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APRIL 1954

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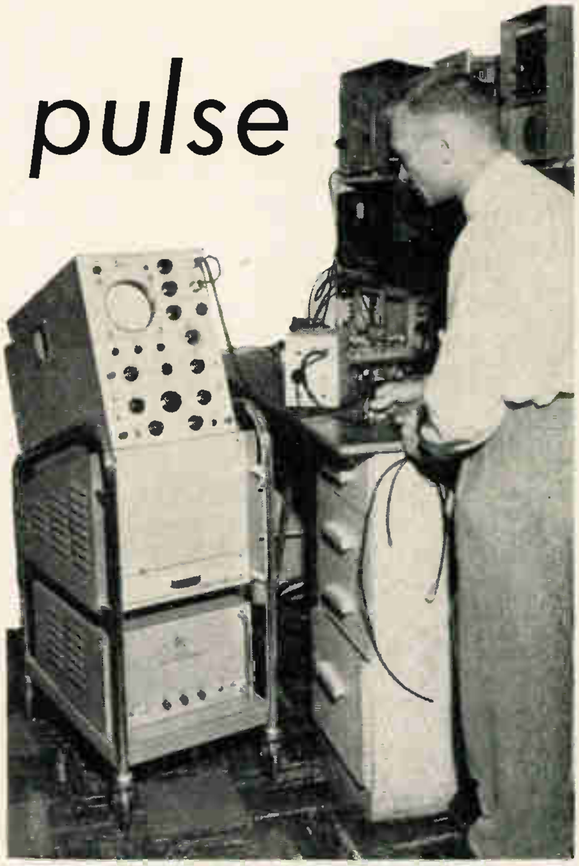

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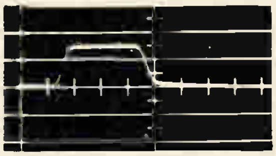
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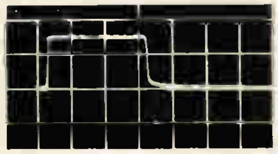
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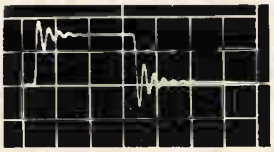
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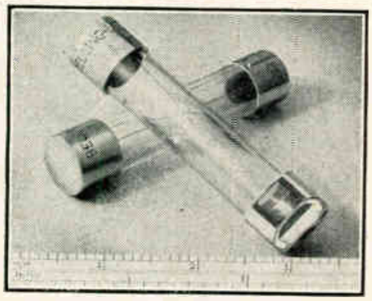

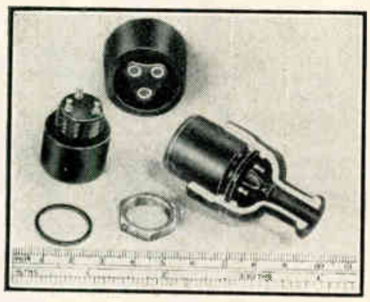

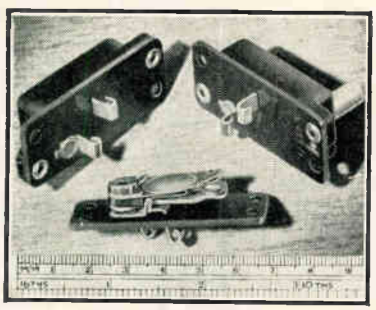

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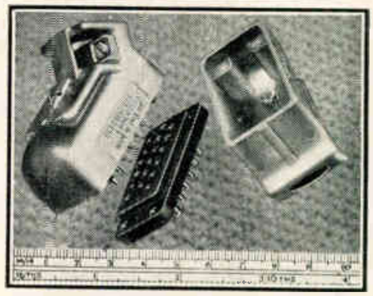

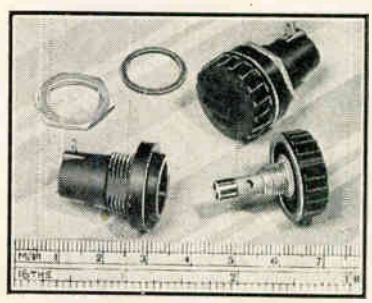

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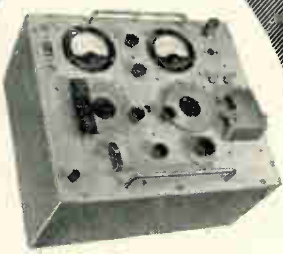

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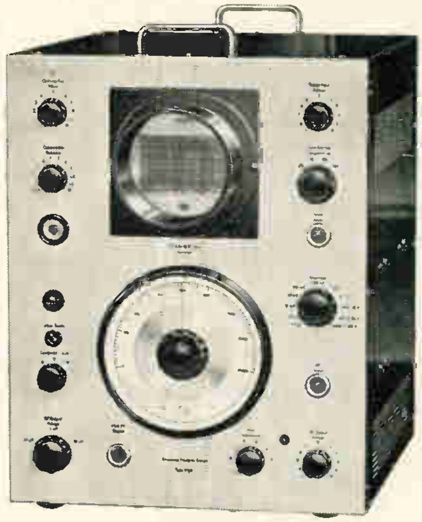

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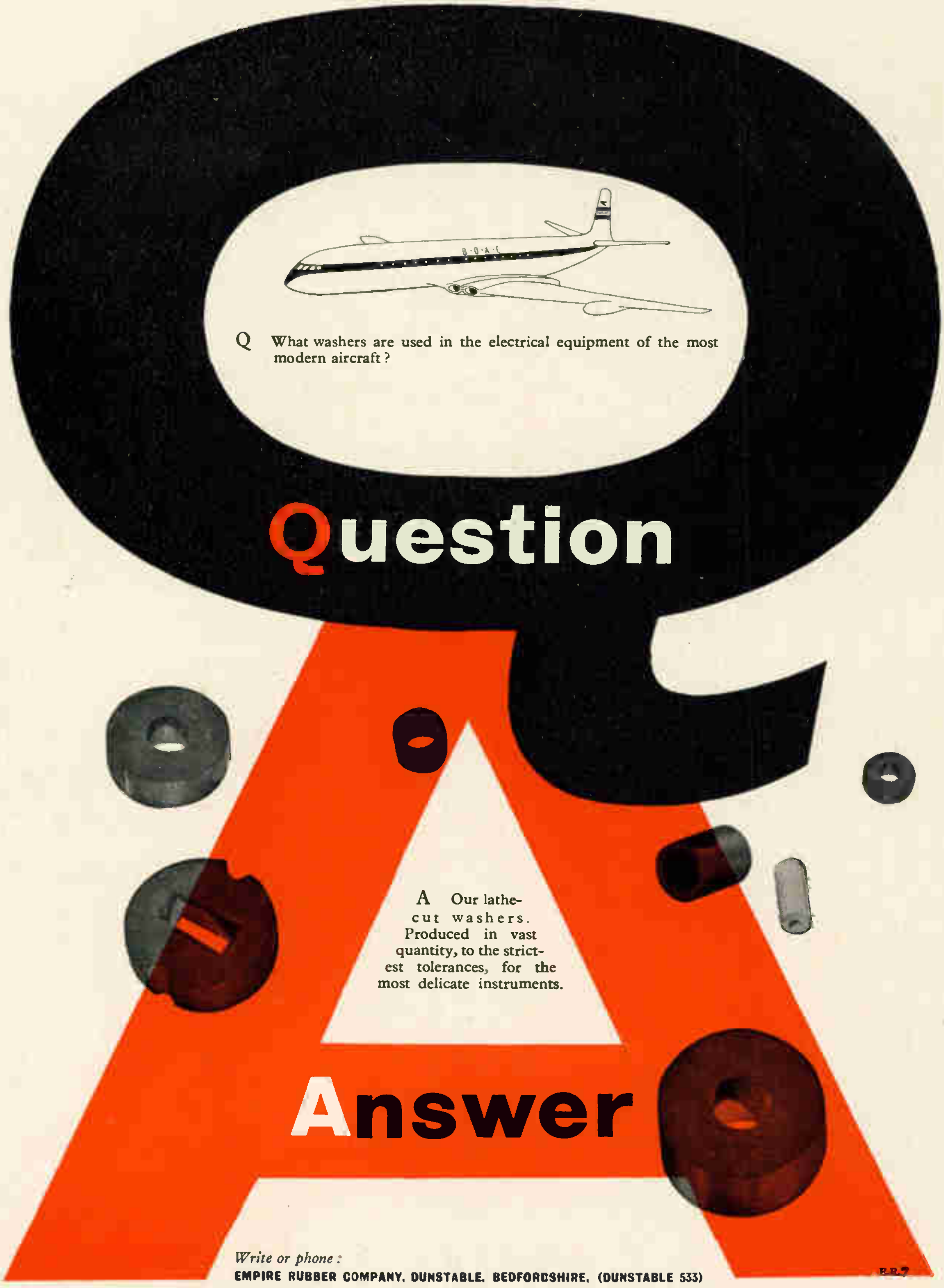
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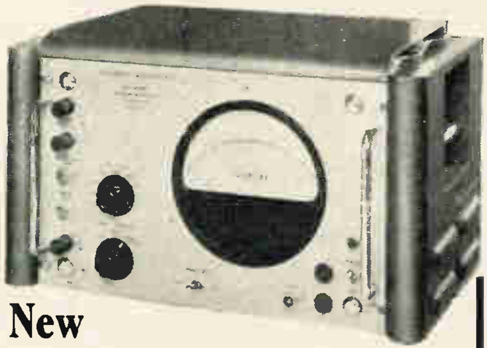

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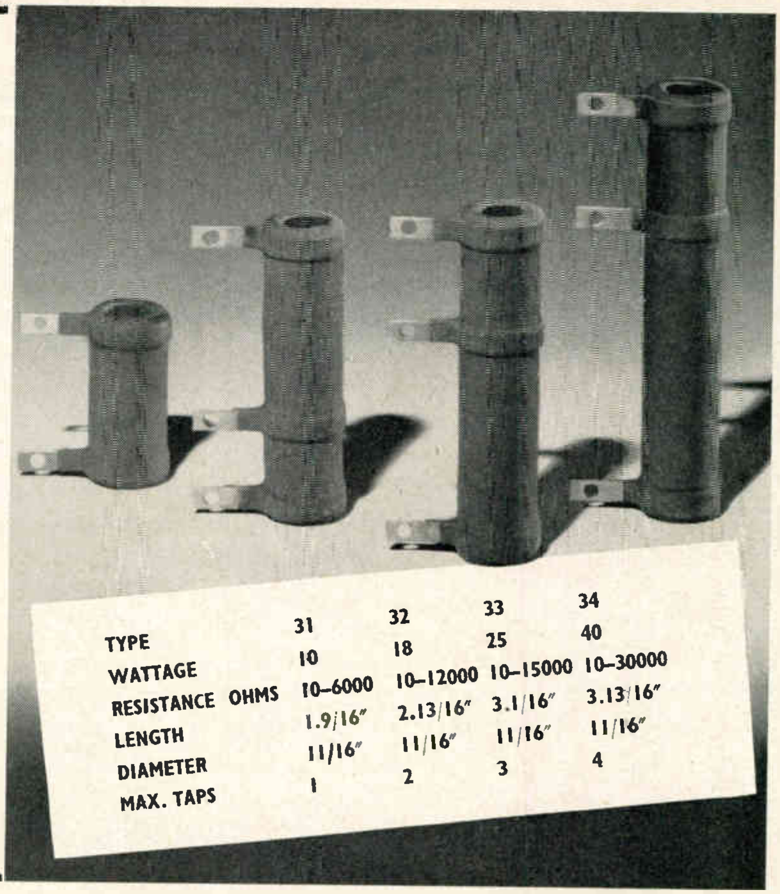

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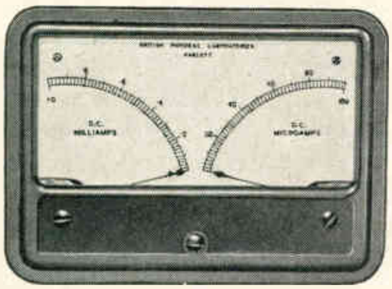

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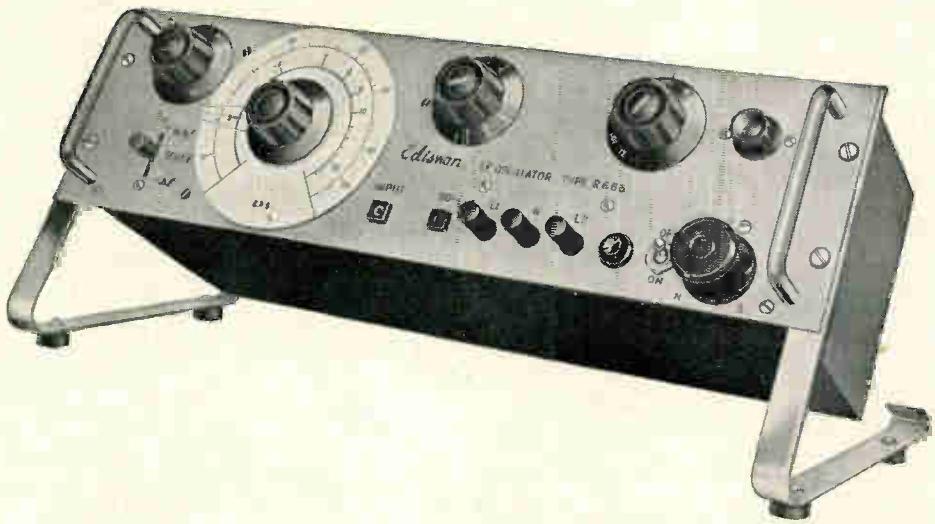

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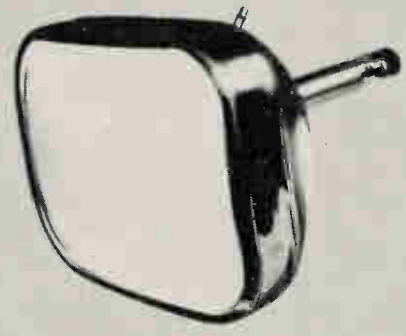

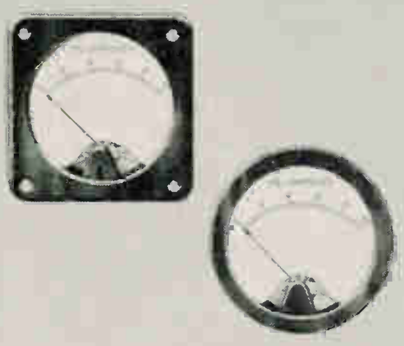

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WIRELESS ENGINEER

Vol. 31 APRIL 1954 No. 4

H. A. Lorentz

HENDRIK ANTOON LORENTZ was born on 18th July 1853, and to mark the centenary Dr. Balth van der Pol contributed a paper entitled "H. A. Lorentz and the Bearing of his Work on Electromagnetic Telecommunication" to the *Journal of the International Telecommunication Union*, which was reprinted in the November number of *Tijdschrift van het Nederlands Radiogenootschap*. Lorentz was for many years Professor at the University of Leiden; when he retired in 1923 he acted as Director of Research at the Teyler Institute, Haarlem, but continued as an Honorary Professor of Leiden until his death on 4th February 1928. At the beginning of the century he was universally regarded as the leading theoretical physicist of his time. Albert Einstein recently wrote, "I often had an opportunity to attend H. A. Lorentz's lectures which he regularly gave to a small circle of younger colleagues after his retirement from his general professorship. Everything that emanated from this supremely great mind was as clear and beautiful as a good work of art; and one had the impression that it all came out so easily and effortlessly as I have never experienced it from anyone else. If we younger ones had known H. A. Lorentz only as a great luminary, our admiration and veneration for him would already have been of an extremely special kind, but what I feel when I think of H. A. Lorentz is not covered by a long way by that veneration alone. For me personally he meant more than all the others I have met on my life's journey."

Dr. van der Pol is uniquely qualified to discuss the work of the two outstanding physicists J. J. Thomson and H. A. Lorentz, for he worked at Cambridge with the former from 1917 to 1919 and then at Leiden with the latter from 1919 to 1922. With regard to the electron he says that it was *invented* by Lorentz and *discovered* by Thomson. Lorentz obtained his doctorate in 1875 for a thesis on the application of Maxwell's equations to the reflection and refraction of light. He postulated the existence of small electrically-charged particles in 1878, and when in 1896 Zeeman, also at Leiden, showed that when a sodium flame was subjected to a strong magnetic field its spectrum lines were displaced, Lorentz deduced from Zeeman's measurements that the value of e/m of the electrons vibrating in the sodium flame was of the order of 10^7. We now know it to be $1{\cdot}602 \times 10^{-20}$ e.m. units/$9{\cdot}12 \times 10^{-21}$ gram $= 1{\cdot}75 \times 10^7$. Lorentz also predicted that the emitted light would be polarized, which Zeeman immediately confirmed. In October 1897, J. J. Thomson published his measurements of the deflection of the particles in a discharge tube by electric and magnetic fields by means of which the value of e/m could be calculated. Lorentz and Zeeman were both awarded the Nobel Prize in 1902.

Lorentz showed that in calculating the electric field at a point in a gas or mixture of gases the polarization of neighbouring molecules must be taken into account. In the ionosphere this may be negligible, but it must be allowed for when calculating the dielectric constant of the atmosphere.

In 1892 he introduced the conception of retarded potentials.

In 1905 Lorentz discussed the reciprocity theorem for linear systems and stated it in a form somewhat more general than that originally used by Helmholtz in 1853, although, as we pointed out in the July 1943 Editorial, Helmholtz disclaimed originality and gave Green the credit for discovering the reciprocity theorem and applying it to static electricity. Helmholtz did not consider alternating currents and only mentioned the magnitude of the current, whereas Lorentz mentions amplitude and phase. His wording is as follows:—"If an e.m.f. applied at a point P in the direction h produces at a point P' a current whose component in an arbitrarily chosen direction h' has the amplitude u and phase v, an equal e.m.f. applied at the point P' in the direction h' will produce a current at P whose component in the direction h has exactly the same amplitude u and phase v." This is merely an elaboration of Helmholtz's wording to cover alternating current.

Van der Pol says that from personal conversations he knows that Lorentz had a great admiration for the work of Heaviside, and in one of his last papers he developed a generalization of a little-known theorem of Heaviside (Electrical Papers, Vol. II, p. 412). Van der Pol states the theorem as follows. Given a constant passive network at rest; if at time $t = 0$ a constant e.m.f. is suddenly applied to the network, in general, transients will occur. After a long time t_1 the transients may be considered to have died down, and only a direct current will, in general, be present in the network. The direct current (if there is any) will cause a Joulean heat dissipation at a constant rate per second. If we called W' the "pseudo heat dissipation" which would have occurred if the constant final current had been present all the time t_1, then, when the steady state has been reached, the total amount of energy A supplied by the e.m.f. exceeds the "pseudo heat dissipation" (if there is any) by twice the excess of the electric energy U over the magnetic energy T, or $(A - W') = 2(U - T)$. It follows that a condenser can only be charged from a d.c. source with an efficiency of 50%. Just as he did with Helmholtz's reciprocity theorem, Lorentz generalized this theorem of Heaviside and introduced distributed capacitances and inductances.

Lorentz made important and very fundamental contributions to the special theory of relativity. He was always deeply interested in the propagation of electromagnetic waves through a moving medium, and when in 1887 Michelson and Morley found that the velocity of light was the same whether in the direction of the earth's motion or in the opposite direction, Lorentz came to the same conclusion as Fitzgerald, viz., that matter moving at a high velocity appears to be contracted in the direction of its motion, and that this would apply to the length-measuring apparatus to a degree just sufficient to cancel the increased time that the light took to travel, and thus give an unchanged observed velocity. Lorentz also postulated that all observations made in a laboratory would be the same whether the laboratory was at rest or travelling with constant velocity through the ether. Unlike Einstein, Lorentz preferred to picture the ether as the wave medium. They both arrived at the same result and established the set of equations known as the Lorentz transformation, which are at the basis of the whole theory of relativity. Einstein went further by generalizing them and making them applicable to systems moving at a variable speed.

Van der Pol says that Lorentz was the ideal chairman for an international science congress, for he was a master of Dutch, English, French and German, and could summarize a complicated contribution in such a way that it became clear to the audience. He was not much in favour of such congresses, for he said that while they were discussing some problem, a scientist working alone in his laboratory might find the solution.

One must not confuse H. A. Lorentz with Ludvig Lorenz of Copenhagen (1829–1891), who made a number of contributions to the *Annalen der Physik*, and whose method of determining the ohm was employed in many standardizing laboratories.

G. W. O. H.

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By J. L. Farrands, B.Sc., Ph.D., A.Inst.P., and J. Brown, M.A., A.M.I.E.E.

(Imperial College of Science and Technology)

SUMMARY.—The Boltzmann interferometer is the most convenient instrument at present available for the investigation of the spectrum radiated by spark-type oscillators. It is shown that the power spectrum of the oscillator is given by the Fourier transform of the interference pattern obtained from the instrument. A typical example is examined in detail.

THERE is at present considerable interest[1,2] in extending the radio spectrum to higher frequencies; i.e., to wavelengths in the millimetre and sub-millimetre bands. Some success has been achieved in extending the frequency range of klystrons and magnetrons, the types of oscillator which have proved so successful at centimetric wavelengths,[3] but there appears to be still a use for oscillators which use sparked resonators.[4]

Such oscillators have the property that the power produced is spread over a wide range of frequencies at relatively low levels. It is essential for a full understanding of the mechanism of operation of these oscillators to determine the power spectrum; i.e., the way in which the power density varies with frequency. The instruments which can be used for such measurements are diffraction gratings, cavity resonators and interferometers. Diffraction gratings are subject to the two disadvantages of low efficiency and the difficulty of interpreting the results, because of the occurrence of second-order spectra. Apart from the constructional problems arising at short wavelengths, cavity resonators are difficult to use when the energy is spread over a wide range of wavelengths because of the occurrence of more than one resonance. Interferometers are relatively simple to use and are very efficient, the most suitable for the present purpose being that known as the Boltzmann interferometer[5,6].

The arrangement of the interferometer is shown schematically in Fig. 1. The radiation from the source is focused into a plane parallel beam by the paraboloidal mirror, A, and is directed on to the two interferometer plates, P_1 and P_2, at an angle of incidence θ. These plates are assumed to be perfect reflectors of sufficient size to give complete specular reflection of the incident radiation, which is then directed towards a second paraboloidal mirror, B. At the focus of B is placed the detector. The apparatus must be aligned in such a way that equal powers reach the detector from each of the plates. This may be done by placing P_1 and P_2 side by side so that they form a continuous surface and then adjusting the axes of A and B so that the detector output is halved when either P_1 or P_2 is removed.

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When the apparatus has been adjusted as above, the interference pattern is obtained by displacing P_2 a distance s normal to the plane of its surface as in Fig. 1, and plotting the detector output, S, against s. The resulting curve is called an interferogram and from it can be deduced the required information on the power spectrum of the source. This has usually been done merely by noting the main periodicities in the interferogram but, as will now be shown, considerably more information can in fact be obtained.

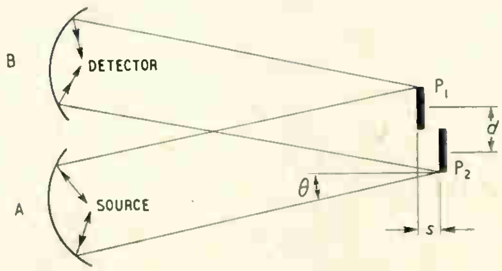

Fig. 1. *General arrangement of interferometer.*

After reflection from the plane mirrors, P_1 and P_2, the incident plane wave is effectively split into two plane waves, which travel in the same direction, but are displaced in time by an interval τ. From the geometrical theory of optics it can be shown that this time interval is given by

$$\tau = 2s/c \cos \theta \quad \ldots \quad (1)$$

where c is the phase velocity of electromagnetic radiation in free space. If the angle θ is small, say less than 10°, cos θ is not appreciably different from unity and then

$$\tau = 2s/c \quad \ldots \quad (2)$$

Let $f(t)$ be the electric field strength at the detector caused by the reflection from P_1. Then the field strength from reflection at P_2 is $f(t - \tau)$ and so the total field strength acting on the detector is

$$F(t) = f(t) + f(t - \tau) \quad \ldots \quad (3)$$

If the source is a spark-type oscillator, the radiation will be in the form of a succession of damped wave trains. It is convenient in the remainder of the analysis to assume that $F(t)$ refers to only one of these wave trains. Most forms of detector give an indication proportional to the total power received; i.e.,

$$S = K\int_{-\infty}^{\infty} |F(t)|^2 dt \quad \ldots \quad \ldots \quad (4)$$

Because of the damped nature of the wave train represented by $F(t)$, it is permissible to use the limits $-\infty$ and $+\infty$ for the time integration; K is a constant of proportionality whose precise value is not required. In stating equation (4), it has been assumed that the detector responds equally to all frequencies; this restriction will be removed below.

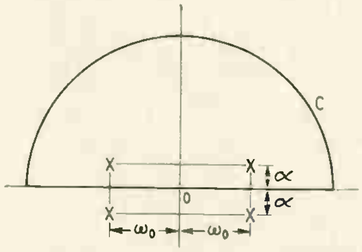

Fig. 2. *Contour for integration in ω-plane: poles of integrand marked by X.*

The time waveform $f(t)$ has an amplitude spectrum $g(\omega)$, where ω equals 2π times frequency, given by the Fourier integral[7]

$$g(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)e^{-j\omega t}\, dt \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

The amplitude spectrum for the waveform $F(t)$ is therefore

$$G(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t)e^{-j\omega t}\, dt + \frac{1}{2\pi}\int_{-\infty}^{\infty} f(t-\tau)e^{-j\omega t}\, dt$$
$$= g(\omega) + e^{-j\omega\tau} g(\omega) \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

The detector output may be expressed in terms of $G(\omega)$ by Parseval's theorem which states[8]

$$\int_0^{\infty} |G(\omega)|^2 d\omega = \frac{1}{4\pi}\int_{-\infty}^{\infty} |F(t)|^2 dt \quad \ldots \quad (7)$$

and so $$S = 4\pi K\int_0^{\infty} |G(\omega)|^2 d\omega \quad \ldots \quad \ldots \quad (8)$$

The expression $|G(\omega)|^2 d\omega$ represents the incident power at the detector which lies in the range of angular frequencies from ω to $\omega + d\omega$. It is possible at this stage to make allowance for the inevitable frequency dependence of the detector response. Suppose that the detector response is $h(\omega)$ for unit incident power at the angular frequency ω. Then integrating over all angular frequencies gives for the detector response in the present case

$$S = \int_0^{\infty} h(\omega)\,|G(\omega)|^2 d\omega \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

The constant $4\pi K$ of the previous equation has been included in the function $h(\omega)$. Now, from equation (6)

$$|G(\omega)|^2 = |g(\omega)|^2\,|1 + e^{-j\omega\tau}|^2$$
$$= 2\,|g(\omega)|^2\,(1 + \cos\omega\tau) \quad \ldots \quad (10)$$

Hence,

$$S = 2\int_0^{\infty} h(\omega)\,|g(\omega)|^2 d\omega + 2\int_0^{\infty} h(\omega)\,|g(\omega)|^2 \cos\omega\tau\, d\omega \quad \ldots \quad \ldots \quad (11)$$

which gives the detector output as a function of τ. The right-hand side consists of two terms which are equal when τ is zero. The second, which depends on τ, may be written $P(\tau)$ and tends to zero as τ tends to infinity for the waveforms of practical interest. The expression for $P(\tau)$ is

$$2\int_0^{\infty} h(\omega)\,|g(\omega)|^2 \cos\omega\tau d\omega$$

i.e., the Fourier cosine transform of $h(\omega)|g(\omega)|^2$. By the inverse transform,

$$h(\omega)\,|g(\omega)|^2 = \frac{1}{\pi}\int_0^{\infty} P(\tau)\cos\omega\tau\, d\omega \quad \ldots \quad (12)$$

The use of this equation depends on extracting the function $P(\tau)$ from the experimentally-obtained interferogram. The relation between τ and s is given immediately by equation (2) and it is then only necessary to subtract from the interferogram the constant term corresponding to the first integral in equation (11). The value of this constant equals the value of S for very large s, since $P(\tau)$ tends to zero as τ tends to infinity. If the apparatus has been correctly aligned, the constant should also equal half the value, which S has when s is zero. When $P(\tau)$ has been obtained in this way, the integration on the right-hand side of equation (12) may be carried out, using if necessary numerical or mechanical methods, to give the function $h(\omega)|g(\omega)|^2$. If $h(\omega)$, the detector response, is known, the power spectrum of the source $|g(\omega)|^2$ is immediately obtained.

