comparable with the space wave; consequently a new phase-meter and recorder, with a range of 0° to 360°, instead of only to 180°, was developed: this allowed the oscilloscope and pulse generator to be dispensed with as soon as the new devices had been calibrated.

The first tests gave the records seen in Figs. 13–16 and Table 1. The conditions were those in which the equations 5–8c are applicable, namely a negligibly small ground wave. Fig. 13 shows the extremely constant phase state for a predominant space wave: the phase remains steadily at 90° even when γ is changed from 0° to 90°, the only phase-jumps occurring at the change of γ to or from a 45° position. Fig. 14 shows the same steadiness when the changes of γ are made at short intervals. Although Fig. 15 is also labelled "predominant space wave," the marked deviations from 90° and lowered amplitudes are attributed in one place to interference by ground wave (p. 294) and in another (p. 296) to an absorption-type fading, "since the ground wave does not come in as an interfering factor. A more thorough examination of the general amplitude characteristics is kept for a later report." The times for Figs. 13–16 are all at or after 22.30 in June. "The smoothness of these amplitude and phase curves, and the good agreement with calculation (Table 1), allow it to be concluded that during long periods the space wave only is present," giving predominantly a 90° left-hand polarisation.

The theoretical effect of the presence of a ground wave is considered on p. 292 and treated graphically in Figs. 3–6 for various ratios of space wave to ground wave from 0.5 to 2, circular polarisation and an angle of arrival of 60° (α in Fig. 1) being assumed. When this ratio is much less than unity, the polarisation alternates in sense between two approximately equal but small maximum values. As the space wave increases (still remaining smaller than the ground wave) a polarisation is to be expected which is weak left-handed for large amplitudes of E_1 and E_2 and much more strongly right-handed for small amplitudes. Finally, when the space wave approaches equality with the ground wave, the right-handed polarisation at small amplitudes approaches the value of 180°, while the left-handed polarisation at large amplitudes still remains comparatively weak. "Thus, as Fig. 4a shows, the right-handed polarisation [marked r on the diagram] will be observed only during very short periods, if it be assumed that all values of phase difference between space and ground waves from 0 to 2π are equally probable." When the ratio of space to ground wave is greater than unity, left-handed polarisation is exclusively found: if the ratio is only slightly above unity, the phase of this polarisation varies strongly between 0° and 180°. Finally, as the ratio increases still further the phase takes on the stable value for the predominant space wave (Fig. 6a). The figures mentioned are all for circular polarisation: Figs. 3b–6b show that the same behaviour is to be expected when the polarisation phase r is less than 90°, with the difference that the symmetry of the phase and amplitude curves is lost.

These theoretical results are confirmed experimentally by observations during the transition from day to night conditions. At first, as the space wave makes its appearance, there is a slow alternation between weak right-handed and left-handed polarisation; this is followed by the gradual predominance of the right-handed polarisation, then (for an extremely short time) by right-handed peaks in the polarisation curve going up to 180°. Finally, exclusively left-handed polarisation appears, at first varying violently but ultimately changing to the stable left-handed polarisation of the predominant night space wave. These results are seen progressively in the curves of Figs. 7 to 12 (Prague and Breslau, received near Berlin), the final stages being shown in Figs. 13–16, already discussed. Thus it may be concluded that "the space waves of Prague and Breslau (propagation south/north) from the moment of their appearance are left-handedly polarised: in the transition period an angle of 45° predominates (Figs. 9, 11) as a result of combined action of ordinary and extra-ordinary components, but in the late night hours the space waves have very frequently, and over long periods, an angle of 90°. Since $R = 1$, the space wave for propagation in the direction of the Pole is left-handedly circularly polarised, in agreement with Appleton's theory."

Finally, to examine the effect of direction of propagation on the polarisation, observation were made on a series of broadcasting stations lying in various directions with respect to Berlin. A horizontal crossed-dipole system was used for reception. Southerly stations such as Rome, Stuttgart, and Munich had a particularly stable left-handed 90° polarisation, and Prague and Breslau gave (as they did with the crossed-loop system) the same during the late night hours. Waves from stations in the north and north-west showed a markedly slighter splitting, but were always left-handedly polarised. London and Bremen were sometimes linearly polarised. The northerly Stockholm showed left-handed polarisation. "A directional effect on polarisation is thus indicated."

1088. PANORAMIC RECEPTION APPLIED TO AERIAL NAVIGATION [for Anti-Collision Indication, Determination of Absolute Altitude, etc.].—M. Wallace. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 42.) Latest development of the "panoramic reception" principle dealt with in 3888 of 1940 and back reference.

ACOUSTICS AND AUDIO-FREQUENCIES

1089. ABSOLUTE PRESSURE CALIBRATIONS OF MICROPHONES [Use of Tourmalin-Crystal Disc (as Microphone & as Sound Source) and the Principle of Reciprocity, to investigate Discrepancies between Results obtained with Thermophone, Electrostatic Actuator, & Rayleigh Disc: Absolute Determination of Piezoelectric Modulus of Tourmalin: etc.]—R. K. Cook. (*Journ. of Res. of Nat. Bur. of Stds.*, Nov. 1940, Vol. 25, No. 5, pp. 489–505.)

1090. LOUDSPEAKER PROBLEMS [Theoretical Examination of the Five Main Requirements and the Factors influencing Their Fulfilment].—K. Hartkopf. (*Funktech. Monatshefte*, Oct. 1940, No. 10, pp. 145–152.)

(1) Wide frequency-range (about 20 c/s to 10 kc/s): only obtainable if the diaphragm has a low resonance frequency and a low density (so that the decreasing radiation at high frequencies, from the membrane as a whole, may be made up for by vibrations in the membrane itself). (2) Freedom from linear distortion (only obtainable by the same design as above): from non-linear distortion (depends on suitable choice of driving mechanism). (3) Output independent of frequency (by making the resonance frequency come well below the lower limit of the working range). (4) As little directive effect as possible (the tone-distorting effect, due to the membrane behaving, at the higher frequencies, as a collection of point sources whose sound fields are superposed on one another—Fig. 12—can only be avoided when the membrane moves as a piston). (5) Good efficiency: formula 39 for the efficiency

of such a loudspeaker with low resonance frequency (" inertia-restrained " loudspeaker) shows various apparent ways of increasing the value, even up to as much as 30% : " unfortunately these values have so far proved unattainable," owing partly to limitations in the materials used and partly to basic physical reasons.

1091. AN EXPERIMENTAL INVESTIGATION OF SUB-HARMONIC CURRENTS. — McCrumm. (*See* 1030.)

1092. PAPERS ON GRAMOPHONE AMPLIFIERS, LOUDSPEAKERS, ETC. [Automatic Bias Control for Output Valves : Negative Feedback to minimise Microphonicity & Motor Rumble : Loudspeakers reproduce Square Waves : Kettle-Drum Baffle : etc.].—Walsh, Olson, & others. (Summaries only : *see* 1244, below.)

1093. A PHOTOELECTRIC PHONOGRAPH REPRODUCER [Fraction of Ounce Stylus-Pressure : Great Reduction in Wear & Needle-Hiss : Problems solved in the Design].—Philco. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 42 and 46, 48.) *See* also 111 of January and back references.

1094. THE " RECORDGRAPH " [for Non-Photographic Recording on 35 mm Film : with Reproducer : 25 Feet give One Hour's Recording of Music " of Excellent Quality," 6¼ Feet give One Hour of Intelligible Speech].—W. L. Woolf. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, pp. 40–41.)

1095. A NEW FILM GRAMOPHONE.—E. J. Wender. (*Wireless World*, Feb. 1941, Vol. 47, No. 2, p. 47.) *See* also 4315 of 1940, and *cf.* Woolf, 1094, above.

1096. GENERAL CONSIDERATIONS OF THE CRYSTAL CUTTER [Rochelle-Salt Recording Head for Home Recording : Characteristics : Coupling Networks : etc.].—T. E. Lynch & S. J. Begun. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 9–11 and 26..29.) From the Brush Development Company.

1097. IMPROVING THE HOME RECORDER [Defects of Equipment now on Sale : Suggested Improvements].—F. E. Williamson. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 15–16.)

1098. " HOW TO MAKE GOOD RECORDINGS " [Book Review].—Audio Devices, Inc. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, p. 23.)

1099. EXTENDED EXPERIMENTAL STUDY OF THE OPTICAL PATTERN [Buchmann & Meyer Method of investigating Gramophone Recording Heads, in General Use without Any Complete Examination of Its Implications since Original Publication in 1930].—C. J. LeBel. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 22 and 24.)

See, for example, 112 of January. " A number of engineers have adopted the practice of directly subtracting the width of the ' noise pattern ' from the pattern width of the noise plus signal " : this is found to be quite incorrect : for practical purposes (where the precision is less than that involved when the width measurements are made by cathetometer) the true relation is satisfactorily represented by the formula for the combination of two a.c. voltages of different frequencies. A curious effect due to lack of shaft rigidity is among the other results given.