A simple example of the foregoing analysis is provided by the time waveform,

$$f(t) = 0 \qquad t < 0$$
$$= e^{-\alpha t}\sin\omega_0 t \quad t \geqslant 0 \quad \ldots \quad \ldots \quad (13)$$

which corresponds fairly closely to the damped wavetrain emitted by a sparked oscillator. The resonant frequency of the sparked resonator is $\omega_0/2\pi$ and the damping constant is α. The amplitude spectrum, calculated from equation (5), is

$$g(\omega) = -\frac{\omega_0}{2\pi(\omega - \omega_0 - j\alpha)(\omega + \omega_0 - j\alpha)} \quad (14)$$

and so $g(\omega)|^2 = \dfrac{\omega_0^2}{4\pi^2(\omega - \omega_0 - j\alpha)(\omega + \omega_0 - j\alpha)(\omega - \omega_0 + j\alpha)(\omega + \omega_0 + j\alpha)}$ .. .. .. (15)

It will be assumed for simplicity that $h(\omega)$ is a constant (i.e., that the detector has a uniform frequency response) and so from equation (11),

$$P(\tau) = \frac{\omega_0^2}{2\pi^2}\int_0^\infty \frac{\cos \omega\tau}{(\omega - \omega_0 - j\alpha)(\omega + \omega_0 - j\alpha)(\omega - \omega_0 + j\alpha)(\omega + \omega_0 + j\alpha)}d\omega \quad .. \quad .. \quad (16)$$

Since the integrand is an even function of ω, this may be written

$$P(\tau) = \frac{\omega_0^2}{4\pi^2}\int_{-\infty}^\infty \frac{\exp(j\omega\tau)}{(\omega - \omega_0 - j\alpha)(\omega + \omega_0 - j\alpha)(\omega - \omega_0 + j\alpha)(\omega + \omega_0 + j\alpha)}d\omega \quad .. \quad (17)$$

The integral can be most easily evaluated by applying the Cauchy residue theorem[9] to the contour shown in Fig. 2, C being a semicircle whose radius is allowed to tend to infinity. The integral round C then vanishes, provided τ is positive, and so

$P(\tau) = \dfrac{\omega_0^2}{4\pi^2} \times 2\pi j \times$ (sum of the residues at the poles of the integrand in the upper half-plane of Fig. 2)

$$= \frac{j\omega_0^2}{2\pi}\left[\frac{\exp j(\omega_0 + j\alpha)\tau}{8j\omega_0\alpha(\omega_0 + j\alpha)} + \frac{\exp -j(\omega_0 - j\alpha)\tau}{8j\omega_0\alpha(\omega_0 - j\alpha)}\right]$$

$$= P(0) \sec\phi \, e^{-\alpha\tau} \cos(\omega_0\tau - \phi) \quad .. \quad (18)$$

where $P(0) = \omega_0^2/[8\pi\alpha(\omega_0^2 + \alpha^2)]$

and $\phi = \tan^{-1}(\alpha/\omega_0)$

From the results given previously on the relation between $P(\tau)$ and the interferogram, it is found that the interferogram for the present case is given by

$$S = \tfrac{1}{2}S_0[1 + \sec\phi . \exp(-2\alpha s/\tau) . \cos(2\omega_0 s/c - \phi)] \quad .. \quad .. \quad (19)$$

where S_0 is the value of S when s is zero. The general characteristics of the time waveform, the power spectrum and the interferogram are shown by the sketch of Fig. 3. In particular the interferogram has the appearance of a damped sinusoidal wave, the period of the oscillation being half the free space wavelength of the radiation; i.e., $\pi c/\omega_0$.

It may be noted that the part of the interferogram defined by $P(\tau)$ is directly proportional to the auto-correlation function of the time waveform.[10] The result in equation (12) is therefore identical to that frequently used in the study of noise problems, where it is known as Wiener-Khintchine theorem.[11]

It has been shown that the power spectrum of a source can be obtained completely from an interferogram measured using a Boltzmann interferometer. This result should be of value in investigations of the fundamental mechanism of sparked resonator oscillators.

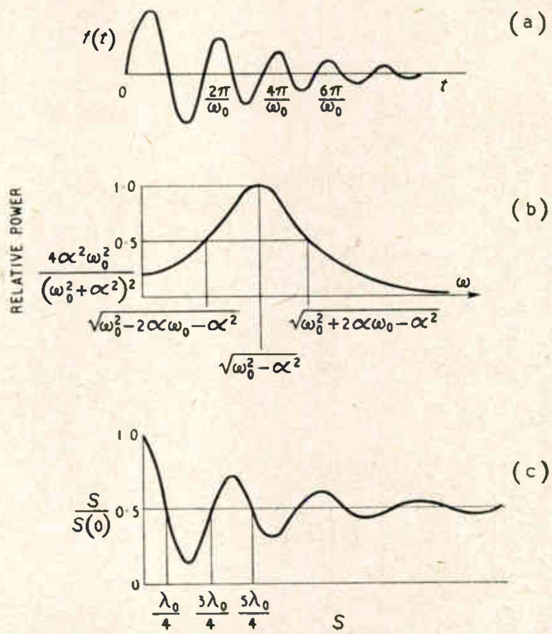

Fig. 3. *Characteristics of the time waveform (a), power spectrum (b) and the interferogram (c) for the example discussed in the text.*

Since this paper was prepared, the authors have learned that Mr. M. H. N. Potok, of the Royal Technical College, Glasgow, is engaged in similar work and hopes to publish examples of the method as applied to the observed radiation from sparked oscillators.

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BANDPASS AMPLIFIERS

Investigation of Design and Stability

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SUMMARY.—In this paper an approach to bandpass amplifier design is presented. This is based on the required overall gain, half-power bandwidth and centre frequency of the pass-band. The amplifier considered is composed of a number of identical groups, each consisting of one or several valves and circuits, having a maximum-flatness frequency response. The conditions for maximum possible gain are found and a graph is given which makes it possible to calculate the number of groups necessary to fulfil the requirements.

The effect of anode-grid capacitances on the performance of single-tuned and stagger-tuned amplifiers is discussed. It is shown that the amount of distortion introduced into the frequency-amplitude response curves depends on a regeneration coefficient α. When α is sufficiently large, oscillations occur. A single-tuned amplifier of any number of stages is inherently stable if $\alpha < \frac{1}{2}$. It is shown that, with stagger-tuned amplifiers, the amount of distortion depends not only on the magnitude of α, but also on the order of staggering. Values of α necessary to produce oscillations in a staggered pair, staggered triple and m staggered pairs are given. The effect of the regeneration on the process of tuning the amplifiers is also discussed.

1. Introduction

MOST of the bandpass amplifiers, especially those operating linearly, can be designed by using appropriate formulae. In general, the design is based on the required gain and bandwidth. The number of stages necessary to satisfy these requirements may be evaluated from a transcendental equation. Each type of amplifier, however, requires the solution of a different equation. In this paper an attempt will be made to present a single approach, which will be valid for several types of bandpass amplifiers. The conditions of maximum obtainable gain will also be derived.

It seems also that the question of bandpass amplifier stability has not been fully worked out. One type of regeneration inherent in bandpass amplifiers is due to anode-grid capacitances. This effect is well known and the criteria of stability have been obtained for certain cases. A more thorough approach to this problem will, however, be attempted: the shape of frequency–amplitude response curves, under conditions of appreciable regeneration, will be investigated, and the conditions of stability for single-tuned and stagger-tuned amplifiers will be given. Also it will be shown how the criteria of stability affect the design of a bandpass amplifier.

The treatment given in this paper is purely theoretical. It should be added, however, that a special five-stage amplifier was constructed for the purpose of experimental investigation. The experimental results, though not highly accurate, seem to corroborate the theory which is here presented. The amplifier employed EF91 miniature pentodes and operated at a frequency of 10 Mc/s. Grid–anode capacitances were artificially increased, by small capacitors, up to about 0·25 pF per valve.

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2. An Approach to Bandpass Amplifier Design

The design of a bandpass amplifier is often based on the following data: the required overall gain, centre frequency and half-power bandwidth. The above data will be taken as the basis for calculations and it will be assumed that the mutual conductances of valves and the tuning capacitances of the circuits are all equal. A bandpass amplifier composed of n identical groups will be considered. Each group may consist of one or more amplifying stages and is characterized by maximum flatness amplitude response given by

$$K_m = \frac{K_{0m}}{(1 + x^{2m})^{\frac{1}{2}}} \quad \cdots \quad (1)$$

where:

K_{0m} = maximum gain of a group
K_m = gain of a group as a function of frequency
m = number of tuned circuits in a group
$x = \frac{f_0}{B_m}\left(\frac{f}{f_0} - \frac{f_0}{f}\right)$ or approximately $x \approx \frac{2\Delta f}{B_m}$
f = frequency
f_0 = centre frequency
Δf = detuning from the centre frequency
B_m = overall bandwidth of a group at points 3 db down.

The following types of groups will be considered:—

(a) one valve with one single-tuned circuit;
(b) one valve with a double-tuned, critically-coupled circuit;
(c) m valves with m staggered single-tuned circuits;
(d) group employing double-tuned coupled circuits with, or without, one single-tuned circuit. All the circuits are separated by valves.

If m is even, the maximum flatness response curve may be obtained by using double-tuned circuits of appropriate Q values and coupling coefficients. If m is odd, an additional single-tuned circuit should be employed.

The design and the characteristics of these basic amplifying units have been investigated by various authors; in particular, much information on the subject can be found in the works of D. Weighton,[1] H. Wallman[2] and A. G. W. Uitjens.[3] It is felt, however, that some explanation should be given with regard to group (d); the analysis of this amplifying unit is given in Appendix 1.

The amplitude response of an amplifier composed of n groups is

$$[K_m]_n = \frac{K_{0m}{}^n}{(1 + x^{2m})^{n/2}} \quad \ldots \quad \ldots \quad (2)$$

The overall half-power bandwidth of the amplifier is related to the bandwidth of a group in the following way:—

$$\left[1 + \left(\frac{2\Delta f_1}{B_m}\right)^{2m}\right]^{n/2} = \sqrt{2} \quad \ldots \quad \ldots \quad (3)$$

where

$$2\Delta f_1 = B_n$$

Thus

$$B_n = B_m(2^{1/n} - 1)^{1/2m} \quad \ldots \quad \ldots \quad (4)$$

The maximum overall gain of the amplifier consisting of n groups may be expressed in terms of the overall bandwidth B_n, the tuning capacitances C and the mutual conductances g_m of the valves (assumed to be equal for all circuits).

Maximum gain of a group is

$$K_{0m} = \left(\frac{g_m}{2\pi C B_m}\right)^t \times s \quad \ldots \quad \ldots \quad (5)$$

where

t = the number of valves in a group

s = a coefficient depending on the type of a group. It will be shown later that $s \leqslant 1$

It follows from (4) and (5) that the maximum gain of n groups is

$$[K_{0m}]_n = K_{0m}{}^n = \left(\frac{g_m}{2\pi C B_m}\right)^{tn} \times s^n$$

$$= \left(\frac{g_m}{2\pi C B_n}\right)^{tn} \times s^n \times (2^{1/n} - 1)^{tn/2m} \quad (6)$$

Let $\quad b = \dfrac{g_m}{2\pi C B_n}$

Then

$$[K_{0m}]_n = b^{tn} \times s^n \times (2^{1/n} - 1)^{tn/2m} \quad (7)$$

It should be noticed that amplification is possible only when $b > 1$, since $s \leqslant 1$.

The number of valves employed in the amplifier is

$$N = nt \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

The maximum gain may be also expressed by

$$[K_{0m}]_n \approx b^{tn} \times s^n \times \left(\frac{\log_e 2}{n}\right)^{tn/2m} \quad \ldots \quad (9)$$

since $\quad 2^{1/n} - 1 \approx \log_e 2/n \quad \ldots \quad \ldots \quad (10)$

This latter approximation is quite close, provided $n > 2$.

Taking decimal logarithms on both sides of Equ. (9), one obtains

$$\log [K_{0m}]_n = \frac{nt}{2m} \times \log [b^{2m} \times s^{2m/t} \times (\log_e 2/n)] \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

Let

$$A_m = b^{2m} \times s^{2m/t} \times (\log_e 2) \quad \ldots \quad \ldots \quad (12)$$

Then

$$\log [K_{0m}]_n = \frac{nt}{2m} \times \log (A_m/n) \quad \ldots \quad \ldots \quad (13)$$

The gain may be expressed in decibels

$$k_{mn} = 20 \log(K_{0m})_n = 10 \frac{nt}{m} \log\left(\frac{A_m}{n}\right) \quad \ldots \quad (14)$$

Therefore

$$m \frac{k_{mn}}{t} = 10n \log\left(\frac{A_m}{n}\right)$$

Now, let

$$F\left(\frac{n}{A_m}\right) = 10 \frac{n}{A_m} \times \log\left(\frac{A_m}{n}\right) \quad \ldots \quad (15)$$

Then, it follows that

$$\frac{m}{t} \frac{k_{mn}}{A_m} = 10 \frac{n}{A_m} \times \log\left(\frac{A_m}{n}\right) \quad \ldots \quad (16)$$

and

$$F\left(\frac{n}{A_m}\right) = \frac{m}{t} \times \frac{k_{mn}}{A_m} \quad \ldots \quad \ldots \quad (17)$$

Equ. (17) with unknown n, is transcendental, but it can be solved graphically. For this purpose the function $F(n/A_m)$ is plotted in Fig. 1, while Fig. 2 shows it on an enlarged scale up to its maximum. The function $F(n/A_m)$ has a maximum value of 1·6 at $n/A_m = 1/e$, and it is equal to zero at $n/A_m = 1$ and $n/A_m = 0$.

The four types of amplifiers mentioned above will now be discussed in some detail.

(a) *Multistage Single-Tuned Amplifiers*

The group is formed of one amplifying stage: one valve followed by a single tuned circuit. For this case $m = t = 1$; also $s = 1$ (see Appendix 1).

The response curve of the amplifier is

$$K_{1n} = \frac{[K_{01}]_n}{(1 + x^2)^{n/2}} \quad \ldots \quad \ldots \quad (18)$$

It can be seen that with a given A_1, the maximum possible amplification which can be achieved, occurs when $F(n/A_1)$ is maximum. Therefore

$$[k_{1n}]_{max} = \frac{10A_1}{e}\log e = 1{\cdot}6A_1 \text{ db} \qquad (19)$$

where

$$A_1 = b^2 \times (\log_e 2) = \left(\frac{g_m}{2\pi CB_n}\right)^2 \times (\log_e 2)$$

At the point of maximum gain, the required number of stages is $n = A_1/e$.

Therefore

$$[k_{1n}]_{max} = 10n \log e = 4{\cdot}34n \text{ db} \qquad (20)$$

Thus, the gain per stage, when the maximum is reached, is given by

$$1/n \times [k_{1n}]_{max} = 10 \times \log e = 4{\cdot}34 \text{ db} \qquad (21)$$

This result was obtained by H. Wallman[1] and W. Kleen.[2]

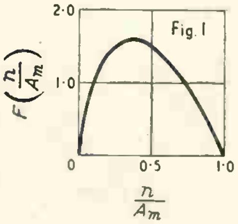
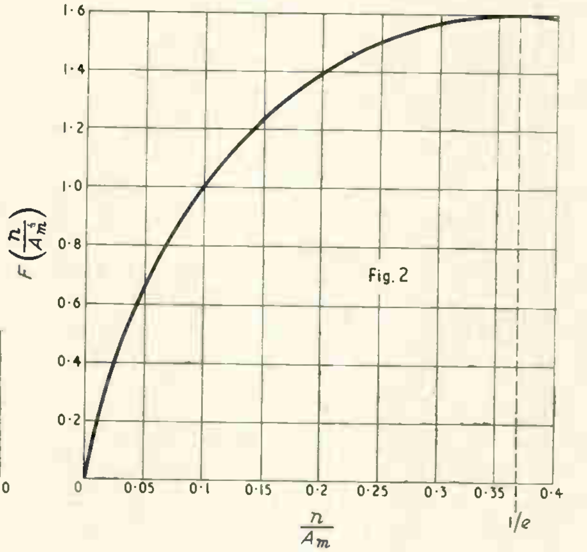


Fig. 1 (left). *Curve from which the required number of stages can be obtained.*

Fig. 2. (right) *Enlarged portion of Fig. 1.*



(b) *Double-Tuned Coupled-Circuit Amplifier*

Each group consists of one valve with a pair of tuned, critically-coupled, circuits. This type of amplifier is only a particular case of the type to be described in (d). It will be discussed in some detail, however, since this amplifier is widely used. It can be seen (from Appendix 1) that in this case $m = 2$ and $t = 1$, while $s = 1/\sqrt{2}$.

The gain of one stage is

$$K_2 = \frac{K_{02}}{(1 + x^4)^{\frac{1}{2}}} \qquad (22)$$

where

$$K_{02} = \frac{g_m}{2\sqrt{2}\pi CB_2}$$

B_2 is the half-power bandwidth of a single stage.

The gain of n such stages is

$$K_{2n} = \frac{[K_{02}]_n}{(1 + x^4)^{n/2}} = \frac{K^n{}_{02}}{(1 + x^4)^{n/2}} \qquad (23)$$

The overall bandwidth is related to the bandwidth of a single stage in the following manner:

$$B_n = B_2(2^{1/n} - 1)^{\frac{1}{4}} \qquad (24)$$

Also, one obtains from (12)

$$A_2 = \left(\frac{\log_e 2}{4}\right) \times \left(\frac{g_m}{2\pi CB_n}\right)^4 \qquad (25)$$

The maximum possible gain in db is given by the expression

$$[k_{2n}]_{max} = 10\frac{A_2 t}{em}\log e = 0{\cdot}8A_2 \text{ db.} \qquad (26)$$

And the required number of stages is $n = A_2/e$. Therefore,

$$[k_{2n}]_{max} = 10nt/m \log e = 2{\cdot}17n \text{ db.}$$

(c) *Amplifier Composed of Stagger-Tuned Groups*

In this case, a group consists of m stagger-tuned stages. It has a maximum-flatness amplitude response as given by Equ. (1). There are as many valves as there are tuned circuits; thus for this case $t = m$.

The maximum gain of a group is

$$K_{0m} = \left(\frac{g_m}{2\pi CB_m}\right)^m \qquad (27)$$

thus, it follows from (5) that $s = 1$.

As before, the maximum possible gain in db is

$$[k_{mn}]_{max} = 1{\cdot}6A_m$$

and it occurs when the number of groups is $n = A_m/e$, where

$$A_m = (\log_e 2)b^{2m} = (\log_e 2) \times \left(\frac{g_m}{2\pi CB_n}\right)^{2m}$$

It may be noticed that the maximum obtainable gain is proportional to b^{2m}, while for a single-tuned amplifier it is proportional to b^2. It is clear, then, that with the same b factors in both cases, the amplifier composed of staggered groups offers some advantages.

(d) *Amplifier Composed of Double-Tuned (plus Single-Tuned) Groups*

There are two cases. If m is even, the curve given by

$$K_m = \frac{K_{0m}}{(1 + x^{2m})^{\frac{1}{2}}}$$

can be realized by using $\frac{1}{2}m$ double-tuned circuits of appropriate coupling coefficients and dynamic impedances. There are $t = \frac{1}{2}m$ valves in a group.

For this case

$$s = 2^{-(m-1/2)}$$

The derivation of this expression is given in Appendix 1.

Thus

$$A_m = b^{2m} \times s^{2m/t} \times (\log_e 2)$$
$$= b^{2m} \times s^4 \times (\log_e 2)$$
$$= (g_m/2\pi CB_n)^{2m} \times 2^{-2(m-1)} \times (\log_e 2) \quad (28)$$

If m is odd, $\frac{1}{2}(m - 1)$ double-tuned pairs and one single-tuned stage unit must be employed in order to obtain the desired amplitude response for a group. Thus, the number of valves per group is $t = \frac{1}{2}(m + 1)$, and the total number of valves in the amplifier is given by

$$N = \tfrac{1}{2}(m + 1)n \quad \ldots \quad (29)$$

In this case

$$s = \frac{\sqrt{m}}{2^{(m-1)/2}}$$

Therefore

$$A_m = b^{2m} \times s^{2m/t} \times (\log_e 2)$$
$$= b^{2m} \times s^{4m/m+1} \times (\log_e 2)$$
$$= \left(\frac{g_m}{2\pi CB_n}\right)^{2m} \times \left(\frac{\sqrt{m}}{2^{(m-1/2)}}\right)^{4m/m+1} \times (\log_e 2) \quad \ldots \quad (30)$$

Again, the maximum possible gain is

$$[k_{mn}]_{max} = 1{\cdot}6 \times \frac{t}{m} \times A_m \text{ db}$$

and the number of groups required is $n = A_m/e$.

(e) *Design Procedure*

In general, $b = g_m/2\pi CB_n$ is appreciably greater than unity. Thus, by employing a suitable type of amplifier it is possible to obtain any desired amplification. The required gain, however, will probably never be higher than 120 db.

The procedure in the design of an amplifier is as follows: first, b should be calculated. For this purpose, the mutual conductances of the valves, the tuning capacitances of the circuits and the overall bandwidth should be known. Then, the type of group should be selected. Also, it must be decided whether stagger-tuned groups, or groups employing coupled circuits, are preferred.

Once that is done, the value of $F\left(\frac{n}{A_m}\right) = \frac{m}{t} \times \left(\frac{k_{mn}}{A_m}\right)$ is computed. The corresponding point can be found on the curve in Fig. 2. Thus, the number of groups n is obtained. For a given amplification and bandwidth, several types of amplifiers may be tried and the preference given to the one which is most convenient and which requires the least number of valves.

It can be seen from (6) that the gain is proportional to the factor $g_m/2\pi C$. Thus, it seems to be desirable to make the factor $g_m/2\pi C$ as high as possible in order to obtain the desired amplification with the minimum number of stages. For a given mutual conductance g_m, a high value of $g_m/2\pi C$ can be obtained by employing small tuning capacitances C. The choice of C, however, is not quite arbitrary; if C is small (which implies high dynamic impedances), the amplifier may become unstable owing to the regenerative effect of grid-to-anode capacitances. On the other hand, even if the amplifier is stable, it may work under conditions of fairly high regeneration and then the analysis which was given above is not valid. Thus, it is necessary to select such values of C as to obtain a stable amplifier working under conditions of negligible regeneration. This problem is discussed in the following section.

3. Stability of Bandpass Amplifiers.

It is generally understood that the grid-to-anode capacitances C_{ga} cause regeneration or positive feedback in a multi-stage bandpass amplifier and the problem has been considered by various authors. M. O'Connor Horgan[5] thoroughly investigated the properties of a single amplifying stage with two tuned circuits, and gave the oscillation conditions for a single-tuned amplifier of up to four stages. The criteria of oscillation in a single-tuned amplifying chain were also examined by W. Faust and H. M. Beck[6]. Recently, A. G. W. Uitjens[3] presented a general but approximate method for the evaluation of permissible stable gain in stagger-tuned and coupled-circuit amplifiers. In this section it is proposed to carry the problem a little further.

(a) *Fundamental Equation*

A chain amplifier employing n valves will be considered. No assumptions will be made as to the anode impedances, except that they are two-terminal networks. The internal impedance of the generator is assumed to be $Z_{in} = 0$. The grid-to-anode impedance of the kth stage, due to C_{ga} which provides a feedback path, will be denoted by $\mathbf{Z}_{fk}$. All the complex quantities will be denoted by black-face letters; the moduli of complex quantities will be represented by ordinary letters. The equivalent circuit of a chain amplifier may be represented as shown in Fig. 3.

The anode impedance $\mathbf{Z}_k$ takes into account the output capacitance of the preceding valve and the input capacitance of the following valve.

Thus $\dfrac{1}{\mathbf{Z}_k} = \dfrac{1}{r_{ak}} + \dfrac{1}{\mathbf{Z}_k'} + j\omega(C_{gk} + C_{ak})$

where

$\mathbf{Z}_k'$ = the impedance connected between the two valves,

r_{ak} = the internal resistance of the kth valve.

Denote

$$g_{mk} - \frac{1}{\mathbf{Z}_{fk}} = \mathbf{g}_{mk}$$

and

$$\frac{1}{\mathbf{Z}_k} + \frac{1}{\mathbf{Z}_{fk}} + \frac{1}{\mathbf{Z}_{f(k+1)}} = \frac{1}{\mathbf{Z}_{kk}}$$

Then, the system of equations, relating the voltages at various stages of the amplifying chain, may be written in the matrix form as shown below:

The system will become unstable when the determinant is equal to zero which implies that

$$A_n = B_n = 0$$

General expressions for gain up to four stages are given in Table 1.

(b) *Single-Tuned Amplifiers*

For the purpose of the investigation of single-tuned amplifiers a number of assumptions and simplifications will be made, without which the calculations would be practically impossible. Thus, it will be assumed that all the mutual conductances of valves, the anode-to-grid capacitances, and the anode impedances are

$$\begin{bmatrix} \frac{1}{\mathbf{Z}_{11}} & \frac{-1}{\mathbf{Z}_{f2}} & 0 & 0 & . & 0 & 0 \\ \mathbf{g}_{m2} & \frac{1}{\mathbf{Z}_{22}} & \frac{-1}{\mathbf{Z}_{f3}} & 0 & . & 0 & 0 \\ 0 & \mathbf{g}_{m3} & \frac{1}{\mathbf{Z}_{33}} & \frac{-1}{\mathbf{Z}_{f4}} & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & . & . & \mathbf{g}_{m,\,n-1} & \frac{1}{\mathbf{Z}_{n-1,\,n-1}} & \frac{-1}{\mathbf{Z}_{fn}} \\ 0 & 0 & . & . & 0 & \mathbf{g}_{mn} & \frac{1}{\mathbf{Z}_{nn}} \end{bmatrix} \begin{bmatrix} \mathbf{V}_1 \\ \mathbf{V}_2 \\ . \\ . \\ \mathbf{V}_{n-1} \\ \mathbf{V}_n \end{bmatrix} = \begin{bmatrix} -g_{m1}\mathbf{V}_g \\ 0 \\ . \\ . \\ 0 \\ 0 \end{bmatrix} \quad \ldots \quad \ldots \quad (31)$$

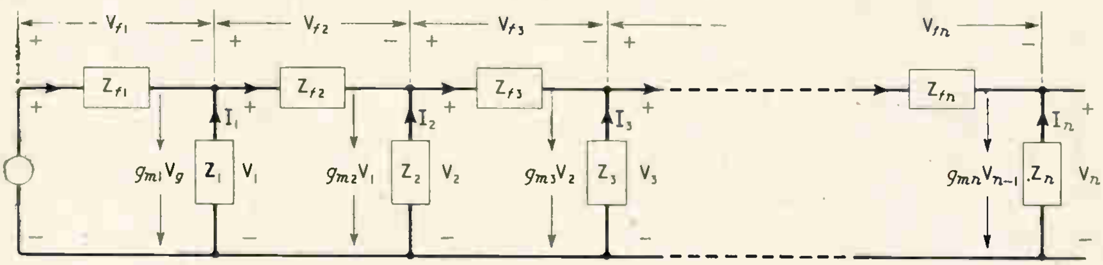


Fig. 3. *Equivalent circuit of amplifier.*

It can be deduced that the overall amplification of the chain may be expressed as

$$\mathbf{K}_n = \frac{\mathbf{V}_n}{\mathbf{V}_g} = \frac{(-1)^n \prod_{k=1}^{n} \mathbf{g}_{mk}}{\mathbf{D}_n} \quad (32)$$

where $\mathbf{D}_n$ is the determinant of the network matrix.

In general, the determinant is a complex quantity

$$\mathbf{D}_n = A_n + jB_n$$

TABLE 1

n	$\mathbf{K}_n$
1	$-\mathbf{g}_{m1}\mathbf{Z}_{11}$
2	$\dfrac{\mathbf{g}_{m1}\mathbf{g}_{m2}}{\dfrac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}} + \dfrac{\mathbf{g}_{m2}}{\mathbf{Z}_{f2}}}$
3	$\dfrac{-\mathbf{g}_{m1}\mathbf{g}_{m2}\mathbf{g}_{m3}}{\dfrac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}\mathbf{Z}_{33}} + \dfrac{\mathbf{g}_{m2}}{\mathbf{Z}_{f2}\mathbf{Z}_{33}} + \dfrac{\mathbf{g}_{m3}}{\mathbf{Z}_{f3}\mathbf{Z}_{11}}}$
4	$\dfrac{\mathbf{g}_{m1}\mathbf{g}_{m2}\mathbf{g}_{m3}\mathbf{g}_{m4}}{\dfrac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}\mathbf{Z}_{33}\mathbf{Z}_{44}} + \dfrac{\mathbf{g}_{m2}}{\mathbf{Z}_{33}\mathbf{Z}_{44}\mathbf{Z}_{f2}} + \dfrac{\mathbf{g}_{m3}}{\mathbf{Z}_{11}\mathbf{Z}_{14}\mathbf{Z}_{f3}} + \dfrac{\mathbf{g}_{m4}}{\mathbf{Z}_{11}\mathbf{Z}_{22}\mathbf{Z}_{f4}} + \dfrac{\mathbf{g}_{m2}\mathbf{g}_{m4}}{\mathbf{Z}_{f2}\mathbf{Z}_{f4}}}$

identical. Furthermore, Q values of the anode tuned circuits are to be of the order of 10 or more.

Also, $\mathbf{g}_{mk} = g_{mk} - j\omega C_{gak} \approx g_{mk} = g_m$ since, in general, $g_m \gg \omega C_{ga}$.

Admittances forming the diagonal of the determinant may be expressed:

$$\frac{1}{\mathbf{Z}_{kk}} = \frac{1}{\mathbf{Z}_k} + j2\omega C_{ga} \approx \frac{1 + jx}{r_d} \quad \ldots \quad (33)$$

where

$$x = Q_0(f/f_0 - f_0/f) \approx \frac{2Q_0\Delta f}{f_0} = \frac{2\Delta f}{B'} \quad \ldots \quad (34)$$

where B' = the bandwidth of a single circuit.

$r_d = \dfrac{Q_0}{\omega_0 C}$ = the dynamic impedance of a circuit.

After a number of algebraic operations the determinant of the network may be written in the form:

$$\mathbf{D}_n = \frac{1}{r_d{}^n} \times \begin{vmatrix} 1+jx & -j\alpha & 0 & 0 & . & 0 & 0 \\ 1 & 1+jx & -j\alpha & 0 & . & 0 & 0 \\ 0 & 1 & 1+jx & -j\alpha & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & . & . & 1 & 1+jx & -j\alpha \\ 0 & 0 & . & . & 0 & 1 & 1+jx \end{vmatrix} \quad (35)$$

where $\alpha = \omega C_{ga} g_m r_d{}^2 \approx \omega_0 C_{ga} g_m r_d{}^2$; it will be called the *regeneration coefficient*. It will be shown that the amount of regeneration and, ultimately, the oscillations, depend on the magnitude of α. The regeneration coefficient at which the oscillations result will be called the critical regeneration coefficient and will be denoted by α_n, where n is the number of stages in the given amplifier.

The oscillation conditions are: $\mathbf{D}_n = 0$, or $\mathbf{D}_{an} = r_d{}^n \mathbf{D}_n = 0$.

If $\mathbf{D}_{an} = A_{an} + jB_{an}$, then

$$A_{an} = B_{an} = 0 \quad \ldots \quad (36)$$

These are two simultaneous equations whose solutions will give the values of x and α_n at the points of instability. In general, there may be more than one solution for x, but only negative x are allowed, since the equivalent input impedance of an amplifier (of any number of stages) is always composed of resistance and capacitance in parallel. This means that the first tuned circuit must appear as a resistance and inductance in parallel. The oscillations will then invariably take place at a frequency lower than the frequency to which the circuits are tuned. On the other hand, only the lowest real positive values of α_n are of interest, because these are minimum values necessary to cause instability.

A heuristic proof is given in the Appendix 2, which shows that $x = -1$, is a solution for any n. Upon its substitution into $\mathbf{D}_{an}$, an equation in terms of α only is obtained, from which the critical regeneration coefficient α_n can be computed.

The equation whose solutions yield critical regeneration coefficients is

$$(n+1)\left(\frac{1}{2}\right)^{\frac{n}{2}} + \binom{n+1}{3}\left(\frac{1}{2}\right)^{\frac{n-2}{2}}\left(\frac{1}{2} - \alpha\right) + \binom{n+1}{5}\left(\frac{1}{2}\right)^{\frac{n-4}{2}}\left(\frac{1}{2} - \alpha\right)^2 + \ldots = 0 \quad (37)$$

The solutions of this equation are given in Table 2.

TABLE 2

Number of Stages	2	3	4	5	6	..	∞
α_n	2	1	0·76	$\frac{2}{3}$	0·62	..	$\frac{1}{2}$

The values for α_n agree with those obtained by O'Connor Horgan[5] and by Faust and Beck[6], except that in their n-stage amplifier they assumed $n + 1$ tuned circuits and not n as in the present notation. Faust and Beck calculated the oscillation conditions up to six stages (seven in this case).

It is interesting to notice that the oscillations will not start even with a very large number of stages provided $\alpha < \frac{1}{2}$. It may also be added that a single-tuned amplifier (with all the circuits tuned alike) is the most critical case from the point of view of stability. If the circuits were detuned with respect to one another, it would be more difficult to cause oscillations; i.e., a higher value of α_n would be required. Unfortunately, the authors did not find it possible to prove conclusively that this is the case; it will be shown later, however, that in an amplifier composed of staggered pairs the value of α_n necessary to cause oscillations is higher than in a single-tuned amplifier with the same number of stages.

A single-tuned amplifier works as a regenerative amplifier when α is smaller than α_n. The amount of positive feedback and, hence, the bandwidth and maximum gain, depend on the magnitude of α, which, in turn, is proportional to C_{ga}. The influence of C_{ga} on the shape of response curves is illustrated in Fig. 4* and Fig. 5. A series of curves, with α as a parameter, are plotted for a two-stage and a three-stage amplifier (see Appendix 2). It can be seen that the curves

* In his book, A. G. W. Uitjens[3] shows a double-peaked response curve, for $\alpha = 1$, for an amplifying stage with two synchronously tuned circuits. The authors found that for the above case the response curve is single-peaked; see Fig. 4.

become asymmetrical when α is greater than zero. With an increase of α the maximum gain of the amplifier increases, while the bandwidth is reduced. Furthermore, with feedback, the maximum gain no longer occurs at the frequency to which the circuits are tuned, but below it. It can be seen from the curves that, as α tends to its critical value, the point of maximum amplification approaches $x = -1$, where the oscillations will start.

It was also found that the amplitude response curves of four- and five-stage amplifiers have only one maximum and are much the same in shape as those for two- and three-stage amplifiers. Thus, it may be expected that this is the case for any number of stages.

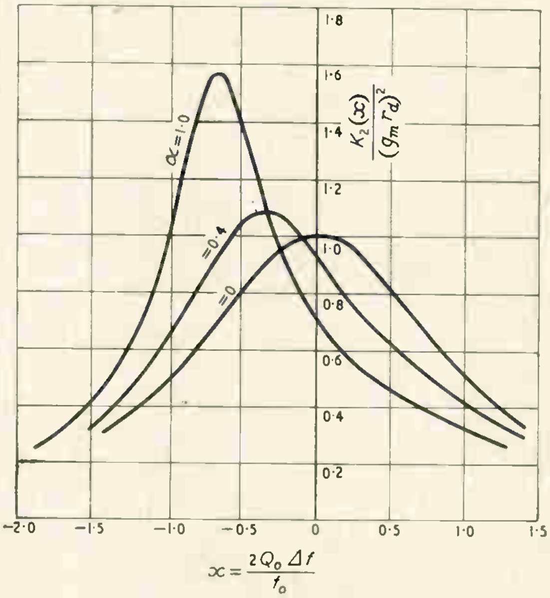


Fig. 4. *Frequency response of a 2-stage single-tuned amplifier.*

It is interesting to know how the bandwidth and the maximum gain depend on α. This is illustrated in Figs. 6 and 7 where the following functions are plotted:—

$$h_2(\alpha) = \frac{B_2(\alpha)}{B_2(0)}; \quad h_3(\alpha) = \frac{B_3(\alpha)}{B_3(0)} \quad \ldots \quad \ldots \quad (38)$$

$$g_2(\alpha) = \frac{K_{2max}}{K_{20}}; \quad g_3(\alpha) = \frac{K_{3max}}{K_{30}} \quad \ldots \quad \ldots \quad (39)$$

$B_2(0)$ is the bandwidth of a two-stage amplifier under conditions of no regeneration.

$B_2(\alpha)$ is the overall bandwidth of two stages when α is greater than zero.

K_{2max} = maximum gain when $\alpha > 0$,

$K_{20} = (g_m r_d)^2$ $(\alpha = 0)$,

and so on.

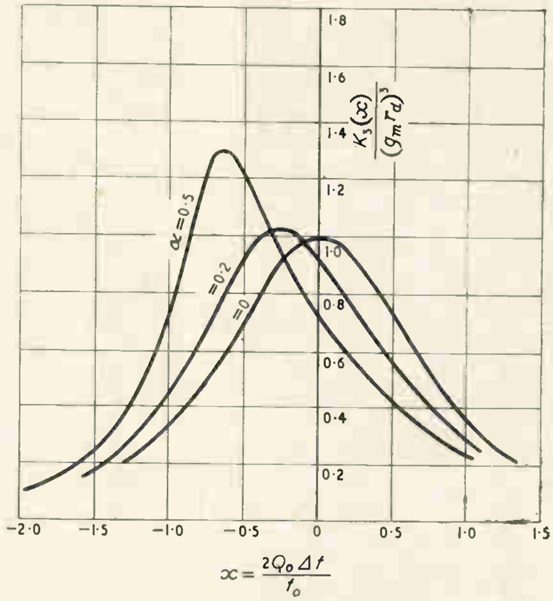


Fig. 5. *Frequency response of a 3-stage single-tuned amplifier.*

In some textbooks and papers the condition of oscillations is given in the form

$$K_0 = g_m r_d = \sqrt{\frac{\alpha_n g_m}{\omega_0 C_{ga}}} \quad \ldots \quad \ldots \quad \ldots \quad (40)$$

Here K_0 should be understood as the limiting value of the product $g_m r_d$ and not the maximum stable gain per stage. It may be pointed out that when regeneration is appreciable the amplification varies from stage to stage and it may be much greater than $g_m r_d$. It is only when $\alpha = 0$ that the product $g_m r_d$ does represent maximum gain per stage.

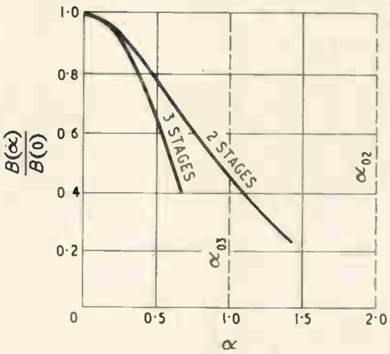


Fig. 6. *3-db bandwidth in single-tuned amplifiers.*

(c) *Stagger-Tuned Amplifiers*

It is now proposed to investigate the influence of C_{ga} on the performance of stagger-tuned amplifiers with the view to obtaining the oscillation conditions and discussing the amplitude response curves. It will be assumed that the circuits are tuned to the desired frequencies which are computed by means of the theoretical formulae. It will be shown later how this tuning can be done. Unfortunately, no general oscillation conditions have been found, since the mathematics in the case of more than three staggered stages becomes very involved. Only the case of arithmetic symmetry of staggering will be considered; i.e., when the overall bandwidth of the amplifier is not an appreciable fraction of the centre frequency (say $B_n \leqslant 0{\cdot}2f_0$).

A *staggered pair* consists of two circuits having equal bandwidths and dynamic impedances. Its amplitude response, under the conditions of negligible regeneration, is

$$K_2 = \frac{K_{02}}{(1 + x^4)^{\frac{1}{2}}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (41)$$

where

$$K_{02} = \tfrac{1}{2}(g_m r_d)^2; \quad x = 2\Delta f / B_2$$

B_2 is the overall bandwidth of the two-stage amplifier.

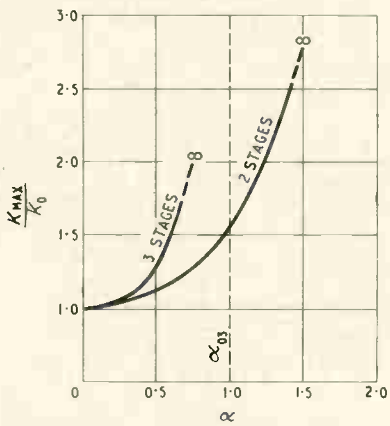


Fig. 7. *Maximum gain in single-tuned amplifiers.*

The bandwidths of single circuits are

$$B' = B_2 \sin\left(\frac{\pi}{4}\right) = B_2/\sqrt{2}$$

and the detuning from the centre frequency

$$\Delta f_1 = \pm \tfrac{1}{2}B_2 \cos\left(\frac{\pi}{4}\right) = \pm B_2/2\sqrt{2}$$

The determinant of the network is

$$\mathbf{D}_2 = \frac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}} + \frac{g_{m2}}{\mathbf{Z}_{f2}} \quad \ldots \quad \ldots \quad \ldots \quad (42)$$

It can be seen that it is immaterial whether the first circuit is tuned below the centre frequency and the second above it, or vice versa, because the product $1/\mathbf{Z}_{11}\mathbf{Z}_{22}$ is the same, provided the dynamic impedances and the bandwidths of both circuits are equal.

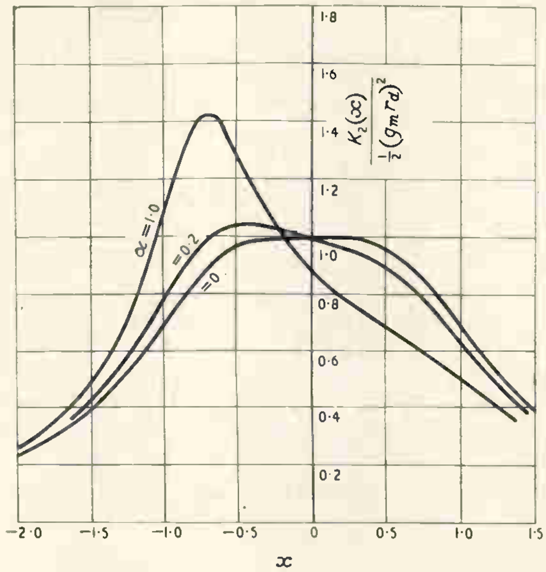


Fig. 8. *Frequency response in a 2-stage staggered amplifier.*

A series of response curves $K_2(x)$ with α as a parameter is plotted in Fig. 8. From these curves it is clear that even a small α seriously affects the shape of the characteristic. It can be seen that $\alpha = 0{\cdot}2$ already introduces a fair amount of distortion and it is probably the maximum regeneration that can be normally permitted.

In Fig. 9 the function

$$g_2(\alpha) = \frac{K_{max}}{K_{02}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (43)$$

is plotted.

The effect of α on the overall bandwidth is illustrated by means of the curve

$$h_2(\alpha) = \frac{B_2(\alpha)}{B_2(0)} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (44)$$

which is plotted in Fig. 10.

However, even with $\alpha > 0$ it is possible to

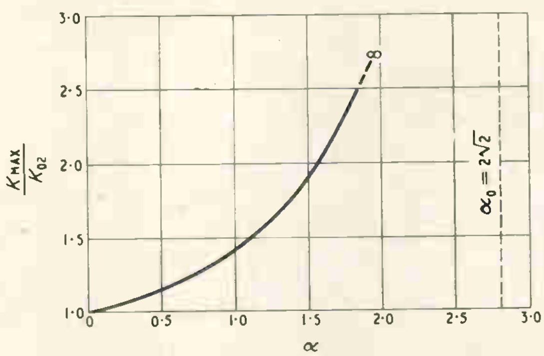


Fig. 9. *Maximum gain in a 2-stage staggered amplifier.*

obtain a symmetrical characteristic for two staggered stages by additional damping of the first circuit and the proper choice of staggering frequencies. The problem can be solved analytically without great difficulty, but the analysis is beyond the scope of this paper.

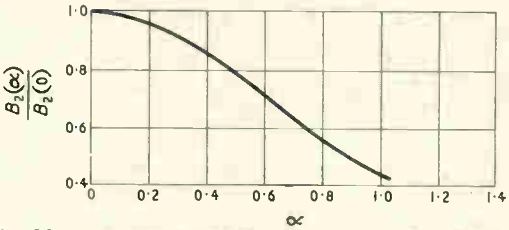


Fig. 10. *3-db bandwidth in a 2-stage staggered amplifier.*

Before an amplifier with more than two staggered stages can be discussed, it will be necessary to introduce a special notation which will represent the order in which the circuits are staggered. When the regeneration is negligible, no special significance can be attached to the order of staggering. If the feedback between the stages is appreciable, however, the amount of distortion introduced into the amplitude response curves depends on the staggering order. Furthermore, the conditions of oscillations are also functions of the way in which the circuits are staggered.

The notation is as follows:

For the kth circuit (counting from the input)

- 0—means that the circuit is tuned to the centre frequency
- 1^+—means that the circuit is tuned to the first frequency above the centre
- 2^+—the circuit is tuned to the second frequency above the centre
- 1^-—the circuit is tuned to the first frequency below the centre, and so on.

Thus, if it is written

$S(1^+, 0, 1^-)$

it should be understood that a three-stage amplifier has its first circuit tuned to a frequency above the centre; the second circuit is tuned to the centre frequency, and the third circuit has its resonance below the centre frequency.

Thus, for two staggered pairs there are the following possibilities:

$S_1\ (1^+, 1^-, 1^+, 1^-)$ } 'interlaced' staggering
$S_2\ (1^-, 1^+, 1^-, 1^+)$ }
$S_3\ (1^-, 1^+, 1^+, 1^-)$
$S_4\ (1^+, 1^-, 1^-, 1^+)$
$S_5\ (1^-, 1^-, 1^+, 1^+)$
$S_6\ (1^+, 1^+, 1^-, 1^-)$

Two staggering orders which give the same response characteristics and the same oscillation conditions will be called equivalent and their equivalence will be denoted $S_i \equiv S_j$.

Thus, by examining Table 1 in Section 3(a) it can be seen that, in the case of two staggered pairs, $S_2 \equiv S_1$, and $S_5 \equiv S_6$, provided the mutual conductances of all valves are equal.

In the case of 'interlaced' staggering of an amplifier consisting of m staggered pairs, a general solution can be found for oscillation conditions. It is shown in Appendix 2 that the oscillations take place at $x_1 = -1$, where $x = \sqrt{2}\,\Delta f/B'$; B' is the bandwidth of a single circuit.

The values of $\alpha = \omega_0 C_{ga} g_m r_d^2$ necessary to produce oscillations are given in Table 3.

TABLE 3

Number of Pairs m	1	2	3	..	∞
α_{2m}	$2\sqrt{2}$	$0{\cdot}76\sqrt{2}$	$0{\cdot}62\sqrt{2}$	..	$\sqrt{2}/2$

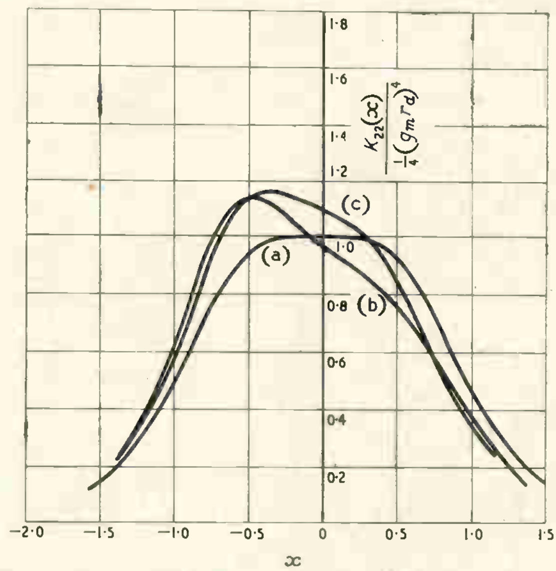


Fig. 11. *Frequency response of an amplifier with two staggered pairs of stages.*
(*a*) $\alpha = 0$
(*b*) $\alpha = 0{\cdot}2$; $S(1^+, 1^-, 1^+, 1^-)$
(*c*) $\alpha = 0{\cdot}2$; $S(1^-, 1^+, 1^+, 1^-)$

It is interesting to notice that critical α is $\sqrt{2}$ times greater than the critical regeneration coefficient in the case of a single tuned amplifier with the same number of stages and the same dynamic impedances r_d.

When the order of staggering is not 'interlaced', the conditions of oscillations, and, consequently, the response curves, are different. In order to get some insight into the matter, two staggered pairs will be considered. If equal g_m for all the four valves are assumed, there are four non-equivalent staggering orders, namely

S_1 (1^-, 1^+, 1^-, 1^+)
S_3 (1^-, 1^+, 1^+, 1^-)
S_4 (1^+, 1^-, 1^-, 1^+)
S_6 (1^+, 1^+, 1^-, 1^-)

The oscillation conditions for those four possibilities are given in Table 4.

TABLE 4

S	S_1	S_3	S_4	S_6
x_1	− 1·0	− 0·8	− 1·27	− 0·815
α_{22}	1·073	1·34	0·96	1·18

The amplitude response curves are given in Fig. 11 for the cases S_1 and S_3. It appears from these curves that when $\alpha = 0{\cdot}2$ the distortion of characteristics is quite appreciable; thus, normally, the permissible value of α would be about 0·1 or, approximately, 10% of α_{22}.

The case of *staggered triple* may be solved analytically without great difficulty, if arithmetical symmetry of staggering is assumed.

For a three-stage amplifier the determinant of the network is

$$\mathbf{D}_3 = \frac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}\mathbf{Z}_{33}} + j\omega C_{ga} g_m \left(\frac{1}{\mathbf{Z}_{11}} + \frac{1}{\mathbf{Z}_{33}}\right) \quad (45)$$

provided all g_m and C_{ga} terms are equal.

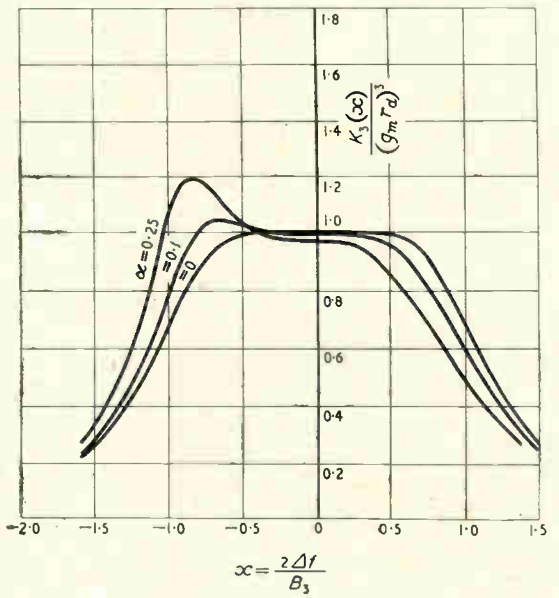


Fig. 12. *Frequency response of a 3-stage staggered amplifier.* $S_1(1^+, 0, 1^-) \equiv S_2(1^-, 0, 1^+)$

By examining the determinant it can be seen that there are three pairs of staggering orders

$$S_a(1^-, 0, 1^+) \equiv S(1^+, 0, 1^-)$$
$$S_b(0, 1^-, 1^+) \equiv S(1^+, 1^-, 0) \quad \ldots \quad \ldots \quad (46)$$
$$S_c(1^-, 1^+, 0) \equiv S(0, 1^+, 1^-)$$

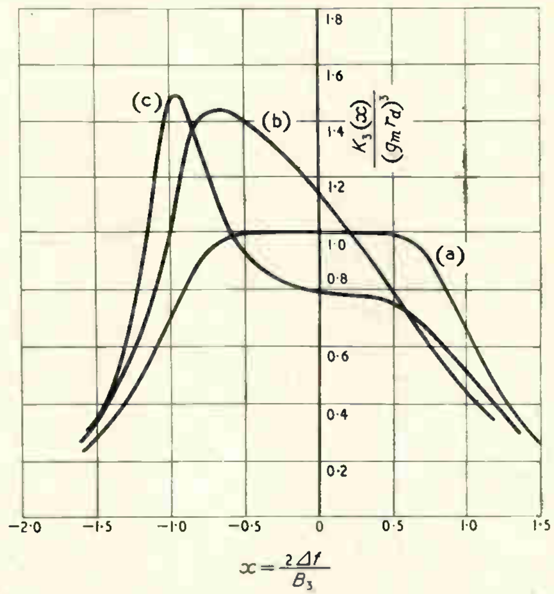


Fig. 13. *Frequency response of a 3-stage staggered amplifier.*
(a) $\alpha = 0$
(b) $\alpha = 0{\cdot}25$; $S(1^-, 1^+, 0) \equiv S(0, 1^+, 1^-)$
(c) $\alpha = 0{\cdot}25$; $S(1^+, 1^-, 0) \equiv S(0, 1^-, 1^+)$

The conditions of oscillations for these three cases are given in the Table 5.

TABLE 5

S	S_a	S_b	S_c
x_1	− 1·17	− 1·15	− 0·916
α_3	0·743	0·518	0·702

where

$\alpha = \omega_0 C_{ga} g_m r_d^2$
r_d = the dynamic impedance of the low Q circuit
$x = 2\Delta f/B_3$
B_3 = the bandwidth of the low Q circuit.

The effect of regeneration, due to C_{ga}, on the response characteristics is illustrated by a series of curves given in Figs. 12 and 13. For the symmetrical case S_a three curves are plotted. It can be seen that, for this case, the regeneration coefficient should not be higher than about 10% of α_3, if serious distortion of the characteristic is to be avoided. The other two cases, S_b and S_c, give more distortion and are more susceptible to oscillations than the symmetrical case.

The case of three staggered stages was investigated experimentally by M. T. Lebenbaum[7] who gave a response curve similar to that of the symmetrical case. He also found it possible to compensate for the distortion of the amplitude response curve by empirical adjustment of stagger-frequencies and damping resistances.

A staggered quadruple may be solved by the same method as that outlined above. There are $4! = 24$ different staggering orders, which, in the case of equal values of g_m, may be reduced to 12 different S_i. The analytical solution is very involved.

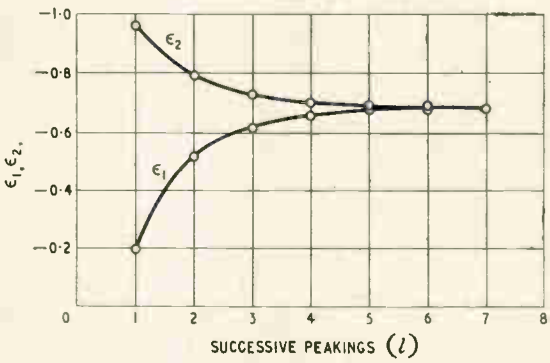


Fig. 14. *Tuning procedure in a 2-stage single-tuned amplifier* ($\alpha = 1$). *Initially* $\epsilon_2 = -2$.

(d) *Tuning*

It is of some interest to find out how the circuits of an amplifier are tuned when some regeneration, due to C_{ga}, is present.

The tuning procedure is usually as follows: an indicator is connected to the output stage, while a signal of a given frequency is applied to the input of the amplifier. In a single-tuned amplifier a single frequency f_0 is applied and all the circuits are trimmed so as to give maximum signal at the output. In a stagger-tuned amplifier, as many different frequencies are, in turn, applied as there are circuits, and for a given frequency an appropriate circuit is trimmed for maximum output at the indicator. It is assumed that the circuits are appropriately damped and have the required bandwidths. When no regeneration is present, the circuits will tune to the required frequencies, if the above procedure is adopted. This is not the case, however, when there is appreciable positive feedback between the stages. Thus, it can be seen from the curves in Figs. 4 and 5 that, if all the circuits are tuned to the same frequency f_0, maximum output occurs below f_0.