1100. MULTIPLE SOUND TRACKS AND LOUDSPEAKERS GIVE AUDITORY PERSPECTIVE TO SOUND MOVIE SCREEN [Walt Disney's " Fantasia " shown on " Fantasound " System].—A. P. Peck. (*Scient. American*, Jan. 1941. Vol. 164, No. 1, pp. 28–30.)

1101. VARIO-LOSSER CIRCUITS [Compressers & Expanders, etc : Derivation of Formulae for Steady-State Transmission & Distortion in terms of Varistor Characteristics].—W. R. Bennett & S. Doba. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, Transactions pp. 17–22.) A three-word comment by A. P. Herbert can be imagined.

1102. A SIMPLIFIED COMPANDOR [Volume-Range Compresser-Expander] FOR TRUNK CIRCUITS [using Metal Rectifiers as the Non-Linear Circuit Elements].—J. Lawton & D. J. Marks. (*P.O. Elec. Eng. Journ.*, Oct. 1940, Vol. 33, Part 3, pp. 120–126.)

1103. " 1940/1941 AMPLIFIER HANDBOOK AND PUBLIC ADDRESS GUIDE " [Book Review].—M. Asch. (*Wireless World*, Feb. 1941, Vol. 47, No. 2, p. 50.)

1104. ENGINEERING REQUIREMENTS FOR PROGRAMME TRANSMISSION CIRCUITS.—F. A. Cowan & others. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 34–35 : preview, copy available.)

1105. THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE RELATIVE ATTENUATION [Bezugsdämpfung] AND LOUDNESS [and the Failure of the Usual Measuring Instruments with Mixed Tones].—K. Braun. (*T.F.T.*, Feb. 1940, Vol. 29, No. 2, pp. 31–36 : *E.T.Z.*, 7th Nov. 1940, Vol. 61, No. 45, p. 1021—summary only.)

The relative attenuation serves as an indication of the efficiency of telephonic instruments. It is measured by a loudness comparison between the telephone microphone and the telephone receiver on the one hand and a calibration circuit (distortionless condenser microphone and distortionless m.c. receiver) on the other. The comparison is carried out on speech, not on a pure tone, and the ear is used as the measuring instrument.

The alternative use of a meter of some kind is here examined. The value of the relative attenuation will depend not only on the spectrum of the frequency-mixture but also on the nature of the rectification at the receiver. Sound-level meters in use to-day employ rectification with a square-law characteristic, whereas for the sound levels important in practice the ear-sensitivity obeys a square-root law. On pure tones the sound-meters measure correctly, but on frequency-mixtures they show a lower value of loudness than that given by the ear, and it is the latter value which is of importance for the purpose of the test.

1106. An Improved Sound-Level Meter [Range 24–130 db: Portable].—W. Mikelson. (*Gen. Elec. Review*, Dec. 1940, Vol. 43, No. 12, pp. 515–517.)

1107. The Audio Noise of Transformers [and Its Predetermination], *and* A Study of Sound Levels of Transformers.—W. C. Sealey: H. Fahnoe. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 35–36: p. 36: previews, copies obtainable.)

1108. Spectrometer for Audio Frequency [Electric Wave Analyser with Motor-Driven Switch and Cathode-Ray Oscilloscope: Permanent Records of Spectrum by Photography].—R. K. Hellman. (*Electronics*, Nov. 1939, Vol. 12, No. 11, p. 76: illustrated summary.)

1109. Energy Considerations on the Pressure of Radiation of Sound [leading to Rigorous Formulae for Rayleigh (Enclosed) & Langevin (Open) Cases: for Small Amplitudes the New Formulae yield the Old, but are Free from Limitations].—F. Bopp. (*Ann. der Phys.*, Ser. 5, No. 6, Vol. 38, 1940, pp. 495–500.)

1110. A Modern Beat Oscillator [with Very High Standards of Performance but Simple in Design, with 6 Valves].—C. W. Caldwell & C. W. Harrison. (*Electronics*, Nov. 1939, Vol. 12, No. 11, pp. 50 and 52.)

1111. An Automatic Electrically-Driven Tuning Fork [without Help of Valves: driven by Dry Cell through Vibrating Contact or Carbon-Microphone Capsule: Bobbin round Pole of Permanent Magnet: Portable Design].—S. Baglione & A. Manfredi. (*La Ricerca Scient.*, July/Aug. 1940, 11th Year, No. 7/8, pp. 526–528.)

1112. A Vacuum-Tube Voltmeter for Audio Frequencies.—Likel. (*See* 1152.)

1113. "Messeinrichtung für die Fernmeldetechnik" [Measuring Apparatus for Communication Engineering: Book Review].—Siemens & Halske. (*See* 1159.)

1114. The Quantum of Sensory Discrimination [Observations on 1000 c/s Tone with Intensity increased Momentarily support Békésy's Quantal Theory].—Stevens & Volkmann. (*Science*, 20th Dec. 1940, Vol. 92, pp. 583–585.)

1115. The Velocity of Sound [measured over Short Distances in Laboratory by Pulses (60 per Sec.) & Oscilloscope: 331.364 ± 0.043 m/s as Average Value at 0° C].—Colwell, Friend, & Gibson. (*Journ. Franklin Inst.*, Dec. 1940, Vol. 230, No. 6, pp. 749–754.)

1116. The Electrical Conductivity of Liquid Dielectrics and Its Alteration by Supersonic Waves [Increased Conductivity: explained as due to Volume Processes similar to Those in Dense Gases].—Seidl. (*Zeitschr. f. Phys.*, No. 5/6, Vol. 116, 1940, pp. 359–365.)

1117. The Smoke Nuisance and Sound Waves [and the Development of an Efficient Source (23 lb Aluminium Cylinder) of High-Frequency Sound].—R. S. Dean. (*Science*, 17th Jan. 1941, Vol. 93, Supp. pp. 10–11.)

1118. The Air-Jet with a Velocity exceeding That of Sound.—J. Hartmann & F. Lazarus. (*Phil. Mag.*, Jan. 1941, Vol. 31, No. 204, pp. 35–50 and Plates.)

1119. The Production of Waves by the Sudden Release of a Spherical Distribution of Compressed Air in the Atmosphere.—Unwin. (*See* 1255.)

PHOTOTELEGRAPHY AND TELEVISION

1120. The Large-Screen Television Receiving Installations of the German Post Office [open to the Public at Two Places in Berlin during the War].—G. Faust. (*Funktech. Monatshefte*, Oct. 1940, No. 10, Supp. pp. 37–40.)

Including some data (dimensions of hall, seating accommodation, picture size, projecting-tube voltage & ray-current, etc.) on the installation at the Ministry and the larger one in Turmstrasse. "The lens raster and fluted screen developed for television are so designed that the incident light is reflected almost only to the space occupied by the viewers: moreover, in contrast to the ordinary cinema screen, all viewers at an angle up to 30° or 45° to the screen normal obtain an equally bright picture." The Turmstrasse screen is 3.00 × 3.60 m², and there are seats for 294 viewers: the maximum ray power is 300 watts.

1121. What's Happened to Television? Troubles in Video Engineering and How They are busying the Remarkable "Committee of 168."—D. G. Fink. (*Technology Review* [of M.I.T.], Jan. 1941, Vol. 43, No. 3, pp. 114–115 and 129..133.)

1122. Rochester Papers on Television Subjects [Apparatus for tracing on C-R-O Screen the Phase-Frequency Curve of Television Circuits: Goldmark's Method for Colour Television of "Live" Programmes: etc.]—(Summaries only: *see* 1244, below). *Cf.* 804 of March.

1123. Apparatus for the Measurement of Insertion Phase Shift at Radio Frequencies [primarily for Work in connection with Line Transmission of Television Signals: Development of Special Rotary Phasemeter giving Direct Visual Indication: Associated Apparatus].—R. F. J. Jarvis & E. F. S. Clarke. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 162–170.)

1124. Television Transmission over Wire Lines [for Local & Inter-City Networks: including Coaxial Lines ("Three-Megacycle System") and a Special Low-Attenuation Cable].—M. E. Strieby & J. F. Wentz. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 35: preview, copy obtainable.)

1125. BAIRD COLOUR TELEVISION [Sydenham Laboratories Demonstration]. — (*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 43–45.) *See* also 803 of March.

1126. THE INTRINSIC SUBSTANCE AND METRIZATION OF COMMUNICATION [Attempt to establish Monistic Theory: Application to Telegraphy, Television, etc.].—Okada & Hujiki. (*See* 1233.)