The question of tuning was approached analytically, and it was found that in a single-tuned amplifier, after a series of consecutive trimmings, the circuits did not tune to the applied frequency f_0. In a two-stage amplifier, both circuits tuned to a single frequency which was somewhat higher than f_0. The process of trimming is illustrated in Fig. 14, where ϵ_1 and ϵ_2 are the detunings from the applied frequency, of the first and second circuits respectively; ϵ_1 and ϵ_2 are expressed in terms of $x = 2\Delta f/B'$. It can be seen that, for $\alpha = 1$, after a series of peakings, the two circuits converge at $\epsilon_1 = \epsilon_2 = -0{\cdot}68$. It may be added that when $\alpha = 0$, the circuits tune to f_0 and only one trimming for each circuit is necessary.

The tuning process in a three-stage amplifier is shown in Fig. 15. It can be seen that, for $\alpha = 1/2$, the first and third stages tune to one

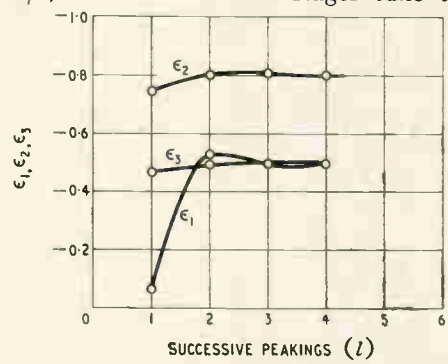


Fig. 15. *Tuning procedure in a 3-stage single-tuned amplifier* ($\alpha = 0{\cdot}5$). *Initially* $\epsilon_2 = 2$, $\epsilon_3 = -1$.

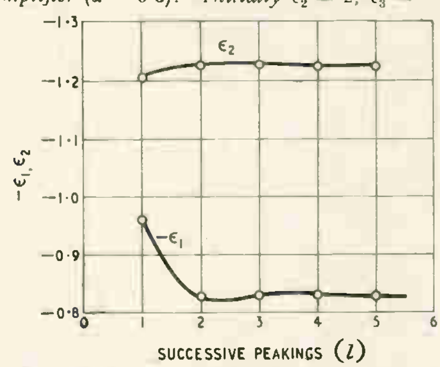


Fig. 16. *Tuning procedure in a 2-stage staggered amplifier* ($\alpha = 1$), $S(1^-, 1^+)$. *Initially* $\epsilon_2 = -4$.

frequency, while the second circuit tunes to another frequency; yet all the circuits trim to the frequencies higher than f_0. It may be pointed out that, when $\alpha = 1$, all the three circuits tune to $\epsilon = -1$ and the amplifier becomes unstable. In a four-stage amplifier, the first and the fourth circuits tune to one frequency, while the second and the third stages have their resonances at another frequency.

It is also found that, if the tuning procedure as described above is adopted, the circuits of a stagger-tuned amplifier do not tune to the theoretically computed frequencies. In a two-stage staggered amplifier both circuits tune to frequencies higher than those applied, and the difference between them is somewhat greater than the difference between the two applied frequencies (see Fig. 16). The detuning from the desired frequencies depends on the magnitude of the regeneration coefficient α. It may be added that, in the case of a 3-stage staggered amplifier, the circuits will not tune to the desired frequencies and, furthermore, the resonant frequencies of the circuits will depend on the order of staggering.

It is possible, however, to tune the circuits to the desired frequencies if the following procedure is adopted: all the circuits of the amplifier, except the one which is to be trimmed, should be detuned far away from the centre frequency. Then, the particular circuit can be trimmed for maximum output at the indicator. It will tune (very nearly) to the applied frequency. With this procedure the signal at the output is small and, therefore, a receiver should be used as an output signal meter.

4. Conclusions

From the theory presented above it may be concluded that:

(i) For a variety of bandpass amplifiers it is possible to calculate the number of stages necessary to obtain a given bandwidth and gain. This can be done with the help of the formulae given in Section 2 and the curve in Fig. 2. The approach to amplifier design presented in that Section is valid only when regeneration is negligible.

(ii) In order to reduce regeneration, it is better to employ low dynamic impedances, rather than small mutual conductances for the valves, because α is proportional to the square of dynamic impedance, while the gain is directly proportional to it.

(iii) The effect of C_{ga} in single-tuned amplifiers is not as serious as it is in stagger-tuned amplifiers. A regeneration coefficient of 30% of the critical value may be permitted in single-tuned amplifiers without causing appreciable distortion of the shape of the response curves. For stagger-tuned amplifiers the regeneration coefficient α should be kept below 10% of the critical value, if response characteristics of good quality are to be obtained.

(iv) With regard to the problem of the best order of staggering, no definite conclusions have been reached by virtue of the theoretical investigation alone. Some experimental work has been done by the authors on three-stage and four-stage staggered amplifiers. On the strength of both the experimental results and the theory the following conclusions can be arrived at:

(a) It is inadvisable to put two high-Q circuits next to each other in a stagger-tuned amplifier;

(b) The first circuit of the amplifier should be tuned to a frequency below the centre frequency;

(c) If the regeneration coefficient is not too high, it is possible to compensate for the distortion of the response curves in stagger-tuned amplifiers by proper damping of anode circuits and appropriate choice of stagger frequencies. This technique may be of little value, however, in the manufacture of large quantities of amplifiers because the anode grid capacitances and mutual conductances may vary from valve to valve. Thus, every single amplifier would have to undergo a lengthy process of compensation. It is advisable, therefore, to keep the regeneration coefficient low.

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APPENDIX 1

Analysis of Amplifier Composed of Double-plus-Single Tuned Groups.

The response curve of the type

$$K_m = \frac{K_{0m}}{(1 + x^{2m})^{\frac{1}{2}}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

may be realized by staggering m single-tuned stages; the theory of stagger-tuned amplifiers is widely known and it will not be considered here. Another way of obtaining this type of response is as follows: a number of stages with double-tuned circuits of appropriate Q values and coupling coefficients k are cascaded. This arrangement is sufficient, if m is even; when m is odd, one single-tuned stage of appropriate bandwidth should also be included. This type of amplifier will now be analysed. It will be assumed that the inductances and the capacitances are equal for all circuits (including the single-tuned circuit).

The transfer impedance of a double-tuned inductively coupled circuit is

$$Z_T = \frac{-j\,r_d\,Qk}{(Qk)^2 + 1 + 2jx_1 - x^2_1} = \frac{-j\,r_d\,p}{p^2 + 1 + 2jx_1 - x^2_1} \quad \ldots \quad \ldots \quad \ldots \quad (A1)$$

where

$$x_1 = Q_0\,(f/f_0 - f_0/f) \approx \frac{Q_0}{f_0}\,2\Delta f$$

and

$$Qk \approx Q_0 k = p$$

On the other hand it is known that the function

$$(1 + x^{2m})^{\frac{1}{2}} = [1 + (2\Delta f/B_m)^{2m}]^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (A2)$$

is the absolute value of

$$\prod_{h=1}^{h=\frac{m}{2}} \sin^2\left(\frac{2h-1}{2m}\right)\pi \left[1 + j\,\frac{2}{B_m \sin\left(\frac{2h-1}{2m}\right)\pi}\left\{\Delta f \pm \frac{B_m}{2}\cos\left(\frac{2h-1}{2m}\right)\pi\right\}\right] \quad \ldots \quad \ldots \quad \ldots \quad (A3)$$

if m is even; and it is the absolute value of

$$\left(1 + j\,\frac{2\Delta f}{B_m}\right) \times \prod_{h=1}^{h=\frac{m-1}{2}} \sin^2\left(\frac{2h-1}{2m}\right)\pi \times \left[1 + j\,\frac{2}{B_m \sin\left(\frac{2h-1}{2m}\right)\pi}\left\{\Delta f \pm \frac{B_m}{2}\cos\left(\frac{2h-1}{2m}\right)\pi\right\}\right] \ldots \quad (A4)$$

if m is odd.

Consider the general product:

$$\left[1 + j\,\frac{2}{B_m \sin\left(\frac{2h-1}{2m}\right)\pi}\left\{\Delta f + \frac{B_m}{2}\cos\left(\frac{2h-1}{2m}\right)\pi\right\}\right] \times \left[1 + j\,\frac{2}{B_m \sin\left(\frac{2h-1}{2m}\right)}\left\{\Delta f - \frac{B_m}{2}\cos\left(\frac{2h-1}{2m}\right)\pi\right\}\right]$$

$$= 1 + \cot^2\left(\frac{2h-1}{2m}\right)\pi + j\,\frac{2 \times 2\Delta f}{B_m \sin\left(\frac{2h-1}{2m}\right)\pi} - \frac{4(\Delta f)^2}{B^2_m \sin^2\left(\frac{2h-1}{2m}\right)}\pi \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A5)$$

By comparison of this product with the denominator of the transfer impedance (A1), it can be seen that in an amplifier with maximum-flatness response curve, every such product can be realized by employing one double-tuned stage, provided that the following conditions are fulfilled:

$$Q_h k_h = \cot\left(\frac{2h-1}{2m}\right)\pi$$

$$\text{and} \quad Q_h/f_0 = \frac{1}{B_m \sin\left(\frac{2h-1}{2m}\right)\pi} \quad \ldots \quad \ldots \quad (A6)$$

There are two cases:

(a) m—even

The response function (2) can be realized by using $\frac{1}{2}m$ double-tuned stages.

In order that the function (A2) in the denominator of the amplitude response may be obtained, the denominators of the constituent transfer impedances should be multiplied by the factors $\sin^2(\pi/2m)$, $\sin^2(3\pi/2m)$ . . . etc. Thus, the maximum gain of a group becomes

$$K_{0m} = g_m^{m/2} \times r_{d1} \times \cot\frac{\pi}{2m} \times \sin^2\frac{\pi}{2m} \times r_{d2} \times \cot\frac{3\pi}{2m}$$

$$\times \sin^2\frac{3\pi}{2m} \times \ldots$$

where

$$r_{dh} = \frac{L}{R_h C} = \frac{Q_h}{2\pi f_0 C} = \frac{1}{2\pi C B_m \sin\left(\frac{2h-1}{2m}\right) \times \pi}$$

Therefore

$$K_{0m} = \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m}{2}} \times \prod_{h=1}^{\frac{m}{2}} \cos\left(\frac{2h-1}{2m}\right)\pi \quad \ldots \quad (A7)$$

But the product of cosines may be expressed as

$$s = \prod_{h=1}^{\frac{m}{2}} \cos\left(\frac{2h-1}{2m}\right)\pi = \frac{1}{2^{(m-1)/2}} \quad \ldots \quad \ldots \quad (A8)$$

Thus, finally

$$K_{0m} = \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m}{2}} \times 2^{-(m-1)/2} = \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m}{2}} \times s \quad \ldots \quad \ldots \quad \ldots \quad (A9)$$

The number of valves entering into a group is $t = \frac{1}{2}m$.

(b) m—odd

In this case the response function (1) may be realized by the use, in addition, of one single-tuned stage of bandwidth $B = B_m$. The total number of valves in the groups is $t = \frac{1}{2}(m+1)$ and the number of double-tuned coupled circuits is $\frac{1}{2}(m-1)$.

Maximum gain of a group is

$$K_{0m} = (g_m)^{(m+1)/2} \times r_{d1} \times r_{d2} \times \cot\frac{\pi}{2m} \times \sin^2\frac{\pi}{2m}$$

$$\times r_{d3} \times \cot\frac{3\pi}{2m} \times \sin^2\frac{3\pi}{2m} \ldots .$$

$$= \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m+1}{2}} \times \prod_{h=1}^{\frac{m-1}{2}} \cos\left(\frac{2h-1}{2m}\right)\pi$$

The product of cosines may be expressed as

$$s = \prod_{h=1}^{\frac{m-1}{2}} \cos\left(\frac{2h-1}{2m}\right)\pi = \frac{\sqrt{m}}{2^{(m-1)/2}} \quad \ldots \quad (A11)$$

$$\text{And, finally} \quad K_{0m} = \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m+1}{2}} \times \frac{\sqrt{m}}{2^{(m-1)/2}}$$

$$= \left(\frac{g_m}{2\pi C B_m}\right)^{\frac{m+1}{2}} \times s \quad \ldots \quad (A12)$$

APPENDIX 2

Analysis of Stability of Bandpass Amplifiers

(a) *Single-Tuned Amplifier*

After the substitution of anode admittances (33) into the determinant of the network matrix (31), one obtains

$$\mathbf{D}_n = \frac{\mathbf{D}_{an}}{r_d^{\,n}} =$$

$$\frac{1}{r_d^{\,n}} \times \begin{vmatrix} 1+jx & -jb & 0 & 0 & . & 0 & 0 \\ A & 1+jx & -jb & 0 & . & 0 & 0 \\ 0 & A & 1+jx & -jb & . & 0 & 0 \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & A & 1+jx & -jb \\ 0 & 0 & 0 & . & 0 & A & 1+jx \end{vmatrix}$$

(A13)

where $A = g_m r_d$; $b = \omega C_{ga} r_d \approx \omega_0 C_{ga} r_d$

The determinant $\mathbf{D}_{an}$ can also be written in the form:—

$$\mathbf{D}_{an} = \begin{vmatrix} 1+jx & -j\alpha & 0 & 0 & . & 0 & 0 \\ 1 & 1+jx & -j\alpha & 0 & . & 0 & 0 \\ 0 & 1 & 1+jx & -j\alpha & . & 0 & 0 \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & 1 & 1+jx & -j\alpha \\ 0 & 0 & 0 & . & 0 & 1 & 1+jx \end{vmatrix} \quad \ldots \quad (A14)$$

where $\alpha = Ab = \omega_0 C_{ga} g_m r_d^2$

The determinant $\mathbf{D}_{an}$ is effectively a complex number and may be written as

$$\mathbf{D}_{an}(\alpha, x) = a_n[C_1(\alpha, x) + jC_2(\alpha, x)]$$

where a_n is some factor which cannot be equal to zero.

The amplifier will become unstable when

$$\mathbf{D}_{an}(\alpha, x) = 0$$

or

$$C_1(\alpha, x) + j\,C_2(\alpha, x) = 0 \quad \ldots \quad (A15)$$

Thus there are two simultaneous equations (A15). whose solutions will give the frequency of oscillations (or x_n) and α_n.

If $x_n = x_n(\alpha)$ is a root of one of the equations (A15), then its substitution into $\mathbf{D}_{an}(\alpha, x)$ will result in a single equation in α; i.e.,

$$\mathbf{D}_{an}(\alpha, x_n) = a_n \begin{Bmatrix} C_1(\alpha, x_n) \\ +j\,C_2(\alpha, x_n) \end{Bmatrix} = 0 \quad \ldots \quad (A16)$$

Thus any x_n which reduces $\mathbf{D}_{an}$ to a single equation can be considered as a solution of one of the equations (A15). It turns out that, for any $n \geqslant 2$, $x_n = -1$ possesses this property and hence may be regarded as a solution. This may be shown as follows:—

Let

$$1 - j = \sqrt{2}\, e^{-j\pi/4}$$

$$-j\alpha = \alpha e^{-j\pi/2}$$

The determinant $\mathbf{D}_{an}(x = -1)$ may then be expressed as

$$\mathbf{D}_{an}(x = -1) = \begin{vmatrix} \sqrt{2}\,e^{-j\pi/4} & \alpha e^{-j\pi/2} & 0 & 0 & . & 0 & 0 \\ 1 & \sqrt{2}\,e^{-j\pi/4} & \alpha e^{-j\pi/2} & 0 & . & 0 & 0 \\ 0 & 1 & \sqrt{2}\,e^{-j\pi/4} & \alpha e^{-j\pi/2} & . & 0 & 0 \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & 1 & \sqrt{2}\,e^{-j\pi/4} & \alpha e^{-j\pi/2} \\ 0 & 0 & 0 & . & 0 & 1 & \sqrt{2}\,e^{-j\pi/4} \end{vmatrix} \quad (A17)$$

Now the procedure is as follows:—

(1) multiply the 1st column by $e^{+j\pi/4}$

(2) multiply the 2nd row by $e^{-j\pi/4}$

(3) multiply the 2nd column by $e^{+j\pi/2}$

(4) multiply the 3rd row by $e^{-j\pi/2}$

(5) multiply the 3rd column by $e^{+j3\pi}$

(6) multiply the 4th row by $e^{-j3\pi}$

The process is continued until, finally, one obtains

$$\mathbf{D}_{an}(x = -1) = e^{-j\frac{\pi}{4}n} \times \begin{vmatrix} \sqrt{2} & \alpha & 0 & 0 & . & 0 & 0 \\ 1 & \sqrt{2} & \alpha & 0 & . & 0 & 0 \\ 0 & 1 & \sqrt{2} & \alpha & . & 0 & 0 \\ . & . & . & . & . & . & . \\ 0 & 0 & 0 & . & 1 & \sqrt{2} & \alpha \\ 0 & 0 & 0 & . & 0 & 0 & \sqrt{2} \end{vmatrix}$$

$$= D_{bn} e^{-j\frac{\pi}{4}n} \quad \ldots \quad (A18)$$

D_{bn} is a real quantity and a function of α only; when equated to zero it will yield the value of α necessary to cause oscillations. Thus it can be assumed that $x_n = -1$ is, indeed, one of the roots of $\mathbf{D}_{an} = 0$; furthermore (as previously explained) this is a physically acceptable solution.

D_{bn} may be regarded as a difference equation, since

$$D_{bn} = \sqrt{2}\, D_{b(n-1)} - \alpha D_{b(n-2)}$$

or

$$D_{bn} - \sqrt{2}\, D_{b(n-1)} + \alpha D_{b(n-2)} = 0 \quad \ldots \quad (A19)$$

This, when solved by standard methods, yields

$$D_{bn} = \frac{1}{2\sqrt{\frac{1}{2} - \alpha}} \left\{ \left[\frac{1}{\sqrt{2}} + \sqrt{\tfrac{1}{2} - \alpha} \right]^{n+1} - \left[\frac{1}{\sqrt{2}} - \sqrt{\tfrac{1}{2} - \alpha} \right]^{n+1} \right\} \quad \ldots \quad (A20)$$

which, when expanded by the binomial theorem, gives the polynomial

$$D_{bn} = \left\{ \binom{n+1}{1} \left(\frac{1}{2}\right)^{\frac{n}{2}} + \binom{n+1}{3} \times \left(\frac{1}{2} - \alpha\right) \left(\frac{1}{2}\right)^{\frac{n-2}{2}} + \binom{n+1}{5} \left(\frac{1}{2} - \alpha\right)^2 \times \left(\frac{1}{2}\right)^{\frac{n-4}{2}} + \ldots \right\} \quad \ldots \quad (A21)$$

The polynomial is ended with the term

$$\binom{n+1}{n+1} \times \left(\frac{1}{2} - \alpha\right)^{\frac{n}{2}} \times \left(\frac{1}{2}\right)^{\frac{n-n}{2}}$$

if n is even, and

$$\binom{n+1}{n} \times \left(\frac{1}{2} - \alpha\right)^{\frac{n-1}{2}} \times \left(\frac{1}{2}\right)^{\frac{n-(n-1)}{2}}$$

if n is odd.

The values of critical regeneration coefficients α_n can be found by solving the equation $D_{bn} = 0$. Only the lowest positive root of this equation should be considered.

It can be verified (from A21) that, when $n \rightarrow \infty$, $\alpha_n \rightarrow \frac{1}{2}$.

The gain of the amplifier is given by

$$\mathbf{K}_n = \frac{(-1)^n \prod^{n} \mathbf{g}_{mk}}{\mathbf{D}_n}$$

If it is assumed that all $\mathbf{g}_{mk} = g_m$, and $\mathbf{D}_n$ is expressed in terms of x and α, then the amplitude response function is given by

$$K_n(x) = \frac{g_m^{\,n}}{D_n(\alpha, x)} \quad \ldots \quad (A22)$$

where $D_n(\alpha, x)$ is the modulus of $\mathbf{D}_n(\alpha, x)$. The successive five response functions are given in Table 1A.

(b) *Staggered Pair*

The two anode admittances may be expressed by

$$\frac{1}{\mathbf{Z}_{11}} = \frac{1 + j(\sqrt{2}x + 1)}{r_d}$$
$$\frac{1}{\mathbf{Z}_{22}} = \frac{1 + j(\sqrt{2}x - 1)}{r_d} \qquad \ldots \quad \ldots \quad \ldots \text{(A23)}$$

where $\qquad x = \sqrt{2}\,\Delta f / B'$

B' being the bandwidth of a single circuit.

The determinant of the network is

$$\mathbf{D}_2 = \frac{1}{r_d^{\,2}}[(2 - 2x^2 + j(2\sqrt{2}x + \alpha)] \qquad \ldots \quad \ldots \text{(A24)}$$

and it is independent of the order of staggering.

The conditions of oscillation are

$$2 - 2x^2 = 0$$
$$2\sqrt{2}x + \alpha = 0 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \text{(A25)}$$

which yield $\quad x_2 = -1 \quad ; \quad \alpha_2 = 2\sqrt{2}$

The amplitude response curve is

$$K_2(\alpha, x) = \frac{\tfrac{1}{2}(g_m r_d)^2}{\sqrt{1 + x^4 + \sqrt{2}\,\alpha x + \alpha^2/4}} \qquad \ldots \text{(A26)}$$

(c) *m Staggered Pairs*

The admittances of the anode circuits are

$$\frac{1}{\mathbf{Z}_{kk}} = \frac{1 + j(\sqrt{2}\,x + 1)}{r_d}$$
$$\frac{1}{\mathbf{Z}_{jj}} = \frac{1 + j(\sqrt{2}\,x - 1)}{r_d} \qquad \ldots \quad \ldots \text{(A27)}$$

where $\qquad x = \sqrt{2}\,\Delta f / B'$

Consider, first, two cascaded staggered pairs. For this case the determinant of the network is

$$\mathbf{D}_4 = \frac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}\mathbf{Z}_{33}\mathbf{Z}_{44}} + jg_m\omega C_{ga}\left(\frac{1}{\mathbf{Z}_{11}\mathbf{Z}_{22}} + \frac{1}{\mathbf{Z}_{11}\mathbf{Z}_{44}} + \frac{1}{\mathbf{Z}_{33}\mathbf{Z}_{44}}\right) - (g_m\omega C_{ga})^2 \qquad \ldots \quad \ldots \quad \ldots \text{(A28)}$$

Again, the conditions of oscillation of two staggered pairs may be found by solving the equation $\mathbf{D}_4 = 0$.

For the case $S_1(1^-, 1+, 1^-, 1+) \equiv S_2(1+, 1^-, 1+, 1^-)$ the amplitude response function is found to be

$$K_{14}(\alpha, x) = \frac{\tfrac{1}{4}(g_m r_d)^4}{\sqrt{\left(1 + x^4 - 4x^2 - \tfrac{3}{2}\sqrt{2}\alpha x - \tfrac{\alpha^2}{4}\right)^2 + \left[(1 - x^2)\left(2\sqrt{2}x + \tfrac{3}{2}\alpha\right)\right]^2}} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \text{(A29)}$$

while for $S_3(1^-, 1+, 1+, 1^-)$ it is

$$K_{34}(\alpha, x) = \frac{\tfrac{1}{4}(g_m r_d)^4}{\sqrt{\left[1 + x^4 - 4x^2 - \tfrac{\alpha}{4}(6\sqrt{2}x + \alpha + 2)\right]^2 + \left[2\sqrt{2}x(1 - x^2) + \tfrac{\alpha}{4}(4 - 6x^2 - 2\sqrt{2}x)\right]^2}} \qquad \ldots \text{(A30)}$$

Now m 'interlaced' staggered pairs will be considered and the conditions of oscillation will be found. The 'interlaced' staggering order is represented by

$S_a(1+, 1^-, 1+, 1^- \ldots) = S_b(1^-, 1+, 1^-, 1+ \ldots)$

If the anode admittances are expressed in the form shown in (A27), then the determinant of the network may be written

$$D_{2m} = \frac{1}{r_d^{\,2m}} \begin{vmatrix} 1 + j(\sqrt{2}x - 1) & -j\alpha & 0 & 0 & . & 0 & 0 \\ 1 & 1 + j(\sqrt{2}x + 1) & -j\alpha & 0 & . & 0 & 0 \\ 0 & 1 & 1 + j(\sqrt{2}x - 1) & -j\alpha & . & 0 & 0 \\ . & . & . & . & . & . & . \\ . & . & . & . & . & . & . \\ 0 & 0 & . & . & 1 & 1 + j(\sqrt{2}x - 1) & -j \\ 0 & 0 & . & . & 0 & 1 & 1 + j(\sqrt{2}x + 1) \end{vmatrix} \qquad \text{(A31)}$$

TABLE 1A

n	Amplitude Response $\quad K_n(\alpha, x)$
1	$\dfrac{g_m r_d}{\sqrt{1 + x^2}}$
2	$\dfrac{(g_m r_d)^2}{\sqrt{(1 - x^2)^2 + (2x + \alpha)^2}}$
3	$\dfrac{(g_m r_d)^3}{\sqrt{(1 + x^2)\,[(1 - x^2)^2 + 4(x + \alpha)^2]}}$
4	$\dfrac{(g_m r_d)^4}{\sqrt{[x^4 - 6x^4 - \alpha(\alpha + 6x) + 1]^2 + [4x - 4x^3 - 3\alpha(x^2 - 1)]^2}}$
5	$\dfrac{(g_m r_d)^5}{\sqrt{(1 + x^2)\,\{[x^4 - 6x^2 - \alpha(8x + 3\alpha) + 1]^2 + [x - x^3 + \alpha(1 - x^2)]^2 \times 16\}}}$

As in Appendix 2(a), the substitution of $x_{2m} = -1$ into the determinant (A31), results in a single equation, which, when solved, gives the second condition of oscillation $\alpha = \alpha_{2m}$. This is proved as follows:

Let

$$1 - j(\sqrt{2} + 1) = a_1 e^{-j\theta_1},$$
$$1 + j(-\sqrt{2} + 1) = a_2 e^{-j\theta_2} \quad \ldots \quad \ldots \quad (A32)$$

and $\quad -j\alpha = \alpha e^{-j\pi/2}$

It follows from Equ. (A32) that

$$a_1 a_2 = 2\sqrt{2}$$
$$\theta_1 + \theta_2 = \pi/2$$

Now $x = -1$ is substituted into the determinant (A31) and a number of algebraic operations are performed, during which the properties $\theta_1 + \theta_2 = \pi/2$ and $a_1 a_2 = 2\sqrt{2}$ are made use of. This leads to an equation in $\alpha/\sqrt{2}$, similar to Equ. (37) and thus, the critical regeneration coefficients for this case are given by

$$\alpha_{2m} = \sqrt{2}\alpha_n \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A33)$$

where only even n should be considered.

(d) *Staggered Triple*

The three anode admittances which enter into a staggered triple may be represented as

$$\frac{1}{\mathbf{Z}_a} = \frac{1 + j(2x + \sqrt{3})}{2r_d} \quad \text{high-}Q\text{ circuit}$$
$$\frac{1}{\mathbf{Z}_b} = \frac{1 + j(2x - \sqrt{3})}{2r_d} \quad \text{high-}Q\text{ circuit} \quad \ldots \quad (A34)$$
$$\frac{1}{\mathbf{Z}_c} = \frac{1 + jx}{r_d} \quad \text{low-}Q\text{ circuit}$$

where $\quad x = 2\Delta f / B_3$

B_3 is the bandwidth of the low-Q circuit, which is also the overall bandwidth of the staggered triple under the condition of negligible regeneration.

r_d is the dynamic impedance of the low-Q circuit.