1127. ON THE BEHAVIOUR OF PHOSPHORS UNDER INTERMITTENT ELECTRON-IRRADIATION [as in Television, etc: Experimental Investigation].—M. Knoll. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 385–414.)

Part I deals with luminosity, beginning with an oscillographic determination of the building-up and decay times of a ZnS + CdS white-light phosphor under short-time excitations (ray released in 1.2×10^{-4} sec. pulses at 7.5×10^{-4} sec. intervals) for various current densities (obtained by altering the spot diameter by means of a concentrating coil, from 60 mm to 1 mm). As the current density is increased in steps from 1.4×10^{-6} to 5×10^{-3} A/cm^2 the shape of the oscillograph trace representing the response of a photocell/multiplier combination alters as shown in Fig. 2, the up curve (building-up process) becoming steeper, with its summit flatter, and the down curve (decay) showing the same change, so that it has a longer straight descent before curving to a gradual approach to the axis. Whether this variation of building-up and decay times with the current density (already found by Schleede & Bartels, 1669 of 1939) depends on an increase in temperature remained to be decided, though the marked alteration shown in the first two tests of Fig. 2 for a comparatively small spot-diameter change from 60 to 20 mm (unlikely to produce much temperature rise in the screen) suggested that the effect was one of electron-concentration rather than of temperature. This is confirmed by Fig. 4, which shows the small difference between the curves at 0° and those at −190° C (*cf.* Riehl & Schön, 1580 of 1940, for ZnS phosphor excited by short-wave ultra-violet light: the process is here explained as a bimolecular reaction, the recombination of an electron and an ion, so that the building-up and decay would be represented by a non-exponential function of the time and the speed of the process would be dependent on intensity but not on temperature).

The above all refers to the building-up and decay *times*. As regards the actual steady luminous *output*, it is known that this decreases with increasing temperature—see Randall's curve for continuous irradiation of zinc-cadmium-sulphide phosphor, Fig. 5. The writer's curves show the decrease in brightness, for intermittent irradiation, as the spot-diameter is reduced from 25 mm to 3 mm and the local temperature consequently raised; the falling-off in brightness is thus more pronounced when the material is on a glass base (upper traces) than when it is on metal (lower traces). The same result is obtained if the diameter is kept constant and the ray current increased. There is no fundamental difference, as regards this decrease of brightness, between zinc-oxide and zinc-cadmium-sulphide phosphors (Figs. 6 & 7 respectively), greatly though these differ in their decay times and electrical conductivity. These records, incidentally, show that the effect is *not* due to a destruction of the phosphor, because they prove the process to be a reversible one, the brightness rising again as the spot diameter is again increased. (Deterioration of the phosphor, at still higher current densities, has wrongly been termed "burning": heating in clean surroundings has no permanent effect, the lasting deterioration produced by overloading being due to reactions between phosphor and binding material or base.)

Section I.3 deals with "momentary overheating" and its accompanying decrease in brightness. In the previous work the heating effects, although produced intermittently, are classed as "steady" because they determine the temperature at which an element of the screen finds itself just as the ray arrives on it. The phenomenon now to be examined (with the quite different apparatus of Fig. 9) makes itself evident when the light intensity proceeding from a highly loaded screen is measured while the ray current is kept constant, the spot is kept moving from element to element by the usual scanning action, and the spot diameter is varied. Although the number of electrons falling on each square centimetre of the screen is thus constant, a marked dependence of the measured light intensity on the spot diameter is found (Fig. 8, where the ordinates represent the focusing-coil current in place of the spot diameters): the falling-off in brightness with increased spot concentration is more marked when larger ray currents are used. This dependence might be explained by negative charging of the surface at greater spot concentration, causing a loss of electron velocity: by saturation of the layer owing to the limited number of available excitation centres: or by "momentary" overheating—a rise in temperature of an element during the 10^{-6}–10^{-7} sec. during which the spot lingers on it. If, on cooling the screen base by liquid air, the drop in brightness as the spot is concentrated becomes *less* than with the uncooled screen, the last explanation must be the correct one; this is found to be the case (Fig. 10).

Section II describes an elaborate investigation of the charging-up processes on a screen, first with a stationary ray and then with intermittent irradiation. The periodically alternating charges and discharges which occur when a ray moves rapidly over a screen surface in oscillographs or television receivers are considered: in the latter they are responsible for two troubles, the overlapping of two interlaced-scanning rasters at high ray-current strengths (Fig. 16) and "image flutter" due to alternate focusing and defocusing of the spot (Figs. 17 & 18), explained by a dependence of the local equilibrium potential in the ray on the focusing. By capacitive removal and amplification of the charges formed and carried off by the ray, the writer succeeds in making certain deductions as to their polarities and magnitudes (at low ray velocities: Figs. 21/23) and in making (at higher velocities) the potential "mountains" on the screen directly visible (Figs. 22/25). The final section deals with secondary-emission processes in phosphors: if the resistance of the latter is not too high, its secondary emission curve can be determined by comparison with the known emission curve of a metal, in an electron-scanning device: or the arrangement of Fig. 20, with its external capacitive exploring electrode, can be used to obtain secondary-emission images of the whole screen surface (Fig. 26) which yield conclusions as to the uniformity and structure even of a sealed-off screen.

1128. Picture Transmission by Submarine Cable [London/New York: including Very Special Types of Network & Amplifier, and Fundamental Theory].—J. W. Milnor. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 35: preview, copy obtainable.)

1129. Recording Paper affected by Electricity only [" Teledeltos " Dry Paper for Facsimile Telegraphy, etc.].—Western Union. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 40.) *See* also 2024 & 4606 of 1939, and *Electronics*, Dec. 1940, p. 82, where it is stated that this paper is now available for public use.

1130. An Electrically-Focused Multiplier Phototube [with 9 Curved Targets (" Dynodes "), the Ninth almost enclosing the Anode: 2.8″ High, 1.25″ Diam: Amplification over 1 Million, Luminous Sensitivity over 10 A/Lumen: Dark Current equivalent to 10^{-7}–10^{-6} Lumen].—J. A. Rachman & R. L. Snyder. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 20–23 and 58, 60.)

1131. The Energy Distribution of Photo-electrons before Emergence.—H. Mayer. (*Zeitschr. f. Phys.*, 11th June 1940, Vol. 115, No. 11/12, pp. 729–739.)

1132. Photoelectric Study of Thin Electrolytic Layers of Ta_2O_5.—W. Bär. (*Zeitschr. f. Phys.*, 11th June 1940, Vol. 115, No. 11/12, pp. 658–677.)

1133. Contributions to the Electronics at Natural Cleavage Surfaces of Metallic Single Crystals: I.—Kluge & Steyskal. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 415–427.)

From the AEG Valve Factory: for previous work *see* 4487 of 1938. " The splitting of metallic single crystals in a high vacuum is a way of observing, without chance of error, the influence of the crystal orientation on the electronic behaviour of the various boundary surfaces. It is shown that the surfaces of cleavage display a surface cleanness which is at least equal to that of films distilled in high vacua." The present part deals with the production of cleavage surfaces of zinc single crystals in a high vacuum, and with introductory photoelectric measurements on these. The measurement of the spectral dependence of the photoeffect (0001 surface) gave by Fowler's method a limiting wavelength of 290 ± 0.7 mμ and a work function of 4.26 ev.

MEASUREMENTS AND STANDARDS

1134. Diathermy Measurement Technique [" Dosemeter-Diatherm " for Ultra-High Frequencies].—Kraus & Teed. (*See* 1252.)

1135. One Method of measuring High-Frequency Feeder-Wire Constant.—Ogihara & Karasawa. (*See* 1069.)

1136. Apparatus for the Measurement of Insertion Phase Shift at Radio Frequencies.—Jarvis & Clarke. (*See* 1123.)

1137. A Radio-Frequency Bridge for Impedance Measurements from 400 Kilocycles to 60 Megacycles [Modification of Schering-Bridge Circuit to give Resistive & Reactive Components in terms of Incremental Values of Capacitance].—D. B. Sinclair. (*Proc. I.R.E.*, Nov. 1940, Vol. 28, No. 11, pp. 497–503.)

Two typical examples are given of measurements made with the bridge, on an aerial and a transmission line at frequencies between 2.5 and 60 Mc/s: in the second case the results are compared with the theoretically derived curve. A bibliography of 36 items is included.

1138. Low-Tension Schering Bridge [with Electrode System for Permittivity Measurements].—Cambridge Instrument. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, pp. 12–13.)

1139. Power-Frequency Visual Detector [Indicator for All 50 c/s Bridge Technique, to supersede Vibration Galvanometer: Various Advantages].—Marconi-Ekco. (*Journ. of Scient. Instr.*, Feb. 1941, Vol. 18, No. 2, p. 28.)