For the case $S_1(1^-, 0, 1^+) \equiv S_2(1^+, 0, 1^-)$ the determinant of the network becomes

$$\mathbf{D}_3 = \frac{1}{4r_d^3}[4 - 8x^2 - 8\alpha x + j(4\alpha - 8x - 4x^3)] \quad (A35)$$

Thus the conditions for oscillation are

$$4 - 8x^2 - 8\alpha x = 0$$
$$4\alpha - 8x - 4x^3 = 0 \quad \ldots \quad \ldots \quad \ldots \quad (A36)$$

which yield

$$x_1 = -\sqrt{\tfrac{1}{2}(1 + \sqrt{3})} = -1{\cdot}17$$
$$\alpha_3 = \frac{1}{2}\frac{\sqrt{6}}{\sqrt{1 + \sqrt{3}}} = 0{\cdot}743$$

The amplitude response function is given by

$$K_3(x, \alpha) = \frac{(g_m r_d)^3}{\sqrt{1 + x^6 + 6\alpha x^3 + 4\alpha^2 x^2 + \alpha^2}} \quad \ldots \quad (A37)$$

The second case is $S_3(0, 1^-, 1^+) \equiv S_4(1^+, 1^-, 0)$, for which the determinant of the network is in the form

$$\mathbf{D}_3 = \frac{1}{4r_d^3}[4 - 8x^2 - 8\alpha x + 2\sqrt{3}\alpha + j(8x - 4x^3 + 6\alpha)] \quad \ldots \quad \ldots \quad \ldots \quad (A38)$$

Here the oscillation conditions are given by

$$4 - 8x^2 - 8\alpha x + 2\sqrt{3}\alpha = 0 \quad \ldots \quad \ldots \quad (A39)$$
$$8x - 4x^3 + 6\alpha = 0$$

which yield

$$x_1 = -1{\cdot}15$$
$$\alpha_3 = 0{\cdot}518$$

The amplitude response function is

$$K_3(x, \alpha) = (g_m r_d)^3 \div$$
$$\sqrt{\left[(1 + \sqrt{3}\alpha + 3\alpha^2) + 2\alpha(1 - \sqrt{3}\alpha)x + 2\alpha(2\alpha - \sqrt{3})\,x^2 + 5\alpha x^3 + x^6\right]} \quad \ldots \quad \ldots \quad (A40)$$

Finally, the last case, $S_5(1^-, 1^+, 0) \equiv S_6(0, 1^+, 1^-)$ has the determinant

$$\mathbf{D}_3 = \frac{1}{4r_d^3}[4 - 2\alpha\sqrt{3} - 8\alpha x - 8x^2 + j(8x - 4x^3 + 6\alpha)] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A41)$$

which is equal to zero, when

$$x_1 = -0{\cdot}916$$
$$\alpha_3 = 0{\cdot}702$$

The response function becomes

$$K_3(x, \alpha) = (g_m r_d)^3 \div$$
$$\sqrt{\left[(1 - \sqrt{3}\alpha + 3\alpha^2) + 2\alpha(1 + \sqrt{3}\alpha)x + 2\alpha(2\alpha + \sqrt{3})\,x^2 + 5\alpha x^3 + x^6\right]} \quad \ldots \quad \ldots \quad (A42)$$

SINGLE-STAGE PHASE-SHIFT OSCILLATOR

Method of Design

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(Department of Electrical Engineering, Municipal College, Portsmouth)

SUMMARY.—It is pointed out that there is no special advantage in making half the components of the phase-shift network of the same value, as is frequently done. A different choice of relative values leads to a network requiring less gain from the valve and enables formulae to be obtained which apply to a network having any number of sections. Some general conclusions as to the suitability of various networks for different applications are drawn from these formulae, and values of frequency and network input impedance are tabulated.

Introduction

SINCE the original description in 1923,[1] a number of papers dealing with the behaviour of the phase-shift oscillator have appeared.[2] The majority of these describe circuits in which feedback takes place through a network of the form shown in Fig. 1 (a) and (b). At one particular frequency such a network will produce a phase shift of 180° and it is approximately at this frequency that oscillation takes place. At (a) and (b) of Fig. 1 are shown oscillators made up of three basic sections of the type of (c) and (d). There does not appear to be any fundamental reason why an oscillator should not function with any number of cells greater than three, but it is common practice to use not more than four. Formulae have been given for these cases;[3,4] the work involved in obtaining these is, however, somewhat laborious and increases rapidly as the number of sections increases. The usual design procedure is to make all the resistors of the same value and the capacitors similarly all of the same reactance, when simpler expressions for the frequency of oscillation and gain may be obtained.

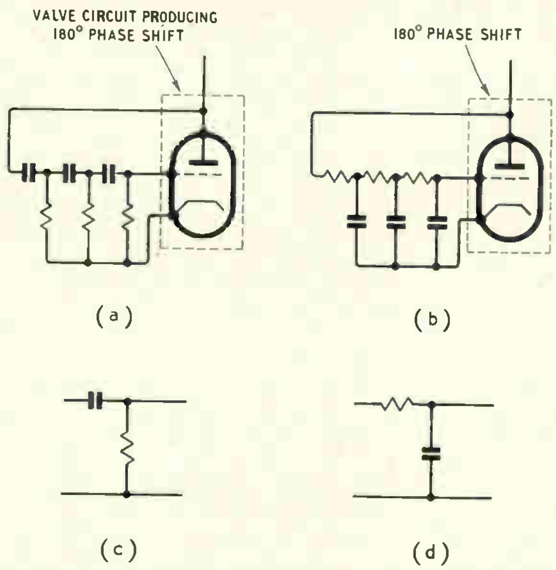

Fig. 1. *Basic circuits of typical phase-shift oscillators (a) and (b), with the basic phase-shift sections (c) and (d).*

MS accepted by the Editor, June 1953

If ganged components are being used for frequency variation it is obviously desirable to have either all the reactances or all the resistances identical, but it is not essential to have both. Fig. 2 shows a three-cell network in which one of the components is made N times the value of the others. A paper by Vaughan[5] considers the effect on the gain required for oscillation of varying the value of N; curves given indicate that the minimum value is not obtained when the components are equal. It is therefore interesting to find the value of N which does require least gain. The expression given by Vaughan for the ratio of input voltage to output voltage for the network of Fig. 2 (a) is

$$V_L/V_G = -[14 + 12N + 3/N]$$

and for Fig. 2 (b)

$$V_L/V_G = -[14 + 3N + 12/N]$$

Differentiating the first equation with respect to N and equating to zero yields the value $N = \frac{1}{2}$, while the second equation yields the value $N = 2$. Thus, in either case the best result is obtained if the first series impedance is of half the value of the succceeding ones. A consideration of the 4-cell circuit shows that an improvement is obtained by halving the first series impedance in this case also.

It therefore seems reasonable to develop a method of design in which the first series impedance has half the value of the others. By so doing hyperbolic formulae can be obtained which are readily applicable to networks containing any number of cells.

Development of Formulae

Consider a three-section RC network with the first series resistance of value $R/2$. Since the network is assumed working into an open circuit, the introduction of a further series resistance $R/2$ at the end of the network as shown in Fig. 3(a) will not in any way affect the properties of the circuit. We may now, however, split up the ladder into a chain of three T-links, as shown in Fig. 3(b). The same procedure could be used for a network containing any number of sections n, in which case n T-links would have been obtained.

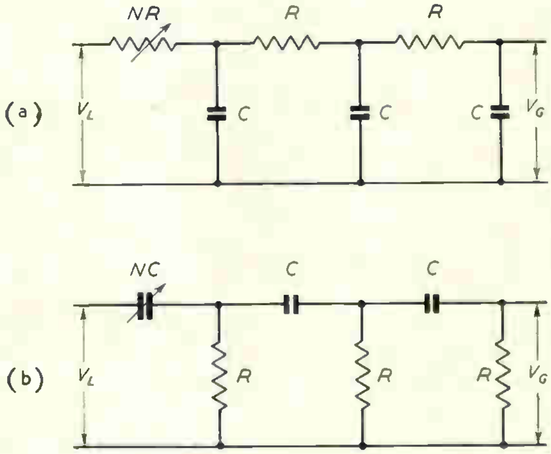

Fig. 2. *Three-cell phase-shift networks having one component N times the value of the others.*

Now it is well known[6] that for such a chain of T-links output voltage on open circuit is related to input voltage by the expression

$$V_G = V_L/\cosh n\theta$$

In this case $\cosh \theta = 1 + \frac{1}{2}R.j\omega C = 1 + j\omega CR/2$. θ will, in general, be complex and so we may write $\theta = \alpha + j\beta$. The condition of interest is the one in which V_L and V_G are in antiphase; i.e., $\cosh n\theta$ has no imaginary component. This leads (see Appendix 1) to the relationship $\beta = \pi/n$. Expanding $\cosh \theta$ we obtain

$$\cosh \theta = \cosh (\alpha + j\beta) = \cosh \alpha \cos \beta + j \sinh \alpha \sin \beta = 1 + j\omega CR/2$$

and equating real and imaginary parts yields the result

$$\omega CR/2 = \sinh \alpha \sin \beta = \tan \beta \sin \beta = \tan (\pi/n) \sin (\pi/n)$$

Whence

$$\omega = [2 \sin (\pi/n) \tan (\pi/n)]/CR$$

or $f = \sin (\pi/n) \tan (\pi/n)/\pi CR$

The input/output voltage ratio is also obtained as

$$V_L/V_G = \cosh n\theta = \cosh \{n \cosh^{-1} [1/\cos (\pi/n)]\}$$

On applying the same reasoning to a ladder with series capacitors and shunt resistors, with the first capacitor of value $2C$ [Fig. 3(c) and 3(d)] it is found that the input/output voltage ratio is unchanged but the frequency is now given by

$$f = 1/[4\pi CR \sin (\pi/n) \tan (\pi/n)] \text{ or}$$

$$\omega = 1/[2 \sin (\pi/n) \tan (\pi/n) CR]$$

The expressions for ω in these two cases may alternatively be written

$$\omega = K/CR \text{ and}$$

$$\omega = 1/KCR \text{ where } K = 2 \sin (\pi/n) \tan (\pi/n)$$

Input Impedance

The above method also enables formulae to be obtained for the input impedance of the network. For an open-circuited chain of T-links, $Z_{IN} = Z_0/\tanh n\theta$ and at the frequency of oscillation this becomes $Z_{IN} = Z_0/\tanh n\alpha$. For the values of α which are obtained, $\tanh n\alpha$ is so close to unity that it may be removed from the equation. Then for the RC network

$$Z_{IN} = Z_0/\tanh \alpha n = Z_0 = \frac{R}{2}\sqrt{1 - 4j/K}$$

and for the CR network

$$Z_{IN} = Z_0/\tanh \alpha n = Z_0 = [RK/2j]\sqrt{1 + 4j/K}$$

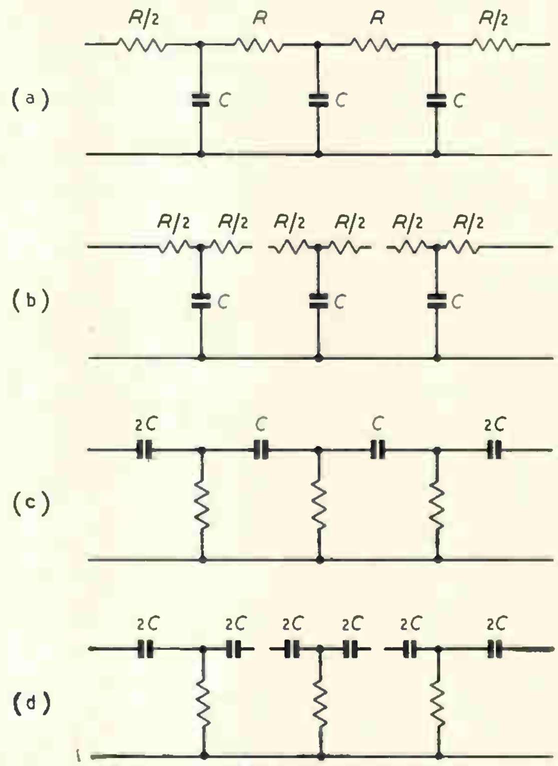

Fig. 3. *This diagram shows how three-stage T-section networks can be broken up into identical sections.*

Alternative Ladder Forms

Instead of halving the first series impedance, the last shunt impedance may be doubled, and an additional shunt impedance of value equal to the last one added on at the beginning of the network. Omission of this first impedance would not affect the formulae for frequency but would alter the input impedance. An RC network, as shown in Fig.4(a), now results and a CR network, as shown in Fig. 4(c). These may be split up in the way shown in (b) and (d), but this time a chain of π-links is obtained. The frequency and voltage ratio formulae are unchanged, but the impedance formulae now become

$$Z_{IN} = 2R/[jK\sqrt{1-4j/K}]$$

and $$Z_{IN} = 2R/\sqrt{1+4j/K}$$

All these results are summarized in Tables 1 and 2, where values are given for oscillators using up to 6 sections.

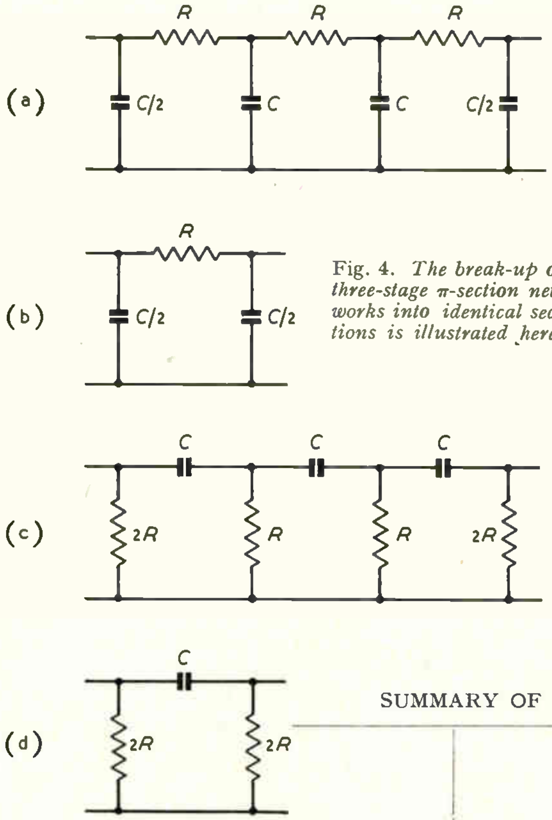

Fig. 4. *The break-up of three-stage π-section networks into identical sections is illustrated here.*

Practical Verification

To obtain a practical verification of these results, the circuit shown in Fig. 5 was set up. Figures obtained were as follows:

Number of sections	3	4	5	6
Frequency (measured)	108	227	373	545 c/s
Frequency (calculated)	106	225	374	550 c/s

It was found that the variation of input/output voltage ratio for the different networks caused a change in output voltage and variation of frequency. The grid lead was accordingly taken to a tapping on the last shunt resistor, the position of which was adjusted as the number of sections was varied so as to maintain output constant at a low value. Variation in h.t. voltage of 30% was found to alter the frequency by less than 1% in the 6-section case, though rather more with 3 sections.

To obtain an idea of the effects of stray capacitance and interelectrode capacitance, an extra 120 pF was connected from grid to earth; the change of frequency was very small, of the order of 1 c/s at 550 c/s. The addition of 1 kΩ in series with the first series impedance caused the frequency to fall from 545 to 541 c/s. The impedance of the cathode follower was assessed at 500 ohms and would, therefore, have only a very small effect on the frequency of oscillation.

These measurements indicated the extent of the most probable errors, and a satisfactory degree of agreement was obtained between theoretical and practical results, as shown by the figures above.

TABLE 1

SUMMARY OF FREQUENCY AND IMPEDANCE FORMULAE

		ω	Input impedance: First series impedance $= R/2$ or $2C$	Input impedance: Last shunt impedance $= 2R$ or $C/2$
Exact Formulae	RC oscillator	K/CR	$[R/2]\sqrt{1-4j/K}$	$2R/jK\sqrt{1-4j/K}$
	CR oscillator	$1/KCR$	$R/2.K/j.\sqrt{1+4j/K}$	$2R/\sqrt{1+4j/K}$
Approximate Formulae	RC oscillator	K_1^2/CR	R/K_1	R/K_1
	CR oscillator	$1/K_1^2CR$	K_1R	K_1R

$K = 2\sin[\pi/n]\tan[\pi/n]$; $K_1 = \pi\sqrt{2}/n$

Approximate Formulae for Large Values of n

If n is large, approximate formulae may be obtained by writing $\sin[\pi/n] = \tan[\pi/n] = \pi/n$. The formulae for frequency then become

$$f = 1/[4\pi CR(\pi/n)(\pi/n)] = [n^2/4\pi^3]/CR$$
$$\text{or} \quad \omega = [n^2/2\pi^2]/CR$$

for the CR oscillator, and

$f = [\pi/n^2]/CR$ or $\omega = [2\pi^2/n^2]/CR$

for the *RC* oscillator. Approximate formulae for the impedance may similarly be obtained (see appendix 2) and are listed in Table 2. It will be seen that, provided n is greater than 4, the approximate formulae give reasonable results, the error when n is equal to 4 being about 13%.

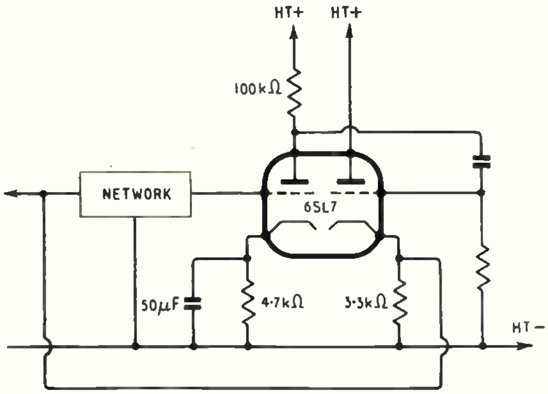

Fig. 5. *Experimental phase-shift oscillator circuit.*

Thus, in the first case, ω decreases with the number of sections and, in the second case, increases with the number of sections. If the design of an oscillator were being considered in which it was desired to obtain the highest possible frequency with a fixed minimum value of capacitance, the *CR* network with a large value of n would have advantages. If, on the other hand, n is restricted to the value 3 or 4, the *RC* network will give the greater frequency.

In the case of a very low-frequency oscillator it is usually desired to obtain the lowest possible frequency for a given total capacitance employed. In the *RC* network frequency is independent of the total capacitance (nC) employed for a given Z_{IN}, but this is not so for the *CR* network in which ω decreases with n. Taking the lowest possible value, n equals 3, shows that the *CR* network yields a lower frequency than the *RC* network, and a three-section *CR* network is therefore the best choice.

Acknowledgment is made to the Governors of the Municipal College, Portsmouth, who enabled this investigation to be carried out.

TABLE 2

VALUES OF IMPEDANCE AND FREQUENCY COEFFICIENTS FOR n from 1 to 6

n	k	k_1^2	Magnitude of Z/R					
			RC oscillator			*CR* oscillator		
			½ series input	½ shunt input	approx.	½ series input	½ shunt input	approx.
3	3	2·19	0·646	0·516	0·675	1·938	1·55	1·48
4	1·414	1·233	0·866	0·817	0·9	1·22	1·15	1·11
5	0·853	0·79	1·095	1·07	1·125	0·935	0·913	0·89
6	0·577	0·55	1·325	1·31	1·35	0·764	0·756	0·74

Conclusion

The foregoing work results in simple formulae for the impedance of the networks concerned and the frequency of oscillation. The relative simplicity of these formulae, whatever the value of n, enables an assessment to be made as to the suitability of different networks for different purposes.

Usually the oscillator must be designed with regard to various limiting factors. One of these will nearly always be the input impedance of the network, which must not fall below a specified value in order to prevent undue loading of the valve. Using the approximate formulae we may express the frequency of oscillation in terms of the impedance, namely: $\omega = \sqrt{2}\pi/(nCZ_{IN})$ for the *RC* section and $\omega = n/(\sqrt{2}\pi CZ_{IN})$ for the *CR*.

LIST OF SYMBOLS

V_L = input voltage to network
V_G = output voltage from network
n = number of sections in network
θ = transfer constant per section = $\alpha + j\beta$
$\cosh\theta = 1 + Z_1/2Z_2$
Z_1 = total series impedance per cell
Z_2 = total shunt impedance per cell
Z_0 = iterative impedance of network
Z_{IN} = input impedance of network
$K = 2\sin[\pi/n]\tan[\pi/n]$; $K_1 = \pi\sqrt{2}/n$
R = resistance/cell of network
C = capacitance/cell of network

APPENDIX 1

Derivation of Formulae for Oscillation Frequency and Gain Required

$V_G = V_L / \cosh n\theta$

$= V_L / [\cosh \alpha n \cos \beta n + j \sinh \alpha n \sin \beta n]$

If the two voltages are to be in antiphase, the imaginary term must disappear. Hence $\sinh \alpha n \sin \beta n = 0$ and since α cannot be zero, $\sin \beta n = 0$. Hence $\beta n = \pi$ (though other solutions are mathematically possible, this is the one which corresponds with the physical reality) and $\beta = \pi/n$. But $\cosh \theta = 1 + Z_1/2Z_2$. Hence for the RC oscillator network of Fig. 3(a): $\cosh \theta = 1 + j\omega CR/2$. Expanding $\cosh \theta$ and equating reals and imaginaries yields $\cosh \alpha \cos \beta = 1$ and $\sinh \alpha \sin \beta = \omega CR/2$. From the first equation $\cosh \alpha = 1/\cos \beta$ whence

$$\sinh \alpha = \sqrt{\cosh^2 \alpha - 1} = \sqrt{1/\cos^2 \beta - 1}$$

$$= \sqrt{\frac{1 - \cos^2 \beta}{\cos^2 \beta}} = \tan \beta$$

Thus $\tan \beta \sin \beta = \omega CR/2$ whence $\omega = 2 \tan \beta \sin \beta / CR$

$$\therefore \omega = 2 \tan [\pi/n] \sin [\pi/n] \,/\, CR$$

and if $K = 2 \tan [\pi/n] \sin [\pi/n]$ then $\omega = K/CR$

For the CR oscillator network of Fig. 3(c) the same reasoning applies with the exception that now $\cosh \theta = 1 + 1/(2j\omega CR)$.

Hence $\tan \beta \sin \beta = \frac{1}{2}\omega CR$ and

$$\omega = 1/[2 \tan (\pi/n) \sin (\pi/n)\, CR] = 1/(KCR)$$

The voltage ratio in either case is given by

$$V_L/V_G = \cosh n\theta = -\cosh n\,\alpha$$

$$= -\cosh [n \cosh^{-1} (1/\cos \pi/n)]$$

APPENDIX 2

Derivation of Impedance Formulae

It is well known that for the T-network of Fig. 6(a) iterative impedance is given by the formula

$$Z_0 = \sqrt{Z_1 Z_2 + Z_1{}^2/4} = \sqrt{Z_1 Z_2 (1 + Z_1/4Z_2)}$$

and for the π network of Fig. 6(b)

$$Z_0 = \sqrt{Z_1 Z_2 / (1 + Z_1/4Z_2)}$$

Thus the iterative impedance of the RC ladder arranged in T sections as in Fig. 3(b) is obtained by putting $Z_1 = R$ and $Z_2 = 1/j\omega C$ then $Z_0 = \sqrt{R/j\omega C + R^2/4}$ Taking R outside the square-root sine and substituting $\omega CR = K$ gives

$$Z_0 = R\sqrt{1/jK + 1/4} = [R/2]\sqrt{1 - 4j/K}$$

But for an open-circuited chain of networks, input impedance is given by $Z_{IN} = Z_0/\tanh m\theta$; now $\tanh m\theta = \tanh (n\alpha + jn\beta)$ and since at the oscillation frequency $n\beta = \pi$, this reduces to $\tanh n\alpha$. α is, however, so large that $\tanh n\alpha$ is equal to unity with better than $\frac{1}{2}\%$ approximation. For the network of Fig. 3(a) we thus obtain

$$Z_{IN} = Z_0 = [R/2]\sqrt{1 - 4j/K}$$

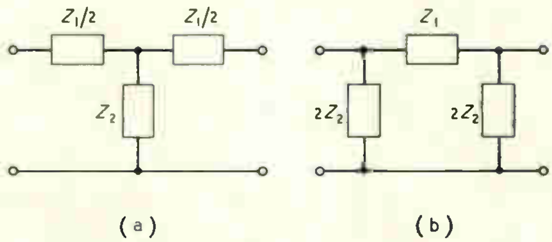

Fig. 6. *Networks employed in deriving the characteristics of the sections.*

Formulae for the other cases may be similarly obtained. When the number of sections is very large

$$K = 2 \tan [\pi/n] \sin [\pi/n] \longrightarrow 2\pi^2/n^2$$

Thus in the limit $Z_{IN} = [R/2]\sqrt{1 - 2jn^2/\pi^2}$ which in magnitude tends to $Z_{IN} = [R/2]n\sqrt{2}/\pi = K_1 R/2$ where $K_1 = n\sqrt{2}/\pi$

REFERENCES

[1] U.S. Patent.No. 1,442,871. H. W. Nicholls, 16th January, 1923.
[2] Most of these after 1941; see, for example, Ginzton and Hollingsworth, "Phase Shift Oscillators", *Proc. Inst. Radio Engrs*, February 1941.
[3] Parton and Roorda, correspondence, *Electronic Engineering*, January 1950
[4] Hinton, "Design of R-C Oscillator Phase-Shift Network", *Electronic Engineering*, January 1950.
[5] W. C. Vaughan, "Phase Shift Oscillator", *Wireless Engineer*, December 1949.
[6] Mallett, "Telegraphy and Telephony", or other standard textbook.

BRIT.I.R.E. CONVENTION

The 1954 Convention of the British Institution of Radio Engineers is being devoted to the application of electronics to industrial control, processes and computation. It is to be held in Christ Church, University of Oxford, from 8th July to 12th July.

The six sessions will cover industrial applications of electronic computors, industrial applications of X-rays and ultrasonics for testing, Radioactive devices for testing, Electronic sensing devices, Electronic actuators and Electronic aids to production.

MEETINGS

I.E.E.

7th April. "A Versatile Transistor Circuit", by E. H. Cooke-Yarborough, M.A. "The Measurement of the Small-Signal Characteristics of Transistors", by E. H. Cooke-Yarborough, M.A., C. D. Florida and J. H. Stephen, Ph.D. "A Bridge for Measuring the A.C. Parameters of Type 'A' Transistors", by A. R. Boothroyd, Ph.D., and L. K. Datta, M.Sc. "The Transistor as a Regenerative Amplifier with some Application to Computing Circuits", by G. B. B. Chaplin, M.Sc.

12th April. "Safety Measures for Radio and Television Equipment", discussion to be opened by E. P. Wethey.

23rd April. "A Method for the Plotting of Magnetic Fields due to Currents", discussion to be opened by F. T. Chapman, C.B.E., D.Sc.(Eng.), and D. G. Sandeman, B.Sc.(Eng.).

26th April. "The Experimental Synthesis of Speech", by W. Lawrence.

27th April. "Auto-Self-Excited Transductors and Push-Pull Circuit Theory", by A. G. Milnes, M.Sc., and T. S. Law, B.Sc. "Composite Cores for Instrument Transductors", by E. H. Frost-Smith, B.A., Ph.D., and A. E. De Barr, B.Sc.

29th April. "The Physics of the Ionosphere", Forty-fifth Kelvin Lecture by J. A. Ratcliffe, O.B.E., M.A., F.R.S.

5th May. "The Reflection and Absorption of Radio Waves in the Ionosphere", by W. R. Piggott, B.Sc. "Some Notes on the Absorption of Radio Waves Reflected from the Ionosphere at Oblique Incidence", by W. J. G. Beynon, Ph.D., D.Sc.

These lectures will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30.

Brit.I.R.E.

21st April. "Crystal Valves in Radio and Electronics", by B. R. A. Bettridge, to be held at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, commencing at 6.30.

CORRESPONDENCE

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

Constant-H.T. Current Amplifier

SIR,—I was interested to read your Editorial in the February 1954 issue of *Wireless Engineer.*

The amplifier circuit you describe, consisting of an amplifier stage followed by a cathode-follower stage, with direct coupling and having load resistances substantially equal in order to present a constant load to the h.t. supply, has been of considerable service, particularly in video amplifiers for television transmitters where modulation is performed at high level.

This application, still in use in the Alexandra Palace transmitter, is described on p. 774 of the classic paper on "The Marconi-E.M.I. Television System", by Blumlein, Browne, Davis and Green, *J. Instn elect. Engrs,* Vol. 83, p. 758, December 1938. See also British Patent 462,536.

The arrangement was again used in the Sutton Coldfield transmitter, and a fairly full description and analysis is given in Section 7.3 of the paper by Nind and Leyton in *Proc. Instn elect. Engrs,* Vol. 98, Part III, p. 416, November 1951.

The conception of the circuit was largely due to the non-existence of pentode or tetrode valves of adequate power for these applications, and it will be noted that the arrangement is particularly well adapted to the use of cascaded units, since the large Miller input capacitance of the triode, to which you refer, is looked after by the low-impedance drive from the cathode-follower output stage of the preceding unit.

Another point helping satisfactory video response with a triode amplifier stage is that the impedance at the anode of V_1 is considerably less than R_3 since the r_a of V_1 is in parallel.

ERIC L. C. WHITE.

E.M.I. Research Laboratories, Ltd.,
Hayes, Middlesex.
19th February 1954.

Transmission-Line Matching System

SIR,—The paper by R. E. Collin and J. Brown in your February issue gives a complete theoretical treatment of two quarter-wave transformers used to match two transmission lines of different characteristic impedances.