1140. The Detection of Initial Failure in High-Voltage Insulation [Extended Use of Arman-Starr H.F. Discharge Bridge: Results].—J. B. Whitehead & M. R. Shaw, Jr. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 39: preview, copy obtainable.) *Cf.* Quinn, 840 of March.

1141. High-Potential Testing Equipment for Quantity Production [of Low-Voltage Apparatus: Danger & Prevention of Surges of Unknown Effective Value].—C. M. Summers. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 37: preview, copy obtainable.)

1142. Direct-Reading Wavemeter [of Novel Design].—H. Straubel. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 70: summary only.) Already dealt with in 249 of 1940.

1143. Absolute Pressure Calibrations of Microphones [Use of Tourmalin-Crystal Disc: Absolute Determination of Piezo-electric Modulus: etc.].—Cook. (*See* 1089.)

1144. Crystal Calibrator for R.F. Measurements [with Switch-Selection of 100 kc/s, 1 Mc/s, & 5 Mc/s Crystals: containing Additional Synchronising Oscillator (Acorn Triode) at 25 or 50 Mc/s for differentiating between Very High Frequencies, *e.g.* 30th or 31st Harmonic of the 5 Mc/s Frequency].—Salford Elec. Instruments. (*Journ. of Scient. Instr.*, Feb. 1941, Vol. 18, No. 2, pp. 27–28.)

1145. Baldock Frequency-Control Station.—Booth & Gregory. (*See* 1222.)

1146. A Mains-Frequency Error Recorder [for Long-Period Observations (for Statistical Analysis) of Frequency Fluctuations: 20th Harmonic modulated with Standard 1000 c/s Tone (Accurate to 1 Part in 10 Million), Resulting Low Beat Frequency taken to Beat-Counting Uniselector connected to Series of Meters].—W. E. Finlayson. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 171–175.)

1147. "Electrical Timekeeping" [Book Review].—Hope-Jones. (*Journ. Franklin Inst.*, Jan. 1941, Vol. 231, No. 1, pp. 95–96.)

1148. A Cathode-Ray Stop-Watch.—Brailsford. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, p. 16.) Already dealt with in 845 of March.

1149. A Cathode-Ray Impulse-Measuring Equipment [for Measurement, on "Target Diagram" Basis, of Instantaneous Impulse Distortions in Automatic Telephone Networks].—Hadfield & Chandler. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 149–155.)

1150. Standard Electrodynamic Wattmeter and A.C./D.C. Transfer Instrument [with Determination of Accuracy at Frequencies up to 2 kc/s].—J. H. Park & A. B. Lewis. (*Journ. of Res. of Nat. Bur. of Stds.*, Nov. 1940, Vol. 25, No. 5, pp. 545–579.)

1151. A New High-Speed Thermal Wattmeter [with Thermocouples acting also as Heaters: Overload Protection by Transformers with Nickel-Iron Cores: for Polyphase Power].—J. H. Miller. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, Transactions pp. 37–40.)

1152. A Vacuum-Tube Voltmeter for Audio Frequencies [covering 0.05 to 500 Volts, 20 to 15 000 c/s: High Input Impedance, Linear Scales, & Inherent Meter Protection: Auxiliary to Analyser Test Set].—H. C. Likel. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 32–34 and 73.)

1153. A Single-Action Compound Reversing Switch [used in Measurement of Voltages around One Microvolt: Free from Thermoelectric Effects: Self-Cleaning, etc.], *and* Multiple-Brush Precision Instrument Switches.—J. K. Berry: Tinsley. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, pp. 6–7: pp. 13–14.)

1154. An Integrating Voltmeter for the Study of Nerve and Muscle Potentials.—Jacobson. (*See* 1251.)

1155. Instruments and Methods for measuring Sensory Events [with Literature References].—Craik. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, pp. 1–6.)

1156. A New Type of Search Coil for Ballistic Measurement of Magnetic Field Strength.—Simpson. (*See* 1161.)

1157. American Apparatus, Instruments, and Instrumentation.—Müller. (*See* 1259.)

1158. Automatic Meter Protection: Alternative Methods of safeguarding Small Moving-Coil Instruments [including Use of Dry-Plate & Other Rectifiers, and of "Metrosil," etc., as Shunt].—T. J. Rehfisch. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, pp. 14–15.)

1159. "Messeinrichtung für die Fernmeldetechnik" [Measuring Apparatus for Communication Engineering: Book Review].—Siemens & Halske. (*Hochf:tech. u. Elek:akus.*, Oct. 1940, Vol. 56, No. 4, p. 128.) "Far more than an expanded catalogue," says the reviewer, Zenneck.

SUBSIDIARY APPARATUS AND MATERIALS

1160. The Impedance due to a Beam of Electrons traversing a Transverse Alternating Deflecting Field.—Rodda. (*See* 1077.)

1161. A New Type of Search Coil for Ballistic Measurement of Magnetic Field Strength [in Non-Homogeneous Fields, primarily of Electron Lenses: Coil on Spool enclosed in Shuttle driven along Tube by Air Jet].—Simpson. (*Review Scient. Instr.*, Dec. 1940, Vol. 11, No. 12, p. 430.)

1162. Square Waves at High Frequencies.—Fenn. (*See* 1043.)

1163. A Cathode-Ray Impulse-Measuring Equipment.—Hadfield & Chandler. (*See* 1149.)

1164. An A.C.-Operated D.C. Amplifier with Large Current Output [primarily for operating String Oscillograph].—Treviño & Offner. (*See* 1038.)

1165. On a Magnetic Field free from Spherical Aberration [primarily for Electron Microscope].—Glaser. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 19–33.)

Author's summary:—"A magnetic field is calculated which in electron-optical image formation is free from aperture error. For the electron motion in a superposed electric and magnetic field a 'velocity potential' is given, with the help of which the laws of electron-optics, and in particular the formula for the aperture error, can be derived in a simple manner." For previous work *see* 4030 of 1938: and *cf.* Marschall, 135 of January.

1166. The Chromatic Aberration in Electron Lenses.—Glaser. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 56–67.)

"The radius of the chromatic dispersion circle and the magnitude of the variation zone of the focal-point position are calculated for any arbitrary superposed electric and magnetic fields, and from these the upper limits for the chromatic aberration in an electron microscope are derived." It is pointed out to begin with that in the electron microscope the effective length of the field is of the same order as the focal length, and consequently the assumptions necessary for the use of the "thin-lens" formula (1) cannot be made. It is found, however, that the value of the chromatic aberration given by this formula can only be decreased by a long lens, so that the value of the focal-length variation thus obtained serves as an upper limit for any field.

1167. **Chromatic Aberration of Electron-Optical Image-Forming Systems.**—Wendt. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 436–443.)

From the Telefunken research laboratories. For previous work *see* 3225 of 1939. Author's summary:—"The first-order chromatic aberration of an electron-optical rotationally symmetrical system is calculated by a perturbation-theory method. Three mutually independent error coefficients are obtained, two of which correspond to the known chromatic aberrations of light optics—namely the variation of the image-plane position [the individual rays of the beam intersect, not in the Gaussian image plane but in front of or behind this, according to whether the original electron velocity is greater or less than the 'most probable' or Gaussian velocity: this may be called the 'chromatic aperture error': as Scherzer has pointed out, it cannot, fundamentally, be eliminated (*see* eqn. 35), though it can be made very small], and the displacement of the spot either towards or away from the axis point [variation of image scale, chromatic extension error: the blurring of the contours of the electron-optical image increases linearly with distance from the axis: cured by a suitable choice of stop positions]; while the third, the variation of rotation [spot displacement perpendicular to line joining it to axis point: chromatic rotational error] is a special property of the magnetic focusing field in electron-optics" [and is unknown in light optics: it can be eliminated by the right selection of an antisymmetrical field in the z-direction].

1168. **On Some Developments in the Image-Formation of Surfaces irradiated by Electrons.**—Ruska & Müller. (*Zeitschr. f. Phys.*, No. 5/6, Vol. 116, 1940, pp. 366–369.)

While much progress has been made with electron-microscopy of thin objects traversed by electrons, the microscopic investigation of surfaces by irradiating them with fast electrons has been little used, owing to the wide velocity-scattering (leading to great chromatic aberration) and the wide angular scattering (leading to a severe limitation of image brightness) of the electrons thrown back from the surface. Ruska's early experiments (1933 Abstracts, p. 517) gave a single-stage magnification of about 8 and a resolving power of 20–30 μ. Now, making use of the latest devices of electron-microscopy, the writers obtain, with two stages, magnifications up to 800 with a resolving power down to 0.5 μ.

1169. **Submicroscopic Resolution in the Image-Formation of Surfaces in the Super-Microscope** [Electron-Microscope].—von Borries. (*Zeitschr. f. Phys.*, No. 5/6, Vol. 116, 1940, pp. 370–378.)