A good approximate solution which the writer used exists for this problem and for the problem of any number of quarter-wave transformers. It may be worth while stating in this connection, especially as it gives some insight into the physical processes involved. Only a brief statement is possible here.

The method assumes the reflections at each discontinuity (change of Z_0) to be small. It is based on a method of designing phase-shifters due to G. J. Halford.[1] The problem there is to transform from an air-filled waveguide to one partially filled with dielectric and therefore of lower Z_0.

Denote the total reflection from the system by r. The transition consists of a number of quarter-wave sections having intermediate values of Z_0. The reflection coefficients at each discontinuity are in the ratio of the binomial coefficients if an optimum match at the design frequency is required, but different if two or more discrete zeros of r at different frequencies are desired. Thus with two transformers arranged binomially the individual reflection coefficients are as $1 : 2 : 1$ to give a flat zero in r at a frequency f, say; but they become $1 : 2 \cos \alpha : 1$ if r is to be zero at frequencies $f(\pi \pm \alpha)/\pi$ (and incidentally not zero at f). If the characteristic impedances are Z_{in}, Z_1, Z_2, and R (to use Collin and Brown's notation), then $Z_1/Z_{in} : Z_2/Z_1 : R/Z_2$ as $1 : 2 : 1$ or as $1 : 2 \cos \alpha : 1$ according to the bandwidth required. Halford quotes results for up to four transformers, and the writer has obtained similar results. A feature of this method is that the more transformers are used between two given characteristic impedances, the less are the individual reflections and hence the more accurate the theory becomes (but the more critical the tolerances).

Collin and Brown deal with a situation of only two transformers where the reflections at discontinuities may still be large, and so the theory explained here is least accurate for their case. The two methods are therefore, in a manner, complementary.

LEO YOUNG.

Electronics Division,
Ship & Shore Elec. Equip. Design,
Westinghouse Electric Corp.,
Baltimore, U.S.A.
1st March 1954.

[1] "A Wide-Band Waveguide Phase-Shifter", by G. J. Halford, *Proc. Instn elect. Engrs,* Part III, May 1953, Pp. 117-124.

Spectrum Equalization

SIR,—In his paper "Spectrum Equalization" (*Wireless Engineer,* May 1953, p. 112), Gouriet says that time delay makes it impossible to achieve ideal equalization, even within a restricted bandwidth. This is quite true, for the ideal equalization characteristic would have a transfer function which was the reciprocal of that of the network to be equalized and so would have a negative time delay.

Later, however, Gouriet says that "This article describes a means of producing the desired equalizing characteristic by adding to the response function its successive derivatives or integrals with respect to time with appropriate adjustment of the amplitudes and signs."

I would like to point out that, in fact, precisely the same restrictions apply to this method as to the conventional equalizer. Taking Fig. 8 of the paper, and including the inevitable capacitance across the transformer secondary and across the valve output, the exact transfer function has four poles and it is only at small values of p that it approximates to pMg_m, which is the Laplace transform of a differentiating network.

In view of this, Gouriet's claim (2) on p. 122 applies equally to any appropriate network and his claim (3) is erroneous.

In saying this, I do not wish to detract in any way from the importance and practical utility of Gouriet's work and I would like to stress much more fully than he did that his claims (1) and (4) have turned out to be very effective indeed in improving the reproduction of television systems. The flexibility obtained with it is of particular importance.

J. PETERS.

Nordwestdeutscher Rundfunk,
Hamburg.
8th March 1954.

SIR,—There was no intention to suggest in my article that the derivative method of equalization would compensate for 'real' time delay. This question is dealt with in Sec. 2.3.

It is, of course, true that the restrictions which apply to linear circuit elements will apply also to any equalizer which incorporates such elements. Over a limited frequency band, however, derivatives may be extracted with any desired accuracy, and I would submit that if the error is too small to observe then one is entitled to regard such error as being non-existent over the frequency band concerned. Furthermore, it is not essential to use conventional circuit elements as the means for obtaining derivatives. For example, the differential of a signal may be obtained by subtracting from the signal a delayed version of it, in which case the differential becomes exact as the delay approaches zero. The transfer characteristic of such an arrangement has more zeros than poles and is therefore not subject to the same restrictions as a differentiating 'circuit', such as a transformer, or an RC network.

The fact that even-order derivatives will provide compensation for an attenuation characteristic without causing dispersion or introducing time delay, does, I consider, support claim (3). It might be argued that in practice, pure derivatives cannot be produced, but this is also true of pure resistance and pure reactance!

G. G. Gouriet.

B.B.C. Research Department,
Kingswood Warren, Surrey.
15th March 1954.

NEW BOOKS

Low Frequency Amplification

By Dr. N. A. J. Voorhoeve. 495 pp. + xv. Philips Technical Library, Cleaver-Hume Press, Ltd., Wright's Lane, Kensington, London, W.8. Price 50s.

Sound amplification has of recent years increased in importance; public address systems have grown in number and scope, and the appreciation of the nicer points of sound reproduction by engineers, musicians and the general public has increased, culminating in a demand for the highest fidelity. There is, however, a notable lack of books dealing with the subject in a thorough fashion. This book attempts to supply this need and the author sets himself a wide interpretation of his subject. About two-thirds of the book is concerned with audio-frequency circuitry, the remainder dealing with signal sources, loudspeakers and problems associated with complete amplification systems.

The author has had as his aim, a guide and reference book for practising sound engineers and for others with a less specialized technical training.

The book is one of the Philips Technical Library series and is a translation from the Dutch. It starts with a short discussion of principles followed by a chapter on valves, containing, by way of illustration, detailed descriptions of a number of Philips valves. Voltage amplifier circuits are next described followed by a chapter on power amplifiers; this last section, as might be expected, being particularly detailed. Chapters are devoted to feedback, components, and power supplies.

The last part of the book is concerned with the operation of complete amplifiers and their ancillary equipment. There is a useful chapter on principles of acoustics, including reference to the properties of the ear, and the effects of the characteristics of amplifier circuits on these properties. Input sources are described briefly, and loudspeakers a little more fully, while there are several chapters on aspects of complete sound reproduction systems, including a detailed chapter on amplification problems in buildings and other public places. The book ends with a description of measuring techniques and instruments, and a section of tables of symbols and terms. There is also a list of the most important formulae developed and used in the book, with references to the appropriate part of the text.

Books of this type are inclined to be somewhat uneven in treatment, having sections of great detail interspersed with discursive passages, and this book does not altogether escape this criticism, but has the compensating advantage of extensive bibliographies with each chapter. References in the text are numerous and the reader can easily amplify his reading about any subject of interest. Some of the information is summarized in the form of tables and graphs in the text and this, together with the general arrangement of the text, assists in easy reference to a particular subject. The style is, in general, simple and interesting, except for an occasional ambiguous or confusing passage. Throughout the book the author has illustrated his matter with numerous references to specific Philips products and, although he states in his preface that products of the leading manufacturers are equivalent, it may well be felt that unnecessary stress has been laid on Philips manufactures in some cases.

Unfortunately there is an unusually large number of small misprints and other errors and, although these are often not important in themselves, they give an impression of carelessness leading to a lack of confidence in the accuracy of the whole of the book. A typical example occurs on page 18 in the chapter on principles, where the treatment of the simple, but often misunderstood, question of the change in voltage gain of an amplifier with differing input and output impedances, is obscured by the substitution in two places of V_i^1 for V_i^2. It is difficult to understand how some of the errors have escaped the notice of the proof readers, for example on pages 396 and 397 cosh θ, sinh θ and tanh γl are printed as cos $h\theta$, sin $h\theta$ and tan $h\gamma l$ in a formula which is simply quoted, making the error difficult to spot by one unfamiliar with it. Even the symbols appendix is not free from such errors.

Some of the symbols in the text have unnecessarily complicated subscripts which do not help either the reader or the compositor; no less than four versions of the "approximately equal to" sign are used at different times, tending to suggest different orders of approximation in each case.

However, if these disadvantages are ignored, the book offers the practising sound engineer and the specialist in allied fields a useful reference book and refresher course in the wider aspects of sound amplification and reproduction.

F. L. W.

Einschwingvorgänge, Gegenkopplung, Stabilität. Theoretische Grundlagen und Anwendungen.

By Johannes Peters. Pp. 181 + xv, with 130 illustrations. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price D.M.27.

The author is head of the research department of the Nordwestdeutscher Rundfunk in Hamburg, and also gives lectures at Hamburg University. The book is of a very mathematical character and might very well have been entitled "the mathematics of back-coupling." It originated in an attempt to develop the theory of feedback amplifiers and the conditions for stability by a strictly accurate method without the usual approximations. The contents are divided into five chapters, of which the first deals with the static and dynamic properties of linear systems; the reader soon finds himself in a world of complex frequencies, Cauchy-Riemann equations and Fourier and Laplace transforms. The second chapter is entitled "Transmission Factors of

Passive and Active Systems"; it deals very thoroughly with the analysis of networks and with the various types of matrices. The third chapter is entitled "Stability, Stability Criteria and Stabilizing"; the author says that it is difficult to determine on what factors the stability depends and he feels justified in devoting a separate chapter to it. The following statement in italics is rather amusing: "*Nyquist's stability criterium holds whenever it is possible to check it by a practical measurement.*" Considerable space is devoted to Nyquist's criterion. Here and in other places the author acknowledges his indebtedness to H. W. Bode's "Network Analysis and Feedback Amplifier Design."

The fourth chapter is devoted to the actual problem of the Feedback Amplifier; all the various types of feedback circuits are very fully discussed, especially from the point of view of their practical utility. The final chapter discusses the analogies between the mechanical and electrical systems and then the use of electro-mechanical converters of various types, including magnetostriction and piezo-electric. Although servo-mechanisms are not mentioned by name, they are closely associated with several items in this chapter. In addition to the index there is a very extensive list of books and papers on the subject. With the book there is issued a sheet of corrections.

Occasionally an example—usually numerical—is given to illustrate the mathematical treatment. The first one, which occurs on p. 6, seems to make a muddle of a simple problem. We give it in the original German. "Beispiel. Das Übertragungssystem sei ein Spannungsteiler, bestehend aus einer Reihenschaltung eines Widerstandes R, einer Induktivität L und einer Kapazität C mit der Spannungsquelle am Eingang. Die Ausgangsspannung wird im Leerlauf parallel zu dem aus Widerstand und Kapazität bestehenden Zweig abgenommen. Dann ist der Übertragungsfaktor $z(\omega) = (R + i\omega L)/(R + i\omega L + 1/i\omega C)$." That is to say, a potential divider consists of R, L and C connected in series across the input voltage, and the output voltage on open circuit is taken "parallel to the branch consisting of R and C"; i.e., presumably across R and C. The numerator of the output/input voltage will then be $R + 1/i\omega C$ and not $R + i\omega L$ as the author states, but the wording is strangely vague.

After several pages devoted to complex frequencies one finds a footnote on p. 13 explaining that frequency in the technical sense means the number of periods per second, but this is due to the fact that, as he explains on p. 2, he normally uses the word frequency to denote the angular frequency ω.

The book is excellently produced and will undoubtedly prove of great interest to anyone desirous of exploring the mathematics of feedback systems. G. W. O. H.

Radio Receiver Design

Part I. Radio Frequency Amplification and Detection. By K. R. Sturley, Ph.D., B.Sc., M.I.E.E., Sen.M.I.R.E. 2nd Edition. Pp. 667 + xx. Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price 56s.

Anyone familiar with the first edition of this book is immediately struck by the relative bulkiness of the second. It actually has 667 pages as compared with 435. The eight chapters have the same headings as before and in broad outline cover much the same ground.

Chapter 1, on general considerations, has been re-written and now occupies 49 pages instead of 16. The changes are mainly additional material on frequency modulation, pulse modulation and noise. The second chapter, on valves, is not much altered save for the addition of 25 pages on noise. Chapter 3, on aerials and aerial-coupling circuits, has also been expanded somewhat. Some information on folded-unipole and folded-dipole aerials has been added, as well as a section on slot aerials. The use of directors and/or reflectors is not mentioned, however, but a couple of pages on balance-to-unbalance transformers has been inserted and a lengthy section covering wave-traps is new.

Chapter 4, on r.f. amplification, is basically unchanged but has had some extra material inserted. There is more about r.f. resistance, Q, and self-capacitance of air-core coils and about mutual inductance, and there is much more about amplification at high radio frequencies.

Chapter 5, "Frequency Changing", has had the section on diode mixers greatly expanded, some nine pages extra on noise have been added and nearly three chapters on the Synchrodyne, but otherwise it is little changed. Chapter 6, "Oscillators", is also not greatly changed, except for the (lengthy) section on tracking.

Chapter 7, on intermediate-frequency amplification, has been considerably expanded and, among other things, there are over 40 extra pages on crystal filters. The last chapter, on detectors, has been relatively little altered. There are several new appendixes.

The book, as a whole, is a very valuable reference book for the designer and the new edition is a considerable improvement on the first. It is very mathematical but the mathematics is all of a quite simple nature and involves little more than ordinary algebra and the j notation, which is explained in an appendix.

A somewhat surprising omission, in view of the way in which air-core coils are treated, is the lack of corresponding data on dust-iron core types, for they are now, by far, the more widely used. They do not appear in the index at all and references to them in the text are confined to a few isolated sentences. While it would undoubtedly have been helpful to have had a discussion on the characteristics of dust-iron core coils in the book, the omission is really rather a minor one in view of its general excellence.

The revision has been very thoroughly carried out and what has always been a most useful and reliable book has been made even more valuable. W. T. C.

Complex Variable Theory and Transform Calculus (2nd Edition)

By N. W. McLachlan, D.Sc.(Eng.). Pp. 388. Cambridge University Press, 200 Euston Road, London, N.W.1. Price 55s.

The first edition was published in 1939 under a slightly different title; the book has been completely revised. Some pure mathematicians and physicists who reviewed the first edition of this book apparently regarded the degree of rigour as inadequate. They must in spirit be the descendants of the Cambridge mathematicians who obstructed Heaviside. It is the attitude of Heaviside that is needed by the technologist who uses mathematics to solve technical and industrial problems to-day. In such problems, most of the difficulty consists in knowing what kind of solution to seek, expect or guess. Operational calculus increases one's power of guessing effectively by many decibels. The process of verifying whether a guess is correct or not is relatively easy. In most cases it will show either that the guess was correct or that it was radically wrong. In the latter case there may be some indication of how to make a better guess. If the reason for error in a solution suggested by operation calculus cannot be easily found, the pure mathematician should be consulted. The technologist only needs to be warned of important pitfalls.

The first seven chapters deal with functions of a complex variable, Cauchy's theorem, singularities, the calculation of residues, the Bromwich contour, branch points, and differentiation and integration under the integral sign; Chapter 5 devotes special attention to gamma, error and Bessel functions. The essential groundwork of complex-variable theory is thus covered, with emphasis on the parts relevant to operational calculus, and particularly on the determination of residues. Chapters 8-10 discuss transform calculus, the Mellin inversion theorem, solution of ordinary linear differential equations, discontinuous functions, impulses and frequency spectra. The remaining chapters deal mainly with applications, but the solution of partial differential equations in two variables by transformation into ordinary differential equations involving the operator p is discussed in Chapter 13; 102 examples for the reader are included, with answers. There is also a bibliography of 273 references. Proofs of many results considered too long or difficult for complete inclusion in the text are indicated in outline with perhaps rather too many references to specific pages of books or papers in this bibliography.

The 'p-multiplied Laplace transform' is used consistently, so that transforms obtained agree with those found by Heaviside's method; for example, $t^n/n!$ corresponds to $1/p^n$, and unit step to unity; all functions of time involved are assumed zero for negative times. If $h(t)$ corresponds to $f(p)$, then $f(j\omega)/j\omega$ is the Fourier transform of $h(t)$, and $|f(\omega)/j\omega|$ is its spectrum.

In electrical applications, the general procedure required is: Let $\phi(p)$ be the transform of the input $h(t)$. The effect of the circuit is to provide an impedance $Z(p)$ so that the output is the transform of $\phi(p)\ Z(p)$ in the time world. The contribution of a resistance R to impedance is R, that of an inductance L is Lp, and that of a capacitance C is $1/Cp$; these can be combined for series and parallel circuits by well-known rules. Now frequently $\phi(p)\ Z(p)$ contains a rational function of p as a factor. In practice, this will usually have only simple poles, and its resolution into partial fractions is then straightforward, and will often reduce $\phi(p)\ Z(p)$ to a combination of functions whose transforms are already known. This reduction to partial fractions is not adequately emphasized in the present book. The deficiency is mitigated to some extent by another book by Professor McLachlan.[1] In collaboration with Professor Humbert,[2] he has also provided a first-class list of transforms with brief indications of restrictions on their validity.

The reduction of $\phi(p)\ Z(p)$ to a combination of known forms, if necessary with the aid of partial fractions or of general rules such as the 'convolution integral', is surely preferable to the use of the Mellin inversion theorem in most cases of interest to the technologist, who is likely to find the application of this theorem difficult. He needs encouragement to investigate 'p' as a high-powered solution detector. Even mistakes made in the early stages will mostly be of the profitable kind by means of which he learns.

The typography is of the high standard one expects from the Cambridge University Press, but one of the few misprints, on page 195, is unfortunate. In equation (3), L should be replaced by R; (3) would then agree with the well-known formula (6) on the same page. A reader eager to apply what he has learnt in Chapters 1-10 might find his confidence sapped for some time by this inconsistency.

The book contains a great deal of useful information, particularly on the determination of residues and in the bibliography, and should be freely available in libraries, but it will be of more value as a book of reference to those familiar with operational calculus than as a textbook to those initially ignorant of it. J. W. H.

[1] N. W. McLachlan, "Modern Operational Calculus with Applications in Technical Mathematics", Macmillan, London, 1948.

[2] N. W. McLachlan, Bibliography, p.376, ref. 235a, and P. Humbert, "Formulaire pour le Calcul Symbolique". Mém. des Sci. Math. Fascicule 100 (1941), 2nd edn (1950).

BRITISH STANDARDS:

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B.S.2042:1953. Price 2s. 6d.

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Covers mainly gas-filled valves and switches but also includes travelling-wave valves, v.m. valves and cavity magnetrons.

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Electronic-Valve Bases, Caps and Holders

B.S.448:1953. Price 22s. 6d.

Covers physical dimensions and tolerances. In loose-leaf form.

British Standards Institution, 2 Park Street, London, W.1.

STANDARD FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for February 1954

Date 1954 Feb.	Frequency deviation from nominal: parts in 10^8		Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
	MSF 60 kc/s 1429-1530 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.	
1	−1·2	NM	+36·8
2	−1·3	NM	+34·8
3	−1·3	−2	+33·8
4	NT	−1	NT
5	−1·2	−1	+32·2
6	NM	−2	NM
7	NM	0	NM
8	−1·3	0	+28·2
9	−1·3	0	+27·3
10	−1·3	+2	+26·2
11	−1·3	+1	+23·7
12	−1·2	+1	+22·1
13	−1·2	0	NM
14	−1·2	+1	NM
15	−1·1	+1	+16·7
16	−1·1	+1	+15·4
17	−1·1	0	+13·4
18	−1·1	−2	+11·5
19	−1·2	−1	+ 9·8
20	−1·2	−2	NM
21	−1·2	−2	NM
22	−1·2	−3	+ 6·8
23	−1·2	−1	+ 5·6
24	−1·3	−3	+ 5·2
25	−1·2	−1	+ 4·8
26	−1·1	−1	+ 4·3
27	−1·1	−1	NM
28	−1·2	−1	NM

The values are based on astronomical data available on 1st March 1954.

The transmitter employed for the 60-kc/s signal is sometimes required for another service.

NM = Not Measured. NT = No Transmission.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses.

ACOUSTICS AND AUDIO FREQUENCIES

534 : 061.3 **919**

International Congress on Acoustics, Delft (Netherlands), 15th–25th June 1953.—P. Chavasse & R. Lehmann. (*Ann. Télécommun.*, Oct. 1953, Vol. 8, No. 10, pp. 335–338.) A brief report of the proceedings, with titles of the papers presented. See also 2855 of 1953.

534.1.001.362 **920**

Transformer Couplings for Equivalent-Network Synthesis.—B. B. Bauer. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 837–840.) Equivalent circuits for mechanical arrays, based on the impedance analogy, are obtained in a simple way by introducing ideal transformer couplings.

534.121.2 **921**

On the Vibration of Mass-Loaded Membranes.—E. T. Kornhauser & D. Mintzer. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 903–906.) The conventional treatment originated by Rayleigh is discussed, and some of the results are shown to be invalidated by an unfounded assumption.

534.13 : 534.414 **922**

Theory of the Free Vibrations of Isotropic Elastic Media.—E. Ledinegg & P. Urban. (*Acta phys. austriaca*, Sept. 1953, Vol. 7, No. 4, pp. 420–435.) First-order perturbation theory is used to calculate the natural frequencies of an inhomogeneous system of arbitrary form. The method is used to determine the variation of the natural frequency of a system when its elastic constants are subjected to small spatially distributed variations. Calculations are made of the variation of resonance frequency of a cylindrical acoustic resonator on introduction of (*a*) an axial rod, and (*b*) a transverse plate. Application to the determination of Lamé's constants is discussed.

534.13 : 621.395.61/.62 **923**

The Coupling of Mechanical and Acoustic Vibration Systems.—W. Güttner. (*Acustica*, 1953, Vol. 3, No. 4, pp. 201–206. In German.) A wide-band transducer is obtained by coupling a Helmholtz resonator to the mechanical system. The optimum bandwidth conditions are attained when the reception, or the radiation, does not involve the resonator. As an example, the frequency response of a crystal microphone is determined.

534.141.4 **924**

On Edge Tones and Associated Phenomena.—A. Powell. (*Acustica*, 1953, Vol. 3, No. 4, pp. 233–243.) Edge-tone phenomena occurring at high jet speeds have been photographed and analysed.

534.2 **925**

The Concept of Radiation Scattering and its Application to Reinforced Cylindrical Shells.—M. C. Junger. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 899–903.) A method of analysis is developed permitting investigation of complex structures which cannot be treated by the methods previously described (3299 of 1952). The radiation pressure is expressed as the sum of two terms, one corresponding to the contribution from a rigid scatterer and the other to the contribution due to the vibration of the actual scatterer in response to the incident wave. Special cases are examined.

534.2 **926**

Acoustic Streaming at Low Reynolds Numbers.—J. M. Andres & U. Ingard. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 932–938.)

534.2 **927**

Acoustic Streaming at High Reynolds Numbers.—J. M. Andres & U. Ingard. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 928–932.)

534.2 **928**

Acoustic Streaming Equations: Laws of Rotational Motion for Fluid Elements.—W. L. Nyborg. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 938–944.)

534.2 **929**

The Propagation of Sound in a Medium with Random Fluctuations of the Refractive Index.—V. Ya. Kharanen. (*C. R. Acad. Sci. U.R.S.S.*, 11th Jan. 1953, Vol. 88, No. 2, pp. 253–256. In Russian.) The effect of small fluctuations in a medium whose refractive index is nearly unity is considered theoretically. An expression for the deflection of the sound wave is derived. The results of the particular cases considered can be applied to the problem of the propagation of sound in the surface layer of the sea. See also 847 of 1947 (Bergmann).

534.2-13 **930**

The Attenuation of Sound Propagated over the Ground.—J. D. Hayhurst. (*Acustica*, 1953, Vol. 3, No. 4, pp. 227–232.) The effect of wind on sound propagation over a concrete runway was investigated experimentally for distances up to 800 m. The only significant parameter is the component of wind along the direction of propagation, but the attenuations are statistically independent of the absolute wind speed. The change of attenuation with frequency and with height above ground is shown graphically.

534.2-14 **931**

Wave Propagation in a Randomly Inhomogeneous Medium: Part 1.—D. Mintzer. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 922–927.) "The propagation of sound pulses from a point source in a medium where the index of refraction varies randomly is studied by means of a Born approximation to the wave equation. The coefficient of variation (standard deviation of the amplitude of a series of pulses, expressed as a percentage of the mean amplitude of the series) is evaluated for pulse lengths short compared with the time in which the refractive index varies significantly, and for ranges large compared with the wavelength of the sound. The results are in agreement with the experiments of Sheehy [1055 of 1950]."

534.21-16 **932**

Magnetic Damping of Acoustic Waves in Conducting Media.—E. T. Kornhauser. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 1011–1012.) An elementary analysis is presented and the results are compared with those of Anderson (2635 of 1953).

534.213-14 **933**

The Acoustic Properties of Gas-Bubble Screens in Water.—E. Meyer & E. Skudrzyk. (*Akust. Beihefte*, 1953, No. 3, pp. 434–440.)

534.213.4-14 : 534.64 **934**

Acoustic Impedance of Rectangular Tubes.—J. K. Wood & G. B. Thurston. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 858–860.) Theoretically derived values of the impedance of a section of a system of infinite parallel planes are in good agreement with measured values for long narrow tubes, when the latter are corrected for end effects.

534.213.4-14 : 534.64 **935**

End Corrections for a Concentric Circular Orifice in a Circular Tube.—G. B. Thurston & J. K. Wood. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 861–863.) The values of the end correction found experimentally for the acoustic impedance of a tube with an orifice are in good agreement with values derived theoretically, treating the orifice as a plane piston source.

534.23 **936**

Optimum Directivity Patterns for Linear Point Arrays.—R. L. Pritchard. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 879–891.) Extended version of 3292 of 1948 (Pritchard & Rosenberg).

534.23 **937**

Approximate Calculation of the Directivity Factor of Linear Point Arrays.—R. L. Pritchard. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 1010–1011.)

534.232 : 546.431.824-31 **938**

Barium Titanate Admittance-Temperature Characteristics.—A. L. Lane. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 873–878.) Admittance variations over the temperature range 34°–67°F are studied for underwater transducers made of $BaTiO_3$ with and without addition of lead as a temperature stabilizer. Though the dielectric and piezoelectric constants of the material vary widely over this temperature range, it is possible for the transducer admittance to vary very little at certain frequencies near resonance.

534.232-14 : 621.395.61 **939**

Notes on Measurements of the Efficiency of Transducers for Water-Borne Sounds.—H. Thiede. (*Akust. Beihefte*, 1953, No. 3, pp. 449–451.) A method particularly applicable in the sonic and lower ultrasonic frequency ranges is described. Measurements of power absorbed for constant excitation at frequencies well below, well above and at the mechanical resonance frequency are made, the last-mentioned measurement being repeated with the transducer radiating in air. Efficiency can then be calculated.

534.321.9 **940**

Intensities produced by Jet-Type Ultrasonic Vibrators.—H. O. Monson & R. C. Binder. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 1007–1009.) An investigation of the influence of inlet pressure, cup position and physical proportions on the intensity and frequency of the vibrations.

534.414 : 534.845 **941**

The Impedance of a Resistance-Loaded Helmholtz Resonator.—U. Ingard & R. H. Lyon. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 854–857.) Resonators with a damping screen are considered, and the dependence of the impedance on the distance between screen and aperture is investigated theoretically; the resistance and reactance components are differently affected. The results are discussed in relation to the design of perforated facings.

534.62 + 621.317.3.029.63/.64 **942**

A New Anechoic Chamber for Sound Waves and Short Electromagnetic Waves.—E. Meyer, G. Kurtze, H. Severin & K. Tamm. (*Akust. Beihefte*, 1953, No. 3, pp. 409–420.) Description of the design and construction of a chamber of dimensions 5·5 m × 10 m × 14 m, with a reflection factor < 10% for sound waves of frequency > 70 c/s and for e.m. waves of frequency > 1 kMc/s. The treatment of the walls is basically similar to that in the pre-war anechoic chamber at the Technische Hochschule, Charlottenburg [6 of 1948 (Meyer et al.)], but behind the fibreglass wedges a cavity 12 cm deep has been provided which, together with slots between the wedges, forms a resonator system. Graphite powder drawn into the wedges by suction provides the attenuation of the e.m. waves.

534.62 **943**

On the Measurement of Power Radiated from an Acoustic Source.—W. G. Cady & C. E. Gittings. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 892–896.) An account is given of experiments which verified the theory developed by Borgnis (2536 of 1953). A slab of ρc rubber, a 90° wedge and a cavity radiometer were used as absorbers.