A report on experiments very similar to those of Ruska & Müller (1168, above) but differing from these in having the angle between the irradiating rays and the image-forming rays very much smaller (Fig. 1: the irradiating angle can be varied from 0° to 8° and the angle of the image-forming rays from 8° to 0°, to correspond). The two-stage arrangement shown gives images of metallic surfaces with a magnification up to 14 000 and a direct resolution of 50 $m\mu$, indirect of 25 $m\mu$. Among special applications are mentioned the control of the evenness of a surface and the detection of foreign bodies.

1170. **The Influence of the Ray Voltage on the Electron-Microscope Image.**—von Borries & Ruska. (*Zeitschr. f. Phys.*, No. 3/4, Vol. 116, 1940, pp. 249–256.)

Since, in the super-microscope and other transmitted-beam electron-microscopes, the image formation is carried out by those electrons which pass through practically without change of direction, it is to be expected that increased ray voltage would allow good resolution to be obtained with thicker objects. On the other hand small differences in mass should be more easily distinguished at low electron velocities. The tests here described were therefore carried out on identical objects with different ray voltages, so as to examine in detail the actual effects.

It was found that with bright-field images an increasing voltage leads to a greater "transparency" of object and that finer details can be observed even with thicker objects: this is explained by smaller wavelength, greater energy at the screen, and better directivity of the ray. With the objects here used (kaolin crystals) there was no clear indication that small mass differences gave higher contrast with lower voltages. With dark-field images it was found that for a constant voltage and increasing thickness of a part of the object, the brightness of the corresponding part of the image first increased and then, after reaching a maximum for a certain thickness, decreased again to zero: these "optimum" thicknesses were greater at the higher voltages than at the lower.

1171. **Previous Maximum Magnification of 25 000 for Electron Microscope increased by Two-Stage Method.**—Houston & Bradner. (*Science*, 10th Jan. 1941, Vol. 93, Supp. p. 10: paragraph only.)

1172. **A Double-Acceleration High-Voltage Electron Gun of Novel Design** [primarily for Electron-Diffraction Work: for Energies 40–100 kV, Beam of a Few Microamperes].—Moss. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, pp. 8–9.)

1173. **An Electron Microscope for Practical Laboratory Service.**—Zworykin, Hillier, & Vance. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 35: preview, copy obtainable.) Further development of the equipment described in the same journal, Nov. 1940, p. 441 onwards (*see* also 4003 of 1940).

1174. **Diffraction Experiments with Very Fine Electron Rays.**—Boersch. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 469–479.)

In ordinary electron-diffraction research the diameter of the ray as it passes through the object is about 0.1 mm, while the divergence of the ray increases this diameter to something like 0.2–0.7 mm at the photographic surface or fluorescent screen. In order to examine smaller domains in the object and to increase the resolving power, the writer has reduced the diameter at the object to 0.005 mm and at the photographic surface to about 0.02 mm. To do this he made use of the experience gained with his shadow microscope (3715 of 1939 and 1571 & 2710 of 1940), and employed a hairpin cathode whose strong emission (0.1–0.5 mA) is markedly directive and whose effective emitting diameter, with suitable Wehnelt-cylinder bias, is only about 20μ; as a result, the usual small-aperture anode stop close to the cathode was no longer necessary. The only fine stop used, close to the object, had an aperture-diameter of 0.005 mm: the special method of preparation (Werner, Zeiss Company: not described: *cf.* von Ardenne, 1990 of 1940) avoided almost entirely the difficulties of uneven edges, dirt, etc., which usually arise even with the ordinary 0.1 mm diameter apertures. The ray adjustment was greatly facilitated by the absence of the small anode stop, and by the provision of a fluorescent surface on the front side of the fine stop, which allowed the image of the cathode to be seen. Results are compared with those obtained with the larger aperture. Certain new charging-up phenomena encountered at the surfaces of insulating objects are discussed.

1175. On the Behaviour of Phosphors under Intermittent Electron-Irradiation.—Knoll. (*See* 1127.)

1176. The Absorption Spectra of Some Zinc-Sulphide Phosphors in the Excited State [Measurements on Zinc Sulphide, Pure and with Addition of Silver & of Copper: Special Behaviour of the ZnSAg Phosphor, giving Several Absorption Bands with Positions different for Different Exciting Wavelengths].—Hoch. (*Ann. der Physik*, Ser. 5, No. 6, Vol. 38, 1940, pp. 486–494.)

"The excitation of and emission from luminescent bodies are linked very closely with photoelectric conduction [Gudden & Pohl, in 1920/21]. This phenomenon itself received its explanation only after the spectrum changes, arising from light absorption, had been examined quantitatively by optical methods. In our opinion the same should hold good even more strongly for the comprehension of luminescence processes."

1177. A Supersonic-Cell Fluorometer [for Measurement of Rise & Decay of Luminescence in Phosphors excited by Cathode-Ray Beams: particularly Suitable for Fast Phosphors: Time Intervals in Decay Process measured in Terms of Distances traversed by Supersonic Waves in Water].—Briggs. (*Journ. Opt. Soc. Am.*, Dec. 1940, Vol. 30, No. 12, p. 653: summary only.)

1178. Measurement of Decay Times in Fluorescence [of Fluorescein, Eosin, & Other Solutions: Improved Fluorometer measuring Times down to & below 10^{-9} Second].—Kirchhoff. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 115–121.)

The fluorometer is of the second Maercks' type dealt with in 4097 of 1938, with a slightly modified technique.

1179. Barium used as Lubricant in Rotating Targets of X-Ray Tubes.—Atlee & others. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 52.) *See* also 171 of January.

1180. New Type Ionisation Gauge [for Pressures below 10^{-4} mm: "Usual Problems of Electrical Leakage & Outgassing reduced to Minimum"].—Distillation Products. (*Electronics*, Nov. 1939, Vol. 12, No. 11, pp. 89 and 90.)

1181. A Pirani Vacuum Gauge of Specially High Accuracy [and Stability: for Pressures down to 10^{-4} mm Hg].—Mura. (*La Ricerca Scient.*, July/Aug. 1940, 11th Year, No. 7/8, pp. 541–545.)

1182. Modified Form of McLeod Gauge, for Pressures from 10 to 0.01 mm Hg: the "Vacustat" Gauge.—Edwards & Company. (*Wireless Engineer*, Feb. 1941, Vol. 18, No. 209, p. 64: paragraph only.)

1183. Recording Paper ["Teledeltos"] affected by Electricity only.—Western Union. (*See* 1129.)

1184. Arc-Backs in Ignitrons in Series [Test of Theory that Great Reduction should be given by Series Connection].—Slepian & Pakala. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p 36: preview, copy obtainable.)

1185. Glow-Discharge Lamps [Survey of Present Knowledge of Characteristics, with Application to Design & Use as Stabilisers, Relays, etc.].—Jaeger. (*Bull. Assoc. suisse des Élec.*, No. 24, Vol. 31, 1940, pp. 557–562: in German.)

Among the practical conclusions regarding existing types are the following:—Striking voltage (varying with electrode spacing, nature and pressure of gas, according to eqn. 5) usually between 100 and 300 volts: in special designs it is stabilised within about 2% and is practically independent of temperature (but *cf.* 852 of March). Striking current necessary for ignition (eqn. 3) between 10^{-11} and 10^{-7} ampere for tubes where the striking voltage of the self-sustained discharge coincides with the sparking voltage, *i.e.* where eqn. 10 holds good; and 10^{-4} ampere or more in tubes where the sparking voltage exceeds the striking voltage of the self-sustained discharge, *i.e.* where eqn. 11 applies. Extinction voltage (depending chiefly on cathode drop—table III) between 65 and 150 volts: extinction current (determined by the "subnormal" glow discharge—section D-E of the current/voltage characteristic, Fig. 5) generally between 0.1 and 1 mA. Power required to produce ignition may therefore range from 10^{-9} to 10^{-5} watt in a tube where eqn. 10 applies, and may be 10^{-2} watt or more where eqn. 11 holds good; but thanks to the short building-up time of a glow discharge the necessary energy supply is only 10^{-14} to 10^{-10} watt-second where eqn. 10 applies. A further instalment will deal with the practical application of the fact that only this remarkably small amount of control energy is required in spite of the comparatively large value of the power needed to bring about ignition.

1186. Some Characteristics and Applications of Negative-Glow Lamps.—Ferree. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, Transactions pp. 8–11.)

1187. On the Auxiliary Electrons due to Photoelectric Effect in a Non-Spontaneous Gaseous Discharge in Air.—Costa. (*Zeitschr. f. Phys.*, No. 7/8, Vol. 116, 1940, pp. 508–514.)

1188. Townsend Breakdown Condition and the Building-Up Time of a Discharge [taking into account Wall Diffusion & Photoionisation].—Bartholomeyczyk. (*Zeitschr. f. Phys.*, No. 3/4, Vol. 116, 1940, pp. 235–245.)

1189. On the Significance of Steenbeck's "Minimum Principle" [in the Theory of Discharges].—Seeliger. (*Zeitschr. f. Phys.*, No. 3/4, Vol. 116, 1940, pp. 207–213.)

Usually expressed by the statement that of the various column régimes possible, that one will occur which has the smallest discharge potential.

1190. New Fields for Magnetic-Contact Relays.—Lamb. (*See* 1257.)

1191. Improved Bimetallic Strip for Thermostatic Control [delivers 5-lb Blows].—Westinghouse. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 20.)

1192. Prize offered by German Government for Development of New Type of Accumulator [using Home-Produced Materials].—(*Zeitschr. V.D.I.*, 11th May 1940, Vol. 84, No. 19, p. 317.)

1193. Reviving Dry Cells [Successful Practical Experiences at Home].—Broadbent. (*Elec. Review*, 31st Jan. 1941, Vol. 128, p. 320.)

Letter prompted by the statement in a new book that there is no "practical" way of reviving a spent cell. *See* also 1059, above.

1194. The MiniMax H.T. Battery of Half the Size of Conventional Type and Longer Life.—Eveready Company. (*See* 1062, above.)

1195. Automatic Meter Protection: Alternative Methods of safeguarding Small Moving-Coil Instruments.—Rehfisch. (*See* 1158.)

1196. The Electrical Strength of Compressed Gases: Part I [Air, Nitrogen, & Carbon Dioxide: Tests with D.C. Potentials up to 220 kV: New Conclusions on Variation of Breakdown Potential with Pressure, for Non-Uniform Fields].—Gänger. (*Arch. f. Elektrot.*, 15th Nov. 1940, Vol. 34, No. 11, pp. 633–652.)

1197. The Electric Strength of Air at High Pressure: II.—Skilling & Brenner. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 34: preview, copy obtainable.)

1198. Atmospheric Variations and Apparatus Flash-Over.—McAuley. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 41–42: preview, copy obtainable.)

1199. Electrical Insulation Research reviewed at National Research Council Conference [Authors' Abstracts of 22 Progress Reports].—(*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 22–26.)

1200. Radiant Heat—Full-Fledged Industrial Tool [Infra-Red Heating for Metals & Plastics, Baking of Varnishes, etc: with Charts for calculating Powers, etc.].—Goodell. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 3–8.)

1201. A New Cellulose Ester Sheet Plastic replacing Paper in Small Tubular Condensers.—McGrady. (Summary only: *see* 1244 below.)

1202. A New Coaxial Tuning Condenser [with Vitreous-Enamel Dielectric].—Robinson. (*See* 1064.)

1203. A New Plastic: Vinylidene Chloride [Great Tensile Strength & Toughness: Non-Inflammable: High Dielectric Strength: etc.].—(*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 21.)

1204. X-Ray Examination of Polyisobutylene [and Comparison with Natural Rubber].—Fuller & Others. (*Bell Tel. System Tech. Pub.*, Monograph B-1250, 1940, 22 pp.)

1205. Important Properties of Electrical Insulating Papers [Types & Applications: Porosity, Chemical Characteristics, etc: Conducting Particles: Power Factor].—Race & others. (*Gen. Elec. Review*, Dec. 1940, Vol. 43, No. 12, pp. 492–499.)

1206. "Electrolytic Condensers: Their Properties, Design, and Practical Uses" [Second Edition: Book Review].—Coursey. (*Nature*, 18th Jan. 1941, Vol. 147, p. 74.)

1207. The Electrical Conductivity of Liquid Dielectrics and Its Alteration by Supersonic Waves.—Seidl. (*See* 1116.)

1208. Change of Dielectric Constant of a Flowing Liquid from Its Value in the Stationary Condition.—Prasad. (*See* 1261.)

1209. On the Law of the Increase in the Electroconductivity of Dielectrics subjected to Strong Electric Fields.—Pruzhinina-Granovskaya. (*Journ. of Exp. & Theoret. Phys.* [in Russian], No. 6, Vol. 10, 1940, pp. 625–629.)

Experiments were conducted with mica, NaCl, and aluminium oxide to check the accuracy of Poole's (*Phil. Mag.*, 1916) and Frenkel's (*Journ. of Exp. & Theoret. Phys.*, 1938) formulae showing the relationship between the conductivity σ of the dielectric and the intensity E of the field in which the dielectric is placed. A number of experimental curves and a table are shown, and the main conclusions are as follows: (1) The relationship between σ and $\sqrt{E}$ (Frenkel) corresponds more closely to the experimental data than the relationship between σ and E (Poole); and (2) the effect of temperature on the slope of the curve $\sigma = f(\sqrt{E})$ is well represented both qualitatively and quantitatively by Frenkel's formula.

1210. Modern Materials in Telecommunications: Part II—Some Organic Structures and their Properties [Polymerisation Synthesis, Cellulose Products, etc: the "Lockerstellen" (Loose Points) Theory for the Lowness of Mechanical Strength of Plastics compared with Theoretical Value].—Radley & others. (*P.O. Elec. Eng. Journ.*, Oct. 1940, Vol. 33, Part 3, pp. 127–133.) *See* also below.

1211. Modern Materials in Telecommunications: Part III—The Nature of Metals and Alloys [including Development of Mechanical Properties by Mechanical Working Operations & by Heat Treatment (Beryllium-Copper, Chromium-Copper, & Other Age-Hardening Alloys): etc.].—Radley & others. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 189–195.) For Part I *see* 3593 of 1940.

1212. Aluminium Solder [Fluxless, requires No Roughening of Surfaces: "Colaweld 'T' Rod"].—(*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 45.)

1213. Non-Magnetic Steel with High Electrical Resistance.—Jessop Steel Company. (*Sci. News Letter*, 14th Dec. 1940, Vol. 38, No. 24, p. 377: paragraph only.)

1214. The Characteristics of Pressed Magnetic "Sendust" Cores [Comparison with "Igeta," Oxide, & "Siemafer" Cores, at Frequencies up to 100 kc/s: Use in Band-Pass Filters, etc.].—Omi & others. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, p. 65: summary only.) For early work on "Sendust" compressed powder cores *see* 1577 of 1937.

1215. Some Evidence for the Existence of Higher Hydrates of Ferric Oxide as Transition Intermediates [and the Transformation of the Ferromagnetic Gamma Oxide into a Non-Ferromagnetic Isomeric Form].—Welo & Baudisch. (*Phil. Mag.*, Feb. 1941, Vol. 31, No. 205, pp. 103–114.)

1216. The Calculation of the Filter Choke of a Mains Unit [with Economy in Material].—Pitsch. (*See* 1066.)

STATIONS, DESIGN AND OPERATION

1217. Signal Range of [Ultra-] High-Frequency Broadcast Stations [F.C.C. Diagram for 46 Mc/s Ranges (calculated for Spherical Earth) giving 1000, 50, & 5 μV/m Contours on Receiving Aerials of 30 ft Height, for Various Powers & Transmitting Aerials].—(*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 41.)

1218. A New Portable Ultra-High-Frequency Transmitter-Receiver [with 75 Calibrated Channels from 28 to 65 Mc/s: Over-All Weight 30 lb].—Westinghouse. (*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 79.)

1219. Noise in Frequency-Modulated Transmissions: Field Tests confirm Advantages over Amplitude-Modulated Systems [Survey of American Results].—(*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 32–35.) Based largely on Guy & Morris's paper, 912 of March.

1220. A State-Wide Frequency-Modulation Police Network: Parts I and II [Connecticut State System: including Descriptions of Mobile Transmitters & Receivers: Field Tests (Comparison with Amplitude Modulation): the Automatic Volume Control Action of F.M. (specially Noticeable in Hilly Country): etc.].—Noble. (*Electronics*, Nov. & Dec. 1940, Vol. 13, Nos. 11 & 12, pp. 18 onwards & 28–31, 66.)

1221. The Future of Amateur Radio: Planning for the Post-War Transmitting Boom.—(*Wireless World*, Feb. 1941, Vol. 47, No. 2, pp. 40–42.)

1222. Baldock Frequency Control Station [Purpose: History: Specification of Equipment & Measurement Accuracy: Description of Equipment & Associated Apparatus: Methods of Measurement employed: Over-All Accuracy achieved].—Booth & Gregory. (*P.O. Elec. Eng. Journ.*, Oct. 1940, Vol. 33, Part 3, pp. 105–114.)

1223. Recent Technical Developments in Wireless and Broadcasting in Great Britain.—Rakshit. (*Sci. & Culture*, Calcutta, Dec. 1940, Vol. 6, No. 6, pp. 314–326.) Concluded from 919 of March.