534.78 **944**

General Analysis of the Acoustic Structure of Speech Sounds by the Superposition of Periodic and Random Components.—R. Husson & R. Saumont. (*C. R. Acad.*

Sci., Paris, 9th Dec. 1953, Vol. 237, No. 23, pp. 1555–1556.) A discussion of the physiological origin of the different types of component and of the ability of the ear to discriminate between them. A new classification of phonemes is given.

534.78 **945**

A Study of the Building Blocks in Speech.—C. M. Harris. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 962–969.) A technique is used in which speech elements are recorded on magnetic tape and joined together as required.

534.78 **946**

A Speech Synthesizer.—C. M. Harris. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 970–975.) The device uses a keyboard arrangement to select for reproduction speech elements magnetically recorded on a drum.

534.78 **947**

Some Experiments on the Recognition of Speech with One and with Two Ears.—E. C. Cherry. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 975–979.)

534.832 **948**

Vibration of Plates Covered with a Damping Layer.—A. van Itterbeek & H. Myncke. (*Acustica*, 1953, Vol. 3, No. 4, pp. 207–212.) The time taken for a halving of the initial amplitude was determined experimentally for steel plates 3–26 mm thick. The variation with the mass of paint used and with temperature is shown graphically.

534.832 : 534.121.1 **949**

Sound Radiation from Plates Excited in Flexural Vibration.—K. Gösele. (*Acustica*, 1953, Vol. 3, No. 4, pp. 243–248. In German.) The sound energy radiated per unit area of the plate is a function of the ratio f/f_{gr} where f is the frequency of the sound and f_{gr} the critical frequency of the plate. For values of this ratio > 1 the radiation is independent of the total area of the plate, for unity value the radiation increases with the area and for values < 1 it decreases to a limiting value. The application of the theoretical results to the construction of single- and double-shell walls is mentioned.

534.84 **950**

Room Acoustics.—H. J. Sabine. (*Trans. Inst. Radio Engrs*, July/Aug. 1953, Vol. AU-1, No. 4, pp. 4–12.) A brief survey of the transmission of sound through the air in a room, and of the ways in which a sound signal may be modified by the acoustic characteristics of the room.

534.84 **951**

Measurements of the Acoustical Properties of Two Roman Basilicas.—A. C. Raes & G. G. Sacerdote. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 954–961.)

534.845-14 **952**

Pulse Method of Measurement of the Reflection from Absorbers of Water-Borne Sound in Tubes.—W. Kuhl, H. Oberst & E. Skudrzyk. (*Akust. Beihefte*, 1953, No. 3, pp. 421–433.) Measurements are made on a c.r.o. of the amplitude of pulses reflected from resonance-type absorbers at the end of a water-filled tube. Pulse durations between 0·5 and 1·5 ms are used, with frequencies in the range 9–22 kc/s. Sources of error, and their elimination, are considered in detail.

621.395.61 **953**

Derivation of the Laws of Force for All Magnetic and All Electric Transducers from a Single Law in Each Case.—F. A. Fischer. (*Akust. Beihefte*, 1953, No. 3, pp. 441–448.) If the magnetic energy of a system of two coupled coils and the electric energy of two coupled electric conductors respectively are calculated, the mechanical force is given by the derivative of the energy with respect to x, assuming that the x coordinate is the only one along which the system varies. The different types of transducers result from a proper choice of this variable coordinate.

621.395.61 **954**

The Theoretical Sensitivity of Three Types of Rectangular Bimorph Transducers.—E. G. Thurston. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 870–872.) Application of the method discussed previously (926 of 1953) to the cases of (*a*) the corner-loaded square bimorph, (*b*) the rectangular bimorph supported along two sides and uniformly loaded, and (*c*) the rectangular bimorph loaded only along a strip.

621.395.61 **955**

A Miniature Piezoelectric Microphone.—J. Medill. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 864–866.) A Rochelle-salt microphone developed for use as a secondary standard in acoustic testing has a diameter of $1\frac{1}{8}$ in. Details are given of its construction and performance.

621.395.61 **956**

A Miniature Microphone for Transistorized Amplifiers.—B. B. Bauer. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 867–869.) The construction and performance of a moving-iron microphone suitable for use in hearing aids are described.

621.395.612.451 **957**

The Uniaxial Microphone.—H. F. Olson, J. Preston & J. C. Bleazey. (*Trans. Inst. Radio Engrs*, July/Aug. 1953, Vol. AU-1, No. 4, pp. 12–19.) Reprint. See 2199 of 1953.

621.395.623.7 : 534.321.9 **958**

Interaction of Two Ultrasonic Waves in Air.—J. Maulois. (*Toute la Radio*, Nov. 1953, Vol. 20, No. 180, pp. 352–354.) Report of experiments made by S. Klein using two ionophone loudspeakers to produce either (*a*) unmodulated waves of slightly different frequencies, or (*b*) an unmodulated and a modulated wave of the same carrier frequency. Audible beats were produced. The possibility of designing a loudspeaker requiring neither horn nor baffle is discussed.

621.395.623.7.011.21 **959**

Loudspeaker Impedance.—V. Salmon. (*Trans. Inst. Radio Engrs*, July/Aug. 1953, Vol. AU-1, No. 4, pp. 1–3.) The operation and testing of loudspeakers, and the calculation of available input power, require knowledge of five impedances, which are here discussed and defined. In estimating loudspeaker performance with different output stages or at extreme frequencies, the source regulation is an important factor. Its measurement is described.

AERIALS AND TRANSMISSION LINES

621.315.212 **960**

Modern Coaxial-Cable Technique in Great Britain.—E. Baguley. (*Elect. Commun.*, Sept. 1953, Vol. 30, No. 3, pp. 186–216.) A discussion of the design, manufacture and testing of long-distance telephone and television wide-band coaxial cables. Comparative performance figures and curves for cables made between 1935 and 1950 are given. The tests described include a 5-kV flashover test, pulse-echo test for detecting irregularities of impedance, h.f. attenuation measurement, impedance measurement between 50 kc/s and 10 Mc/s and cross-talk measurements.

621.315.212 : 621.372.2 961

The Transmission Characteristics of Coaxial Cables.—E. Adam. (*Öst. Z. Telegr. Teleph. Funk Fernsehtech.*, July/Aug. & Sept./Oct. 1953, Vol. 7, Nos. 7/8 & 9/10, pp. 98–107 & 122–134.) A simple treatment of the subject based on work published by various authors, from Maxwell up to the present time.

621.372.2 + 538.566 962

The Effect of the Radiation Condition in the case of Complex Wave Number, and its Significance in the Problem of Surface Waves.—Haug. (See 1162.)

621.372.2 963

Normalized Impedance and Reflection Coefficient.—P. A. Lindsay. (*Wireless Engr*, Feb. 1954, Vol. 31, No. 2, pp. 43–47.) Starting from the formula giving the impedance Z at the end of a transmission line of length l in terms of the characteristic impedance Z_0, the propagation constant and l, perspective drawings are constructed of surfaces representing the relations between the normalized load impedance Z/Z_0 and the voltage coefficient of reflection.

621.372.2 : 537.226 964

Propagation in a Dielectric Transmission Line.—M. Jouguet. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1656–1657.) In addition to the E_0 and H_0 modes, mixed modes with m-order symmetry round the circumference of the line can exist. Two infinite series of modes designated $(EH)'_{m,n}$ and $(EH)''_{m,n}$ correspond to any value of m. The values of the cut-off frequency, phase velocity and attenuation are determined for various cases.

621.372.2 + 538.566] : 621.3.012 965

New Chart for the Solution of Transmission-Line and Polarization Problems.—G. A. Deschamps. (*Elect. Commun.*, Sept. 1953, Vol. 30, No. 3, pp. 247–254; *Trans. Inst. Radio Engrs*, March 1953, Vol. MTT-1, No. 1, pp. 5–13.) This chart, an orthographic projection of the Poincaré sphere (see 2418 of 1951), is considered as a modification of the Smith chart. It is normally used with a hyperbolic protractor. The examples given of its applications include the evaluation of the reflection coefficient of a stratified medium and of junction-insertion loss. Polarization problems are treated by assimilating polarization ratio to reflection coefficient.

621.372.43 966

Transmission-Line Matching System.—R. E. Collin & J. Brown. (*Wireless Engr*, Feb. 1954, Vol. 31, No. 2, pp. 31–35.) The two-section quarter-wave transformer is analysed. By tolerating a certain mismatch at the centre of the band it is possible to obtain a perfect match at two frequencies located symmetrically about the centre frequency. This arrangement gives an increase of 20–45% in bandwidth over the commonly used binomial transformer, which gives perfect matching at the centre frequency only. Simple design procedure and performance curves are presented.

621.372.8 967

Velocity of Energy in Waveguides.—G. Sincich. (*Alta Frequenza*, Oct. 1953, Vol. 22, No. 5, pp. 239–243.) A calculation is made of the instantaneous energy velocity for the TM or TE mode. The velocity is always less than that for a free wave; its value is zero, maximum or equal to the group velocity according as the longitudinal component of the electric field (for the TM mode) or the magnetic field (for the TE mode) is maximum, zero or equal to its r.m.s. value respectively.

621.372.8 968

On the Propagation Constant in Gentle Circular Bends in Rectangular Wave Guides — Matrix Theory.—A. T. de Hoop. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1325–1327.)

621.396.67 969

A Note on the Cylindrical Antenna of Noncircular Cross Section.—Y. T. Lo. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1338–1339.) The equivalent radii are derived for aerials of polygonal and elliptical cross-section.

621.396.67.012.12 970

An Automatic Recorder of Aerial Radiation Diagrams.—E. G. Hamer & J. B. L. Foot. (*J. Brit. Instn Radio Engrs*, Jan. 1954, Vol. 14, No. 1, pp. 33–42.) The instrument described compares a local a.f. reference signal with an a.f. signal of the same frequency and of amplitude proportional to the r.f. signal from the aerial. Arrangements are provided for mounting large aerials at various heights, and for the presentation of results in different ways.

621.396.67.029.64 : 621.317.3 971

Measurements on Aerials for Centimetre Waves.—Bouix. (See 1127.)

621.396.674.3 : 538.566 972

The Interaction between Electromagnetic Wave and Dipole.—F. Borgnis. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 463–466.) The expression for the mean active power abstracted from the e.m. wave by an electric or magnetic dipole is derived in terms of the electric or magnetic field, the length of the dipole (d), and the conjugate of the complex dipole current, from considerations of the near field. The expressions are valid for $d \ll \lambda$ and $r \ll \lambda$, where r is the distance from the dipole. The maximum effective cross-sectional area of either type of dipole with respect to a plane wave is shown to be $(3/8\pi)\lambda^2$.

621.396.677.71 973

Vertically Polarized Microwave Antenna.—R. K. Thomas & M. E. Ringenbach. (*Radio & Telev. News, Radio-Electronic Engng Section*, Oct. 1953, Vol. 50, No. 4, pp. 13 . . 27.) A design giving a fan-shaped beam uses a stub-supported rigid coaxial line with longitudinally spaced circumferential slots.

621.396.677.71 974

Automatically Deiced X-Band Beacon Antenna.—C. E. Thomas, Jr. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 152–155.) Details are given of a slotted-waveguide array with an omnidirectional radiation pattern and a narrow vertical beam width, built to withstand wind velocities > 150 knots. The radome heating circuit is controlled by a bridge which includes a capacitor exposed to the weather.

621.396.677.859 : 621.396.96 975

Designing Radomes for Supersonic Speeds.—S. S. Oleesky. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 130–135.) Designs which will not attenuate or distort the radar beam are discussed.

AUTOMATIC COMPUTERS

681.142 976

Phantastron computes Pulse-Width Ratios.—L. D. Findley. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 164–167.) Description of an analogue computer developed for determining the ratio of the widths of two pulses occurring simultaneously in two channels of a radar system. The output is readily convertible into digital form. Other applications are indicated.

681.142 **977**

Programme Control of an Electronic Computer.—H. Harmuth. (*Acta phys. austriaca*, Sept. 1953, Vol. 7, No. 4, pp. 390–401.)

681.142 **978**

Digital Computers at Manchester University.—T. Kilburn, G. C. Toothill, D. B. G. Edwards & B. W. Pollard. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 487–500.) An account is given of the development of the universal high-speed computer; its features include a c.r.-tube store for 10 240 binary digits, an intermediate store for more than 280 000 digits, completely automatic transfer between the two stores, a fast multiplier, and input and output systems using 5-hole teleprinter tape.

681.142 **979**

The Construction and Operation of the Manchester University Computer.—B. W. Pollard & K. Lonsdale. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 501–512. Discussion, pp. 540–543.) The account particularly stresses techniques used to achieve reliability and ease of maintenance, and includes details of the performance over a period of about 61 weeks. See also 978 above.

681.142 **980**

Universal High-Speed Digital Computers: a Decimal Storage System.—T. Kilburn & G. Ord. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 513–522. Discussion, pp. 540–543.) Three decimal-digit storage systems using c.r. tubes are described. The best compromise as regards speed of operation, storage capacity and reliability is obtained with a c.r.-tube screen comprising ten separate elements. In a serially controlled store holding 32 words of 8 decimal digits the digit period was 40 μs and could be reduced to 30 μs. These results compare favourably with those for the binary store used in the Manchester University computer.

681.142 : 621-526 **981**

The Design and Testing of an Electronic Simulator for a Hydraulic Remote-Position-Control Servo Mechanism.—F. J. U. Ritson & P. H. Hammond. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 568–569.) Discussion on 1054 of 1953.

681.142 : 621-526 **982**

Analogue Computers for Feedback Control Systems.—R. A. Bruns. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 250–254.)

681.142 : 621.314.222 **983**

Transformer-Analogue Network Analysers.—M. W. H. Davies & G. R. Slemon. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 469–480. Discussion, pp. 481–486.) The use of voltage transformers as multipliers for complex quantities is explained. A network analyser is described comprising a measuring section and a number of identical panels each with two multiplying units. These panels can be used to represent impedances, admittances, etc. Negative resistance and unilateral mutual inductance can easily be represented. Applications discussed include the solution of linear simultaneous equations.

681.142 : 621.385 **984**

Valve Reliability in Digital Calculating Machines.—L. Knight. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311 pp. 9–13.) A discussion of measures which can be taken to reduce the number of valve failures and to reduce the inconvenience caused when failures do occur.

681.142 : 621.385.832 **985**

Recent Advances in Cathode-Ray-Tube Storage.—F. C. Williams, T. Kilburn, C. N. W. Litting, D. B. G. Edwards & G. R. Hoffman. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 523–539. Discussion, pp. 540–543.) Modifications have been made to the system described by Williams & Kilburn (2258 of 1949) and used in the Manchester University computer; the defocus-focus system and the signal amplifier are discussed particularly. An account is given of experimental work undertaken to clarify the storage mechanism. The theoretical basis of the system is examined; the original theory, though inaccurate in detail, is satisfactory for practical purposes and can be used to predict storage results. The tube operation is analogous to that of a triode valve, the collector, bombarded spot and surrounding screen surface corresponding respectively to the anode, cathode and control grid.

CIRCUITS AND CIRCUIT ELEMENTS

621.318.572 : 621.385.832 **986**

A Multi-Decade Predetermined Counter.—A. Dorn. (*Electronic Applic. Bull.*, June/July 1953, Vol. 14, Nos. 6/7, pp. 91–101.) The automatic four-decade counter described is a modified version of that noted in 603 of February. The maximum counting rate is 12 500 per sec, and the minimum duration of a complete cycle of counts is $\frac{1}{3}$ ms.

621.372 **987**

Directional Coupling with Transmission Lines.—W. L. Firestone. (*Tele-Tech*, Nov. 1953, Vol. 12, No. 11, pp. 95–97 . . 178.) Adaptation of devices developed in connection with waveguides to forms with open-wire lines, for use at lower radio frequencies.

621.372 **988**

Response of an Amplifier Stage with Antiresonant Circuit to an Input Voltage whose Instantaneous Frequency varies linearly as a Function of Time.—P. Poincelot. (*C. R. Acad. Sci., Paris*, 23rd Nov. 1953, Vol. 237, No. 21, pp. 1314–1315.) Analysis is given for an input which can be represented by a particular Fourier integral.

621.372.2 : 534.321.9 **989**

Equivalent-Network Representations for Solid and Mercury Delay Lines.—S. Dairiki, T. E. Lawrence & R. A. Mapleton. (*J. acoust. Soc. Amer.*, Sept. 1953, Vol. 25, No. 5, pp. 841–853.) An equivalent-network representation is obtained from consideration of the piezoelectric properties of the quartz crystal used to convert the electrical energy into ultrasonic energy. A formula is derived for the transfer function of the line. When mercury and fused-quartz lines are compared on the basis of the gain-bandwidth product only, the fused-quartz line is superior; but other factors (e.g. production of spurious signals) must be taken into account when selecting a line for a specific application.

621.372.413 **990**

Characteristics of an Elliptical Electromagnetic Resonant Cavity operating in the TE_{111} Mode.—T. P. Higgins & A. W. Straiton. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1297–1299.) "Equations and graphs are presented of the resonant wavelength and quality factor of elliptical resonant cavities operating in the TE_{111} mode. Both components of this mode are treated and distinctive characteristics of each are shown as a function of eccentricity of the cavity."

621.372.413 **991**

Interaction between Classical Electron and Quantized Electromagnetic Field.—I. R. Senitzky. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1309–1311.) The equations of motion are solved by a method involving the corresponding difference equations, and an expression is derived for the probability of transition between a high-energy state and neighbouring states of the field inside a resonant cavity.

621.372.5 **992**

The Transformation Properties of Loss-Free Quadripoles between Homogeneous Lines, and a Proof of Weissfloch's Transformation Law using Circle Geometry.—H. Lueg. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 478–484.) A method for evaluating certain parameters in the application of Weissfloch's transformation law (3287 of 1943 and back references). This law has applications in measuring technique and circuit theory in the cm-λ and dm-λ regions.

621.372.5 **993**

On the Synthesis of Reactance 4-Poles.—H. J. Carlin & R. La Rosa. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1336–1337.) Using theory developed by Belevitch (1547 of 1952), formulae are derived for the elements of the impedance or admittance matrix of a loss-free quadripole which, when terminated by a resistor, realizes a prescribed physical driving-point impedance.

621.372.5.012 **994**

A Block-Diagram Approach to Network Analysis.—T. M. Stout. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 255–260.) An extension of the method described by Graybeal (1534 of 1952) to electrical networks, with examples of application in the analysis of ladder, bridged-T and parallel-T networks.

621.372.5.029.64 : 621.318.1 **995**

Ferrites in Microwave Applications.—J. H. Rowen. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1333–1369.) A discussion of the microwave Faraday effect and of the mechanism of power absorption in ferrites. Plane-wave theory is given, and is extended to cover waveguides. The measurement and applications of the effects are surveyed. See also 1233 of 1952 (Hogan).

621.372.512.029.63 : 621.372.21 **996**

Coupled Lines as High-Frequency Transformer.—O. Bronder. (*Fernmeldetech. Z.*, Oct. 1953, Vol. 6, No. 10, pp. 475–480.) Systems comprising two parallel two-conductor lines are considered. Voltage and current distribution and input impedance are calculated in terms of terminating impedance, overlap length and coupling. An indication is given of the requirements to be satisfied for wide-band operation, and some particular arrangements are discussed.

621.372.54 **997**

Tentative Graphical Representation of the Image Transfer Coefficient of Ladder-Type Filters with or without Losses.—J. E. Colin. (*Câbles & Transm.*, July 1953, Vol. 7, No. 3, pp. 242–262.) The method is based on the expression of the image transfer coefficient $p = a + jb$ as a function of frequency in accordance with the classification of filters given previously (2748 of 1949 and 575 of 1950).

621.372.543.2.029.5 **998**

A Set of 0.4-Octave Band-Pass Filters for Frequencies between 10 and 200 kc/s.—H. Pursey. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, pp. 31–33.) Filters designed for eliminating harmonics are described. In order to achieve the desired sharp cut-off on the high-frequency side the filters are operated into an abnormally low impedance, about a tenth of the centre-frequency impedance.

621.372.56 : 621.372.8 **999**

Broadband Rotary Waveguide Attenuator.—B. P. Hand. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 184–185.) The attenuator comprises three collinear sections of round waveguide, each with a resistive film arranged in a diametral plane; the middle section is rotated to obtain the desired attenuation. Some performance figures are given for an experimental model; the characteristics are independent of frequency.

621.372.6 **1000**

A General Network Theorem, with Applications.—B. D. H. Tellegen. (*Proc. Instn Radio Engrs, Aust.*, Nov. 1953, Vol. 14, No. 11, pp. 265–270.) Slightly modified reprint of paper noted in 62 of 1953.

621.373.42 **1001**

'Chameleon' Oscillator.—T. Roddam. (*Wireless World*, Feb. 1954, Vol. 60, No. 2, pp. 52–55.) An oscillator giving high frequency stability and using relatively few components is based on a cathode-coupled Hartley circuit with resistance in the cathode lead.

621.373.421.13 **1002**

The Measure of Activity of Oscillators and the Performance Index.—W. Herzog. (*Arch. elekt. Übertragung*, Oct. 1953, Vol. 7, No. 10, pp. 470–472.) The measure of activity of an oscillator is defined as the ratio of grid-voltage amplitude to anode-current amplitude. In crystal-controlled oscillators it is proportional to the crystal performance index. The measure of activity is evaluated for several common types of oscillator.

621.373.424.029.4 **1003**

Design of Heterodyne Oscillators.—H. Lennartz. (*Funk u. Ton*, Oct. 1953, Vol. 7, No. 10, pp. 526–534.) The choice of frequencies for producing a given beat frequency, and the design of the variable tuning capacitor are considered. Precautions required to ensure frequency stability are discussed.

621.373.43 **1004**

The Operation of Generators for Steep-Fronted Waves.—J. Lagasse, J. Favarel & P. Sido. (*C. R. Acad. Sci., Paris*, 9th Nov. 1953, Vol. 237, No. 19, pp. 1151–1152.) When the self-inductance of the generator is taken into account in the analysis, a third-order differential equation is obtained; simplification is introduced by taking advantage of a particular solution. Graphical methods of investigation, based on the work of Bergeron, are also outlined.

621.373.52 **1005**

Transistor Oscillator for Use in Multifrequency Pulsing Current Supply.—F. E. Blount. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1313–1331.) Discussion of an oscillator for use in the transmission of digital information, at frequencies in the band 700–1 700 c/s, over telephone trunk-lines. Performance details are given.

621.374 : 621.318.572 **1006**

Introduction to the Use of Electronic Tubes in Pulse Techniques.—P. A. Neeteson. (*Electronic Applic. Bull.*, June/July 1953, Vol. 14, Nos. 6/7, pp. 102–112.) Circuit phenomena produced by switching are briefly reviewed and the operation of valves as nonlinear or switching elements is discussed as an introduction to the consideration of some well known pulse circuits.

621.374.33 **1007**

A Special Time-Discriminating Selector for Electronic Pulses.—A. Alberigi, F. Lepri & G. Stoppini. (*Nuovo Cim.*, 1st April 1952, Vol. 9, No. 4, pp. 365–368.) A circuit is described which is able to select the last of a series comprising an arbitrary number of pulses distributed in an arbitrary way within a fixed time interval.

621.375.1 : 621.396.822 **1008**

Determination of the Noise Factor of Various Amplifiers by a Comparison Method.—W. Mansfeld. (*Funk u. Ton*, Oct. 1953, Vol. 7, No. 10, pp. 501–507.) The relative noise factor can be determined by using a standard-type signal generator connected to the input of the amplifier and a band-pass filter coupled to a valve voltmeter at the output.

621.375.232 **1009**

Wide-Band I.F. Amplifiers.—H. S. Jewitt. (*Wireless World*, Feb. 1954, Vol. 60, No. 2, pp. 86–90.) Bandwidths > 10 Mc/s, such as are required for dealing satisfactorily with very short pulses, are achieved without necessitating alignment of the amplifier with a particular set of valves, by using a negative-feedback design technique. The amplifier is treated as a series of pairs of valves, the first of each pair operating without and the second with feedback. A table gives component values in a form requiring a minimum of computation. A particular 12-stage amplifier designed by this method for a centre frequency of 60 Mc/s had a bandwidth of 20 Mc/s to the −1db points and an overall gain of about 90 db; the response varied only very slightly when all the valves were changed.

621.375.3 **1010**

Magnetic Amplifier uses Conventional Inductors.—A. I. Bennett, Jr. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 181–183.)

621.375.3 **1011**

Negative Inductance cuts Magnetic-Amplifier Lag.—G. M. Ettinger. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 162–163.) The speed of response of a magnetic amplifier is improved, without reducing its sensitivity, by balancing out the effect of control-circuit inductance by means of a 'negative-inductance' device comprising a valve with an iron-cored mutual inductor.

621.375.3.024 **1012**

The Design of a Practical D.C. Amplifier Based on the Second-Harmonic Type of Magnetic Modulator.—S. W. Noble & P. J. Baxandall. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 567–570.) Discussion on 72 of 1953.

621.375.4 **1013**

Transistors: Theory and Application: Part 11—Cascading Transistor Amplifier Stages.—A. Coblenz & H. L. Owens. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 158–161.) Formulae and values of circuit parameters are tabulated for various possible arrangements using point-contact or junction transistors.

621.375.4.029.3 : 621.314.7 **1014**

Power Transistors for Audio Output Circuits.—Giacoletto. (See 1247.)

621.396.822 : 621.372 **1015**

Physical Basis of Thermal Noise.—D. A. Bell. (*Wireless Engr*, Feb. 1954, Vol. 31, No. 2, pp. 48–50.) An examination is made of methods developed by various workers for analysing circuit noise due to random motion of charge carriers. It is concluded that it is not necessary to postulate thermodynamic equilibrium in order to be able to calculate the thermal noise.

621.375.4 + 621.373.52 **1016**

Principles of Transistor Circuits. [Book Review]—R. F. Shea (Ed.). Publishers, Chapman & Hall, London, 535 pp., 88s. (*Wireless Engr*, Feb. 1954, Vol. 31, No. 2, pp. 51–52.) A comprehensive work on transistors and their circuitry, written by nine members of the staff of the electronics laboratory of the G.E.C. Company of America.

621.376 + 621.314.26 **1017**

Modulators and Frequency Changers. [Book Review]—D. G. Tucker. Publishers: Macdonald & Co., London, 232 pp., 28s. (*Brit. J. appl. Phys.*, Oct. 1953, Vol. 4, No. 10, p. 319.) For research, development and maintenance engineers. High-power transmitting modulators are not treated.

GENERAL PHYSICS

534.014.5 **1018**

Graphical Presentation of Oscillator Resonance, Applicable to the Study of Nonlinear Systems.—P. Liénard. (*Acustica*, 1953, Vol. 3, No. 4, pp. 212–223. In French.)

535.31 : 535.13 **1019**

Derivation of the Laws of Geometrical Optics from Maxwell's Field Theory.—G. Mandl. (*Acta phys. austriaca*, Sept. 1953, Vol. 7, No. 4, pp. 365–389.)

535.42 : 538.56 : 621.372.8 **1020**

The Diffraction of Electromagnetic Waves by a Semi-infinite Circular Waveguide.—J. D. Pearson. (*Proc. Camb. phil. Soc.*, Oct. 1953, Vol. 49, Part 4, pp. 659–667.) Formulae are obtained for the currents on the waveguide, and asymptotic expressions are derived for the longitudinal components of the electric and magnetic vectors in the waveguide at large distances from the mouth.

537.122 : 538.56 **1021**

A Collective Description of Electron Interactions: Part 2 — Collective vs Individual Particle Aspects of the Interactions.—D. Pines & D. Bohm. (*Phys. Rev.*, 15th Jan. 1952, Vol. 85, No. 2, pp. 338–353.) Part 1: 2975 of 1951.

537.221 : 546.47 **1022**

The Electromotive Force developed by a Creeping Zinc Crystal.—F. D. Coffin & S. L. Simon. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1333–1334.)

537.311.1 **1023**

Theory of Plasma Waves in Metals.—P. A. Wolff. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 18–23.) The Hartree approximation is used to investigate the effect of the crystal lattice on plasma oscillations in metals. A formula is derived for the oscillation frequency; for free electrons this reduces to that given by Bohm & Gross (88 and 89 of 1950); for insulators there are no oscillations. In metals with occupied *d* bands there is strong coupling between the plasma oscillations and the *d* electrons, causing frequency broadening.