1224. Network Broadcasting: a Discussion of Some of the Technical Problems entailed in the Operation of Radio Broadcasting Networks.—Rackey. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 16–21.)

1225. Radio Extension Links to the Telephone System [including Use of Vodas, Vogads, Codans, Compandors & Expandors: Sterba, Bruce, Rhombic, & Pine-Tree Aerials: etc.].—Heising. (*Bell S. Tech. Journ.*, Oct. 1940, Vol. 19, No. 4, pp. 611–646: *Bell Tel. System Tech. Pub.*, Monograph B-1255, 36 pp.)

1226. A Simplified Compandor [Volume-Range Compresser-Expander] for Trunk Circuits [using Metal Rectifiers as the Non-Linear Circuit Elements].—Lawton & Marks. (*P.O. Elec. Eng. Journ.*, Oct. 1940, Vol. 33, Part 3, pp. 120–126.)

GENERAL PHYSICAL ARTICLES

1227. A General Interferential Method [directly applicable to All Optical Interferometry Arrangements].—Sturkey & Ramsay. (*See* 1021.)

1228. Interference Phenomena with a Moving Medium [Pattern changed in Manner corrected by Fitzgerald Contraction & Larmor-Lorentz Frequency Change: etc: Experiments with Ripples on Mercury Surface].—Ives & Stilwell. (*Journ. Opt. Soc. Am.*, Dec. 1940, Vol. 30, No. 12, p. 653: summary only.)

1229. New Investigations on Magnetic Rotation in Doubly Refracting Media.—Gabler. (*Zeitschr. f. Phys.*, No. 5/6, Vol. 116, 1940, pp. 271–280.)

"The equations representing the behaviour of a doubly refracting medium in a magnetic field are subjected to a general discussion. Two possible cases can be distinguished. First, the magnetic rotation is small; it then rapidly disappears as soon as marked double refraction occurs. Second, the magnetic rotation is large; in this case the magnetic rotation first *increases still further with the double refraction* and then, as the double refraction becomes stronger, approaches a final value of rotation by a series of decaying oscillations. According to the magnitude of the original magnetic rotation this limiting value is π, 2π, 3π . . ." These theoretical results were confirmed experimentally, a water-cooled coil producing a magnetic field of about 3000 oersteds for a short time; a Kerr cell was used as a medium with a controllably increasing double refraction.

1230. On the Stability and Magnitude of Electronic Charges: Part II—Scalar Wave Functions.—Landé & Thomas. (*Journ. Franklin Inst.*, Jan. 1941, Vol. 231, No. 1, pp. 63–70.)

MISCELLANEOUS

1231. "Relaxation Methods in Engineering Science: a Treatise on Approximate Computation" [Book Review].—Southwell. (*See* 1028.)

1232. A New Method for introducing Relaxed Initial Conditions in Transient Problems.—Johnson. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 34: preview, copy obtainable.)

1233. The Intrinsic Substance and Metrization of Communication [Attempt to establish Monistic Theory (comparable with Principle of Energy in Physics) of "Principle of Communications": Amount of Information given by $C = e^{N_i}$: Application to Telegraphy, Telephony, Television, etc: related to Hartley's Frequency-Band × Time by $K \log C = F T$, where K is a Constant depending on Transient Phenomenon].—Okada & Hujiki. (*Nippon Elec. Comm. Eng.*, July 1940, No. 21, p. 64: summary only.)

1234. The Varioplex—a New Development in Telegraphy, *and* Basic Principles of the Varioplex Telegraph [Method providing an Ever-Ready Two-Way Channel occupying Band-Width which is Zero when Idle and Variable when Busy].—Shute: Holcomb. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 35: p. 35: previews, copies obtainable.)

1235. "Lattice Theory" [Book Review].—Birkhoff. (*Science*, 27th Dec. 1940, Vol. 92, p. 606.)

1236. Recent General Trends in Mathematics.—Michal. (*Science*, 20th Dec. 1940, Vol. 92, pp. 563–566.)

1237. Simplifying Engineering Problems by means of Graphs [with Sections on Finding a Mathematical Expression to fit an Empirical Curve: with Bibliography].—Lang. (*Journ. Inst. Eng. Australia*, Oct. 1940, Vol. 12, No. 10, pp. 279–290.)

1238. Parallel Coordinates and Their Application: I [including Application to Nomography].—Watanabe. (*Jap. Journ. of Math., Transactions & Abstracts*, Oct. 1940, Vol. 17, No. 2, pp. 127–138: in French.)

1239. A Construction Theorem for evaluating Operational Expressions having a Finite Number of Different Roots.—Cromwell. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, p. 34: preview, copy obtainable.)

1240. A Smoothing Method for Statistical Series.—Ono. (*Jap. Journ. of Math., Transactions & Abstracts*, Oct. 1940, Vol. 17, No. 2, pp. 117–126: in German.) A footnote at the end refers to previous publication of the idea on which the method is based, in Henderson's *Mathematical Theory of Graduation*.

1241. Aspects of the Theory of Statistics [Book Reviews].—(*Nature*, 18th Jan. 1941, Vol. 147, pp. 70–71.) Reviews of recent books by Greenwood, Chambers, Treloar, and Kenney.

1242. "Punched-Card Methods in Scientific Computation" [Book Review].—Eckert. (*Nature*, 1st Feb. 1941, Vol. 147, p. 131.) Confined to description of achievements with Hollerith equipment.

1243. A Note on Slide-Rule Practice [Square Roots of Sum or Difference of Squares, and Hyperbolic Functions, etc., obtained Quickly & Accurately with the "Darmstadt" Slide Rule].—Edelmann. (*E.T.Z.*, 7th Nov. 1940, Vol. 61, No. 45, pp. 1015–1016.)

1244. Rochester Fall Meeting of I.R.E. and R.M.A. [with Summaries of Some Papers].—(*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 24–27 and 72.) For programme *see* 627 of February.

1245. New R.M.A. Technical Bulletin [replacing *R.M.A. Engineer*].—(*Electronics*, Dec. 1940, Vol. 13, No. 12, p. 71.) No. 2 contains Worcester's article on "Recent Improvements in F.M. Receiver Design"—*see* also 1049, above.

1246. Exchange Periodicals from Foreign Countries [during the War].—Montgomery. (*Science*, 13th Dec. 1940, Vol. 92, p. 555.)

1247. The Distribution of the Periodical Literature of Science [in Research Centres: Disadvantages of Present Methods: a Suggested Solution involving Micro-Films].—Seidell. (*Science*, 10th Jan. 1941, Vol. 93, pp. 38–39.)

1248. Microfilm Sets of Periodicals [New Reduced Rates made possible by Harvard University Grant].—Bibliofilm Service. (*Current Science*, Bangalore, Oct. 1940, Vol. 9, No. 10, p. 480.)

1249. Reading Machine for Microfilm [Student's Model at 32 Dollars].—(*Nature*, 18th Jan. 1941, Vol. 147, p. 84.)

1250. Instruments and Methods for measuring Sensory Events [with Literature References].—Craik. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, pp. 1–6.)

1251. An Integrating Voltmeter for the Study of Nerve and Muscle Potentials [Condenser-Charging Principle, with Push-Button Discharge through High-Inertia Galvanometer without Appreciable Restoring Spring].—Jacobson. (*Review Scient. Instr.*, Dec. 1940, Vol. 11, No. 12, pp. 415–418.)

1252. Diathermy Measurement Technique [and the Complete Equipment of "Dosemeter-Diatherm" for Ultra-High Frequencies: Generalisation of Mittelmann's Expression for "Patient Power"].—Kraus & Teed. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 39–40 and 82, 84.) For Mittelmann's work *see* 1253, below.

1253. Dosimetry in Short-Wave Therapy [and the Determination of "Equivalent Patient Resistance," etc.].—Mittelmann. (*Electronics*, Nov. 1939, Vol. 12, No. 11, pp. 52..60.) Based chiefly on earlier papers dealt with in 1693 of 1938 and back reference.

1254. "Foundations of Short-Wave Therapy" [Book Review].—Holzer & Weissenberg. (*Gen. Elec. Review*, Jan. 1941, Vol. 44, No. 1, p. 64.)

Presumably a new issue of the translation reviewed in *Electrician*, 3rd Jan. 1936, Vol. 116, p. 15. The present reviewer stresses the particular interest of Weissenberg's "low-energy working" for neurological treatment, and the question of specific action.

1255. The Production of Waves by the Sudden Release of a Spherical Distribution of Compressed Air in the Atmosphere [Amplitudes & Wavelengths fall off from Wave to Wave: No Indication of becoming Shock Wave: etc.].—Unwin. (*Proc. Roy. Soc.*, Ser. A, 10th Jan. 1941, Vol. 177, No. 969, p. S 82.)

1256. Communication in Seismic Prospecting.—Honnell. (*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 5–8.)

1257. New Fields for Magnetic-Contact Relays [Ultra-Sensitive M.C. Relays with Contact-Pressure magnified Several Thousand Times by Magnetic Contact-Points: 75 Watts handled at 110 Volts by as little as 0.5 Microampere or 0.25 Millivolt: Application to Gas & Fire Detectors, Vehicle-Operated Traffic Lights (Disturbance of Earth's Magnetic Field), Photoelectric Controls, Carrier-Current Remote Controls, Automatic Gain Adjustment of Telephone Repeaters, etc.].—Lamb. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 35–38.) From the Weston Electrical Instrument laboratories.

1258. An Electronic Relay [for Heat Control] with Improved Characteristics.—Hawes: Hall & Heidt. (*Science*, 3rd Jan. 1941, Vol. 93, p. 24.) Prompted by Hall & Heidt's letter, 4138 of 1940. For an additional note by these workers see *ibid.*, 27th Dec. 1940, Vol. 92, p. 612.

1259. American Apparatus, Instruments, and Instrumentation [Survey of Instruments for Measurement of Length & Linear Displacement, Time, Temperature, High Vacuum, etc: Electrical & Electronic Instruments: Automatic Recorders & Controllers: Analysis: etc.].—Müller. (*Indust. & Eng. Chemistry*, Analyt. Ed., Oct. 1940, Vol. 12, No. 10, pp. 571–630.)

1260. Research in 1940 [including Magnetic Crack Detector Equipment, Dynamometer for Cutting-Tool Pressures, Rayleigh Disc as Absolute Standard for Microphone Calibration, etc.].—(*Met.-Vickers Gazette*, Jan. 1941, Vol. 19, No. 331, pp. 124–130.)

1261. Change of Dielectric Constant of a Flowing Liquid from Its Value in the Stationary Condition.—Prasad. (*Sci. & Culture*, Calcutta, Dec. 1940, Vol. 6, No. 6, pp. 369–370.) In a letter from Prosad on an X-ray investigation.

1262. Use of Johnsen-Rahbek Effect to convert Varying Voltage into Variation of Capacity [*e.g.* for Automatic Frequency Control in Receiver].—Marconi Company. (*Wireless World*, Jan. 1941, Vol. 47, No. 1, p. 30.) Patent summary.

1263. A Cathode-Ray Stop-Watch.—Brailsford. (*See* 1148.)

1264. Three-Tube Oscillograph Recorder for Aeroplane-Strut Testing.—Southern Instruments. (*Journ. of Scient. Instr.*, Jan. 1941, Vol. 18, No. 1, p. 13.)

1265. The Electrically Driven Magnetically Supported Vacuum-Type Ultracentrifuge [driven at Constant Speed by Transitron Oscillator & Power Amplifier (Oscillator Frequency 1188 c/s, Automatic Slip-Control giving 1000 r.p.s. within $\frac{1}{2}$ r.p.s: Other Possible Applications].—Skarstrom & Beams. (*Review Scient. Instr.*, Dec. 1940, Vol. 11, No. 12, pp. 398–403.)

1266. Power and Combustion [and the Various Conversions of the Sun's Energy].—Egerton. (*Nature*, 25th Jan. 1941, Vol. 147, pp. 122–123.) Summary of Thomas Hawksley Lecture.

1267. Infra-Red Telescope on Simplified Principle [No Electron-Focusing: Infra-Red Rays focused (by Concave Mirror) onto Fluorescent Screen already brought to Faint Glow by Ultra-Violet Light].—George: R.C.A. (*Sci. News Letter*, 28th Dec. 1940, Vol. 38, No. 26, p. 406.)

1268. A Phototube Relay for Infra-Red Radiation [*e.g.* for Burglar Alarm with Greatly Extended Range: Definite Operation with Beam Length of 1200–1800 Feet].—Smith. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 54 and 56.)

1269. Quantitative Absorption Measurements on Benzol and Benzol Derivatives in the Near Infra-Red [with Simple Apparatus using Ordinary Valves, etc., but possessing a Threshold Value of 1–2‰ compared with Eye (2%) and Photographic Plate (10%)].—Kempter. (*Zeitschr. f. Phys.*, No. 1/2, Vol. 116, 1940, pp. 1–18.)

1270. "Handbook of Chemistry and Physics" [24th Edition: Book Review].—(*Communications*, Dec. 1940, Vol. 20, No. 12, pp. 18 and 29.)

1271. An A.C.-Powered *pH* Set.—Goodwin. (*Science*, 20th Dec. 1940, Vol. 92, pp. 587–588.)

1272. The Determination of Average Molecular Weights or Particle Sizes for Polydispersed Systems [including a Theoretical Discussion of the Light-Absorption Method].—Kraemer. (*Journ. Franklin Inst.*, Jan. 1941, Vol. 231, No. 1, pp. 1–21.)

1273. Photoelectric Supervision of Revolving Furnaces [in Cement and Chemical Works: to avoid Sintering Troubles, etc., on Unexpected Stoppage].—Siemens & Halske. (*Bull. Assoc. suisse des Élec.*, No. 23, Vol. 31, 1940, pp. 540–541.) *Cf.* 266 of January.

1274. A Multi-Purpose Photoelectric Reflectometer [for Ceramic, Paint, Textile, Paper, & Chemical Industries].—Hunter. (*Journ. of Res. of Nat. Bur. of Stds.*, Nov. 1940, Vol. 25, No. 5, pp. 581–618.)

1275. An Electrically-Focused Multiplier Phototube [Amplification over 1 Million].—Rachman & Snyder. (*See* 1130.)

1276. A High-Sensitivity Phototube Circuit [particularly Useful for detecting Small Changes in Light Intensity].—Bull & Lafferty. (*Electronics*, Nov. 1940, Vol. 13, No. 11, pp. 31–32: Erratum Dec. 1940, No. 12, p. 71.)

1277. Photoelectric Integrating-Sphere Densitometer determines Density of Motion-Picture Film.—Albersheim. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 36.)

1278. The Regulation of Tungsten and Mercury Lamps [for Radiometric Measurements: Regulation to better than 1/10th of 1% for 30 Minutes by Photoelectric Regulator].—Stewart. (*Journ. Opt. Soc. Am.*, Dec. 1940, Vol. 30, No. 12, p. 652: summary only.)

1279. An Automatic Telescope Control [by Photocell: Rotating-Polaroid-Sheet Device as Detector of Exact Centering].—Hardy. (*Journ. Opt. Soc. Am.*, Dec. 1940, Vol. 30, No. 12, pp. 654–655: summary only.) *Cf.* Rubenstein, 948 of March.

1280. Photoelectric Control Gauge for Width of Moving Steel Strip.—General Electric. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 20.)

1281. New Broadway Sign controlled by Phototubes [giving Moving Cartoons, Living Silhouettes, etc., on Bank of Lamps].—Leigh. (*Electronics*, Dec. 1940, Vol. 13, No. 12, pp. 48 and 50.) Latest development of the advertising device dealt with in 752 of 1938.

1282. Summary of Events in World of Science in 1940.—(*Sci. News Letter*, 21st Dec. 1940, Vol. 38, No. 25, pp. 387–389 and 398–400.)

1283. Electrical Developments of 1940.—(*Gen. Elec. Review*, Jan. 1941, Vol. 44, No. 1, pp. 6–62.)

1284. The Practical Application of Research [in Various Fields and Industries: the Vital Rôle played by Measurements].—Lee. (*Elec. Engineering*, Jan. 1941, Vol. 60, No. 1, pp. 8–14.)

1285. How Do We Rate? [Analysis of Nobel Awards, yielding Comparison of Various Nations].—Brill. (*Scient. American*, Jan. 1941, Vol. 164, No. 1, p. 3.)

1286. "Science *versus* Materialism" [Book Review].—Kapp. (*Elec. Review*, 31st Jan. 1941, Vol. 128, p. 303.)

1287. "Physical Science in Art and Industry" [Book Review].—Richardson. (*Nature*, 18th Jan. 1941, Vol. 147, pp. 67–68.)

1288. "Troubles of Electrical Equipment" [Book Review].—Stafford. (*Gen. Elec. Review*, Jan. 1941, Vol. 44, No. 1, p. 65.) "Shows an excellent working knowledge that comes from long experience . . ."

1289. "The Amateur Radio Handbook: Second Edition" [Book Review].—Radio Society of Great Britain. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, p. 195.)

1290. A Group Inverter for 12-Circuit Carrier Systems [enabling Original Lower-Sideband Systems to be connected to New Upper-Sideband Systems (conforming to C.C.I.F. Recommendations)].—Scowen & Welsby. (*P.O. Elec. Eng. Journ.*, Jan. 1941, Vol. 33, Part 4, pp. 183–185.)