537.311.33 **1024**

Theory of A.C. Space-Charge Polarization Effects in Photoconductors, Semiconductors, and Electrolytes.—J. R. MacDonald. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 4–17.) Linear theory is developed for solid or liquid materials containing charge carriers which can move freely within the material but are blocked by the electrodes. The carriers may be electrons, holes, ions or ion vacancies. The general solution for the admittance of the material is obtained for an arbitrary ratio between the mobilities of positive and negative carriers, and is discussed for some special cases. Results are compared with those derived from other theories.

537.525.5 **1025**

The Field-Emission-Initiated Vacuum Arc: Part 1 — Experiments on Arc Initiation.—W. P. Dyke, J. K. Trolan, E. E. Martin & J. P. Barbour. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1043–1054.) The experiments were carried out under conditions of high vacuum and clean cathode surface. Results show (*a*) that breakdown is immediately preceded by recognizable emission anomalies, (*b*) that breakdown occurs at a critical current density of the order of 10^8 A/cm², for applied microsecond pulses in the range 8·8–60·1 kV, and (*c*) that breakdown is independent of cathode bombardment.

537.525.5 **1026**

The Field-Emission-Initiated Vacuum Arc: Part 2 — The Resistively Heated Emitter.—W. W. Dolan, W. P. Dyke & J. K. Trolan. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1054–1057.) Theory is developed for the heat flow in an emitter of geometry approximating to that used in the experiments reported in 1025 above. The calculations support the view that breakdown is initiated by a resistive heating process.

537.533 : 537.525.92 **1027**

Space-Charge Effects in Field Emission.—J. P. Barbour, W. W. Dolan, J. K. Trolan, E. E. Martin & W. P. Dyke. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 45–51.) "A progressive reduction of the observed field current below values expected from the empirical law for increasing values of the potential is attributed to space charge. The current density expected in the presence of space charge is calculated from the Fowler-Nordheim field emission theory using values of the cathode electric field obtained from a solution of Poisson's equation for plane electrodes with boundary conditions appropriate to field emission. The result is a generalization of Child's equation, and is asymptotic to it when the applied potential is large compared with the value required for appreciable field emission."

537.533 : 538.691 **1028**

"Brillouin Flow" with Thermal Velocities.—J. R. Pierce & L. R. Walker. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1328–1330.) "A type of electron flow in a constant magnetic field is described. The beam of electrons is supposed to be everywhere in thermal equilibrium and the usual Brillouin flow is found when the equilibrium temperature tends to zero. Some considerations are put forward bearing on the choice of a suitable beam temperature in specific problems."

537.533.8 **1029**

A Modified Theory of Production of Secondary Electrons in Solids.—A. van der Ziel. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 35–39.) Difficulties in previous theories of energy loss and secondary-electron production in metals [see e.g. 3069 of 1952 (Dekker & van der Ziel)] are removed by replacing the Coulomb interaction between a primary electron and a lattice electron by a screened Coulomb interaction.

537.56 : 538.63 **1030**

Magneto-ionic Theory of Weakly Ionized Gases in the Presence of an Oscillating Electric Field and a Constant Magnetic Field.—R. Jancel & T. Kahan. (*J. Phys. Radium*, Oct. 1953, Vol. 14, No. 10, pp. 535–540.) The velocity distribution functions for a nonuniformly ionized gas are calculated by solving the Boltzmann differential equations. Explicit expressions are derived for the magneto-ionic conductivity, the dielectric tensor, the Hall effect, the deflection of the electron beam and the generalization of Langevin's mobility formula. Comparison is made with other methods of calculation.

537.562 : 538.63 **1031**

The Conductivity Tensor of Electron Plasmas in the presence of a Constant Magnetic Field.—M. Bayet, J. L. Delcroix & J. F. Denisse. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1503–1505.) Assuming the mean collision frequency to be independent of velocity, it is shown that the form of the conductivity tensor given by Jancel & Kahan (1030 above) differs from that given by Huxley (1266 of 1952). In order to represent the magnetoresistance terms correctly by Jancel & Kahan's method, closer approximation is necessary.

538.22 **1032**

Some Magnetic Properties of Metals: Part 6 — Surface Corrections of the Landau Diamagnetism and the de Haas-van Alphen Effect.—R. B. Dingle. (*Proc. roy. Soc. A*, 7th Oct. 1953, Vol. 219, No. 1139, pp. 463–477.) An expression is given for the magnetic moment of a large but finite system of electrons in terms of the volume and two mutually perpendicular surface areas together with constants independent of the shape of the system. The theory is verified by calculating the values of the constants for two different shapes. Corrections to part 5 (1967 of 1953) are noted.

538.221 **1033**

A Two-Electron Example of Ferromagnetism.—J. C. Slater, H. Statz & G. F. Koster. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1323–1341.) The method of dealing with problems of ferromagnetism on the basis of energy-band theory [*Rev. mod. Phys.*, 1953, Vol. 25, p. 199 (Slater)] is applied to a simple case.

538.51 **1034**

The Law of Induction.—G. Vallauri. (*Alta Frequenza*, Oct. 1953, Vol. 22, No. 5, pp. 211–238.) A survey of the literature indicates a lack of clarity on this subject. The law of induction is formulated generally in terms of a geometrical entity called the 'flux line', which exists in the field of a solenoidal vector.

538.52 **1035**

Induction Phenomena consequent on the Movement of Material in Primary Magnetic Fields, and their Experimental Applications: Part 3 — Fundamental Theory for Very General Cases.—H. Hinteregger. (*Acta phys. austriaca*, Sept. 1953, Vol. 7, No. 4, pp. 337–354.) Theory applicable to any type of motion is developed. Part 2: 388 of March.

538.561 : 537.533 **1036**

Motion of an Electron in a Magnetic Undulator.—R. Combe & M. Feix. (*C. R. Acad. Sci., Paris*, 23rd Nov. 1953, Vol. 237, No. 21, pp. 1318–1320.) Rigorous solutions are obtained for the equations of motion of an electron in a millimetre-wave generator of the type described by Motz et al. (3582 of 1953).

538.561 : 537.533 **1037**

Frequencies and Power of Waves Radiated by a Magnetic Undulator.—R. Combe & M. Feix. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1660–1662.) Continuation of investigation noted in 1036 above. The dimensions of an undulator for generating mm waves are determined from rigorous calculations of electron trajectories. The results differ greatly from values derived from classical theory. The values found for radiated power are of the same order.

538.566 : 537.56 **1038**

The Equations of Propagation of Electromagnetic Waves in an Ionized Gas.—A. M. Confetta. (*R. C. Ist. lombardo*, 1952, Vol. 85, No. 2, pp. 495–502.) Two different methods are used to derive the equations for the propagation of e.m. waves in an ionized gas subjected to a time-varying e.m. field and to a constant magnetic field; terms depending on past states are found to occur.

538.566.029.64 : 535.51-7 **1039**

Effect of a Metal Plate on Total Reflection.—W. Culshaw & D. S. Jones. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406B, pp. 859–864.) The phase changes which occur on total reflection are modified when a metal plate is placed near and parallel to the reflecting boundary. By moving the plate, the phase difference between plane waves of equal amplitudes polarized in and perpendicular to the plane of incidence can be varied from $-\pi$ up to the positive value obtained without the plate. This has been confirmed experimentally using a wavelength of 1·25 cm and a 45° perspex prism. When the refractive index is $\geqslant 1 + \sqrt{2}$, there are two positions of the plate for which the reflected wave is circularly polarized, the electric vector rotating in opposite directions for these two positions.

538.566.2 **1040**

Theory of a [linear] **Conductor near the Boundary of Two Media.**—A. A. Pistol'kors. (*C. R. Acad. Sci. U.R.S.S.*, 11th Oct. 1952, Vol. 86, No. 5, pp. 941–943. In Russian.) The electromagnetic field due to an oscillation of angular frequency ω in the conductor can usually be split into two components; a cylindrical-wave field and a spherical-wave field. Near the axis of the conductor, which is parallel to the boundary plane, the field is of a special type. The condition for the existence of the two components is derived and applied to particular cases.

538.691 **1041**

Deflection of High-Energy Electrons in Magnetized Iron.—S. Berko & F. L. Hereford. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1127–1130.) The effective magnetic field acting on electrons traversing a ferromagnetic medium is shown, by experiments, to be equal to the flux density.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 : 621.396.96 **1042**

Radio Echo Studies of Meteor Ionization.—T. R. Kaiser. (*Advances Phys.*, Oct. 1953, Vol. 2, No. 8, pp. 495–544.) The physical properties of the meteors and the columns of ionization which they produce, and the properties of the atmosphere in the meteor ionization region were investigated using, mainly, pulse equipment operating in the 4–10-m waveband. The development of a satisfactory theory of scattering of radio waves from meteor trails, together with the theory of evaporation from meteors, makes possible the detailed interpretation of the radio echoes obtained. In particular, the estimated incident flux of meteors is found to be sufficient to maintain a continuous ionospheric layer extending from ~130 km down to 115 km, below which ionization will be distributed in patches becoming fewer (and larger) with decreasing height. Over 40 references.

523.72 : 621.396.822 **1043**

Observations of Solar Radio-Noise Storms.—B. Vauquois, P. Coupiac & M. Laffineur. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1630–1632.) Observations indicate that simple storms, i.e. those caused by a single bipolar group of sunspots, exhibit a directional effect varying with wavelength.

523.745 : 621.396.822.029.62 **1044**

Radio Noise Bursts from Solar *M*-Regions.—A. K. Das & B. N. Bhargava. (*Nature, Lond.*, 7th Nov. 1953, Vol. 172, No. 4384, pp. 855–856.) The passage of *M*-regions is characterized by a notable increase in the short-term variability of noise intensity at 3 m λ.

523.755 : 537.56 **1045**

Ionization and Recombination Processes in a Plasma and the Ionization Formula of the Solar Corona.—G. Elwert. (*Z. Naturf.*, June 1952, Vol. 7a, No. 6, pp. 432–439.) For a plasma not in thermodynamic equilibrium, formulae are derived for (*a*) the photo-ionization, (*b*) the ionization by collisions, (*c*) the recombination with emission of light, and (*d*) the recombination due to triple collisions. By equating the number of collision ionizations with the number of photorecombinations, an ionization formula is obtained for the solar corona from which the temperature of the corona can be estimated.

523.852 : 621.396.822.029.62 **1046**

Radio-Frequency Radiation from the Spiral Nebula Messier 81.—R. H. Brown & C. Hazard. (*Nature, Lond.*, 7th Nov. 1953, Vol. 172, No. 4384, p. 853.) The intensity measurement of the radio source observed has been combined with previous observations to determine the ratio between the radio flux and the light flux for individual nebulae. The calculated flux from a nebula of apparent magnitude + 10 (Shapley-Ames) is $\sim 4{\cdot}2 \times 10^{-26}$ W/m²/(c/s) at 158·5 Mc/s.

523.852.3 : 621.396.822 **1047**

An Extended Radio-Frequency Source of Extragalactic Origin.—R. H. Brown & C. Hazard. (*Nature, Lond.*, 28th Nov. 1953, Vol. 172, No. 4387, pp. 997–998.) Extension of observations noted in 2215 of 1952.

550.3 : 519.2 **1048**

Statistical Analysis of Geophysical Time Series.—R. P. W. Lewis & D. H. McIntosh. (*Met. Mag., Lond.*, Aug. 1953, Vol. 82, No. 974, pp. 239–242.) Notes are provided on dealing with the effects of linear and periodic trends on standard deviation and correlation coefficient. Significant tests in coherent series are discussed.

550.384 **1049**

The Phased-Superposed-Epoch Method of Analysis, and an Application to Geomagnetic Activity.—E. J. Chernosky. (*Trans. Amer. geophys. Union*, Aug. 1953, Vol. 34, No. 4, pp. 519–528.) A method is described in which geomagnetic-activity variations are analysed by grouping the data according to their phases (increasing, decreasing, or no-change), as determined by considering the characteristics for pairs of successive days.

550.384 : 523.74/.75 **1050**

Geomagnetic Activity and the Sunspot Cycle.—R. Ananthakrishnan. (*Nature, Lond.*, 7th Nov. 1953, Vol. 172, No. 4384, pp. 854–855.) A table is given, for the last four sunspot-maximum epochs, of the numbers of magnetically calm days and of slightly, moderately and highly disturbed days, together with sunspot numbers and a measure of the prominence activity. Geomagnetic activity shows correlation with prominence activity rather than with sunspot activity.

550.384.4 **1051**

Diurnal Magnetic Variations near the Magnetic Equator.—S. K. Pramanik & P. S. Hariharan. (*Indian J. Met. Geophys.*, Oct. 1953, Vol. 4, No. 4, pp. 353–358.) Observations made at nine places in South India are analysed in conjunction with observations for South America. High diurnal ranges of H occur in a belt of 5°–6° of latitude, with a maximum near the magnetic equator.

551.510.535 **1052**

Abnormal Ionospheric Absorption observed during February 1952.—R. Eyfrig. (*Ann. Géophys.*, Oct./Dec. 1953, Vol. 9, No. 4, pp. 325–327.) Observations from stations all over the world are analysed. Very high absorption was observed during the period 24th–28th February within a limited region. The eastern and western limits of the affected region are not known accurately, because of the sparseness of stations; no effect was observed in America or in the Far East. The southern limit was observed in Africa, roughly along the line joining Casablanca and Djibouti. An explanation involving corpuscular radiation fits the observations better than one based directly on wave radiation from the sun. The absorption is thought to occur in low-altitude ionized layers such as that detected by Gnanalingam & Weekes (3427 of 1952).

551.510.535 **1053**

A Self-Consistent Calculation of the Dissociation of Oxygen in the Upper Atmosphere: Part 2 — Three-Body Recombinations.—H. E. Moses & Ta-You Wu. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1408–1409.) Continuation of work noted in 102 of 1953. Results based on the assumption that recombination occurs mainly as a three-body nonradiative process indicate that dissociation occurs at a level about 5 km higher than that previously calculated.

551.510.535 **1054**

Bifurcation of the E Region.—J. R. Lien, R. J. Marcou, J. C. Ulwick, D. R. McMorrow, D. B. Linsford & O. C. Haycock. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 508–509.) The retardation time, relative to an u.h.f. reference signal, of a radio signal of frequency about 1 Mc/s above the critical frequency was measured by rocket-borne instruments. Electron-density/altitude graphs were derived from the retardation-time/time-of-flight records; bifurcation of the E layer is clearly indicated. The results are in close agreement with those calculated from records obtained with the N.B.S. Model C-3 ionosphere recorder. The separation of the electron-density maxima was 13–18 km.

551.510.535 **1055**

Direction-Finding Studies of Large-Scale Ionospheric Irregularities.—E. N. Bramley. (*Proc. roy. Soc. A*, 22nd Oct. 1953, Vol. 220, No. 1140, pp. 39–61.) Continuation of work noted in 3091 of 1951 (Bramley & Ross). A report is given of measurements on pulse-modulated transmissions in the frequency range 2–15 Mc/s, reflected from the ionosphere. Both vertical-incidence and oblique-incidence observations were made. The directional variations of the reflected signals were studied, and are interpreted as due to tilting or wrinkling of the constant-ionic-density surfaces in the ionosphere. The results indicate large-scale horizontal movements in the ionosphere. In the E_s layer these appear to be of the nature of drifting clouds of ionization, while in the F layer the effects are consistent with horizontally travelling ripples having wavelengths of 50–400 km and speeds up to 350 m/s. The direction of motion is more often towards east or west than towards north or south, and evidence of a diurnal variation has been observed.

551.510.535 **1056**

Reflexions from Irregularities in the Ionosphere.—G. H. Munro. (*Proc. roy. Soc. A*, 7th Oct. 1953, Vol. 219, No. 1139, pp. 447–463.) Complexities in records of $h't$ and $h'f$ for the F region are shown to be due to curvature of the reflecting surface. The order of curvature associated with travelling disturbances is calculated and the variation in the type of complexity is shown to result from differing group retardations in the different paths. A 50-km-base triangular system of three 5·8-Mc/s pulse-transmitters, and a panoramic type 1–15-Mc/s recorder were used respectively for $h't$ and $h'f$ recording.

551.510.535 **1057**

Examination of the Formation of the Ionosphere F Region.—K. Rawer & É. Argence. (*Ann. Géophys.*, Jan./March 1953, Vol. 9, No. 1, pp. 1–25.) Continuation of work noted in 987 of 1952 (Rawer et al.). Two different possible mechanisms are discussed, namely (*a*) photo-ionization of O_2, and (*b*) ionization by soft X rays. The photoionization hypothesis is only acceptable if the dissociation of the O_2 is assumed to take place at a relatively high altitude of about 130 km. Ionization by X rays of solar origin certainly occurs, but a recent calculation of the spectral distribution of solar energy indicates too high an ionization at 95–110 km.

551.510.535 **1058**

Recombination Coefficient in the F-Regions: a Possible New Process of Ionization of Nitrogen Molecules.—R. B. Banerji. (*Nature, Lond.*, 21st Nov. 1953, Vol. 172, No. 4386, pp. 953–954.) Discussion of a possible dissociative recombination process according to which the daytime solar radiation at visible wavelengths may be instrumental in ionizing nitrogen molecules if positively charged particles are present.

551.510.535 : 523.78 **1059**

The Solar Eclipse of 25-2-1952 at Gao.—F. Delobeau. (*Ann. Géophys.*, Oct./Dec. 1953, Vol. 9, No. 4, pp. 317–324.) Ionosphere observations made during the eclipse are reported. Though the occultation was only partial, a diminution of E- and F_2-layer ionization compared with normal days was observed; the effect was very pronounced at 0735 hours U.T., when the sunspot near the western limb of the sun was obscured. On the other hand, when this sunspot disappeared on 26th February, as a result of the rotation of the sun, there was no noticeable reduction of the E-layer ionization. The effect is difficult to explain in terms of classical theory. The diminution of ionization of the F_2 layer is significant.

551.510.535 "1953" : 621.396.11 **1060**

Ionosphere Review: 1953.—T. W. Bennington. (*Wireless World*, Feb. 1954, Vol. 60, No. 2, pp. 66–68.) Twelve-month running averages and monthly-mean values are plotted for the sunspot numbers and the noon and midnight F_2 critical frequencies from 1947. It is inferred that the critical frequencies are likely to decrease only very slightly before the next sunspot minimum, and that the latter is to be expected between March 1954 and April 1955.

551.594 : 621.317.72 **1061**

The Agrimeter for Continuous Recording of the Atmospheric Electric Field.—J. A. Chalmers. (*J. atmos. terr. Phys.*, Oct. 1953, Vol. 4, No. 3, pp. 124–128.) Description of an instrument based on measurement of the 'bound' charge on a portion of the earth's surface.

551.594.221 **1062**

The Pilot Streamer in Lightning and the Long Spark.—B. F. J. Schonland. (*Proc. roy. Soc. A*, 22nd Oct. 1953, Vol. 220, No. 1140, pp. 25–38.)

551.594.221 : 621.396.969.029.63 **1063**

The Study of Lightning Streamers with 50 cm Radar.—F. J. Hewitt. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406 B, pp. 895–897.) Radar echoes were observed during the whole period between the successive strokes in a lightning flash. Some components of these echoes appear to be associated with the processes leading up to the next stroke. Photographic c.r.o.-trace records of the stroke, at its commencement and 12 ms later, are reproduced and discussed.

551.594.6 **1064**

Methods of Synchronizing the Observations of a "Sferics" Network.—A. L. Maidens. (*Met. Mag., Lond.*, Sept. 1953, Vol. 82, No. 975, pp. 267–270.) Methods in use in the British network are described.

LOCATION AND AIDS TO NAVIGATION

621.396 : 551.594.6 **1065**

The Reception of Atmospherics at High Frequencies.—F. Horner. (*J. atmos. terr. Phys.*, Oct. 1953, Vol. 4, No. 3, pp. 129–140.) Report on h.f. atmospheric-noise observations made at a single point (Teddington) with a view to assessing the practical possibility of basing estimation of source distances on them. Atmospherics were recorded simultaneously at two frequencies in the upper part of the h.f. band, and the source identity was checked from c.r.d.f. data. Observations were expected to, and generally did, exhibit the following features: (*a*) reception at both frequencies from sources within ground-wave range; (*b*) no reception when the observation station lies in the skip zone for both frequencies; (*c*) reception on either the lower frequency or both frequencies, according as the observation station lies beyond the skip zone either for the lower frequency or for both frequencies. Difficulties of the method and results achieved are discussed.

621.396.96 **1066**

Theoretical Performance of Airborne Moving Target Indicators.—F. R. Dickey, Jr. (*Trans. Inst. Radio Engrs*, June 1953, No. PGAE-8, pp. 12–23.) Fluctuations in the strength of echoes from fixed objects, due to the movement of the aerial, are considered and simple formulae developed to facilitate ground clutter attenuation calculations. The expression for the ratio of mean-square voltage change between two successive signals received from the ground to the mean-square signal voltage is the sum of four terms, one involving rotation, and the other three the displacement components. Each term is developed in a power series, three different beam shapes being taken into account.

621.396.96 : 621.396.677.859 **1067**

Designing Radomes for Supersonic Speeds.—S. S. Oleesky. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 130–135.) Designs which will not attenuate or distort the radar beam are discussed.

621.396.963.325 **1068**

A High-Definition General-Purpose Radar.—J. W. Jenkins, J. H. Evans, G. A. G. Wallace & D. Chambers. (*J. Brit. Instn Radio Engrs*, Jan. 1954, Vol. 14, No. 1, pp. 5–21. Discussion, pp. 21–23.) A detailed description is given of equipment for operation in the 3-cm waveband; it is compact enough to be mobile, and can be used with only minor modifications for local aircraft control, airfield surface-movement control, harbour control, etc. Variable pulse width and automatically centering time-base are used. The paraboloid aerial reflector is moulded from a plastic of good dimensional stability. P.p.i. display is given on two 15-in. tubes.

621.396.969 **1069**

Some Possible Reductions in Gust Loads through Use of Radar in Transport Airplanes.—H. B. Tolefson. (*Bull. Amer. met. Soc.*, May 1953, Vol. 34, No. 5, pp. 187–191.) Analysis of turbulence measurements made in different weather conditions indicates that a 10% reduction of the magnitude of the largest gust loads might be achieved, but that little if any reduction of loads due to the more numerous weak gusts is to be expected from the use of airborne radar to detect storm areas. Passenger comfort could be appreciably increased. The use of contour radar is desirable for selecting the smoothest path through storm areas that cannot be avoided.

MATERIALS AND SUBSIDIARY TECHNIQUES

535.371 **1070**

Fluorescence, Phosphorescence, and Photostimulation of NaCl(AgCl) with High-Energy Irradiation.—M. Furst & H. Kallmann. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1356–1367.)

537.224 **1071**

Studies of the Heterocharges of Electrets.—S. Wikström. (*Ericsson Tech.*, 1953, Vol. 9, No. 2, pp. 225–234.) Report of investigations of the dependence of the charging and discharging rate on temperature, the influence of a d.c. field at room temperature on a prepared electret, the influence of pressure during charging and discharging, and the influence of polarization on the capacitance and loss angle.

537.226 : [546.48.882.5 + 546.817.882.5 **1072**

Dielectric Properties and Phase Transitions of $Cd_2Nb_2O_7$ and $Pb_2Nb_2O_7$.—G. Shirane & R. Pepinsky. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, p. 504.) Measurements were made at temperatures down to 40°K, at a frequency of 10 kc/s and a field strength of 5 V/cm. The dielectric constant of cadmium niobate, which is 310 at room temperature, rises to a maximum of 1 200 at 185°K, the Curie point. The corresponding constants for lead niobate are 185 and 360 (at 14°K) respectively. Ferroelectric-type hysteresis and a dielectric constant anomaly at 85°K were observed in the former material only.

537.226 : [546.48.882.5 + 546.817.882.5 **1073**

Low-Temperature Dielectric Properties of Cadmium and Lead Niobates.—J. K. Hulm. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 504–505.) The results of measurements at temperatures down to 1·2°K, at 1 kc/s and 10 V/cm, are similar to those reported by Shirane & Pepinsky (1072 above).

537.311.1 **1074**

Changes in the Electrical, Thermal, and Thermoelectrical Properties of Monovalent Metals by Lattice Distortions.—A. W. Sáenz. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1142–1151.) A transport equation is derived for the distribution of conduction electrons in monovalent metals with static lattice distortions, simple assumptions regarding interaction energy being made. Using an iteration method, and considering temperatures very much higher than the Debye temperature of the lattice, a set of integral equations is obtained and solved explicitly. General expressions are found for the resistivity, thermal conductivity and absolute thermoelectric power tensors and are applied to specific calculations for a metal having an array of parallel positive-negative edge dislocations.

537.311.33 : 538.632 **1075**

Current Carrier Lifetimes Deduced from Hall Coefficient and Resistivity Measurements.—L. P. Hunter, E. J.

Huibregtse & R. L. Anderson. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1315–1320.) A method for determining the lifetime of charge carriers in semiconductors, based on theory presented by Landauer & Swanson (165 of January), gives results in reasonable agreement with those obtained on the same samples by injection methods.

537.311.33 : 546.23 **1076**

Anisotropic Resistivities of Selenium Crystals at High Frequencies.—H. W. Henkels & J. Maczuk. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1562–1563.) Some measurements are reported; results are compared with values obtained previously.

537.311.33 : 546.23 **1077**

The Structure of Amorphous Selenium.—H. Richter, W. Kulcke & H. Specht. (*Z. Naturf.*, Aug. 1952, Vol. 7a, No. 8, pp. 511–532.) A study of the amorphous material, prepared in various ways, and of its transition to the crystalline state.

537.311.33 : 546.26-1 **1078**

The Electrical Resistance of Graphite at Low Temperatures.—J. M. Reynolds, H. W. Hemstreet & T. E. Leinhardt. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1152–1155.) The resistance of large-crystal natural graphite increases with increasing temperatures from 1·35°K to room temperature. That of polycrystalline graphite decreases over practically the whole of this range; at 5°K it is nearly independent of temperature.

537.311.33 : [546.28 + 546.289 **1079**

Electron Multiplication in Silicon and Germanium.—K. G. McKay & K. B. McAfee. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, pp. 1079–1084.) "Electron multiplication in silicon and germanium has been studied in the high fields of wide *p-n* junctions for voltages in the prebreakdown region. Multiplication factors as high as eighteen have been observed at room temperature. Carriers injected by light, alpha particles, or thermal-generation are multiplied in the same manner. The time required for the multiplication process is less than 2×10^{-8} second. Approximately equal multiplication factors are obtained for injected electrons and injected holes. The multiplication increases rapidly as 'breakdown' voltage' is approached. The data are well represented by ionization rates computed by conventional avalanche theory. In very narrow junctions, no observable multiplication occurs before Zener emission sets in, as previously reported. It is incidentally determined that the efficiency of ionization by alpha particles bombarding silicon is $3{\cdot}6 \pm 0{\cdot}3$ electron volts per electron-hole pair produced."

537.311.33 : 546.28 **1080**

Paramagnetic Resonance in *N*- and *P*-Type Silicon.—F. K. Willenbrock & N. Bloembergen. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, p. 1281.) Experiments were performed at 9 kMc/s at 78°K. The absorption signal was roughly proportional to impurity concentration.

537.311.33 : 546.289 **1081**

Absorption of Infrared Light by Free Carriers in Germanium.—H. B. Briggs & R. C. Fletcher. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1342–1346.) Measurements were made of the radiation absorbed when free carriers were injected across a *p-n* junction; the absorption was proportional to the carrier concentration. The absorption/wavelength curve exhibits the maxima previously observed in ordinary *p*-type Ge; the positions of these maxima depend on temperature. An explanation of the observations based on degenerate energy bands is advanced.

537.311.33 : 546.289 **1082**

Infrared Absorption in *P*-Type Germanium.—W. Kaiser, R. J. Collins & H. Y. Fan. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1380–1381.) Measurements made at temperatures down to 5°K indicate that the absorption coefficient is proportional to the hole concentration. There is a strong absorption band above 10 μ, caused by excitations within the filled band due to the presence of holes, and two weaker bands at shorter wavelengths, one of which disappears at low temperatures.

537.311.33 : 546.289 **1083**

Optical Studies of Injected Carriers: Part 1 — Infrared Absorption in Germanium.—R. Newman. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1311–1312.) Measurements were made of the amount of radiation transmitted through a *p-n*-junction Ge diode into which carriers were injected in pulses. The results indicate that for injection into low-resistivity material (*p*-type) the injection current is proportional to the injected carrier density, while for injection into high-resistivity material (*n*-type) there is a departure from proportionality.

537.311.33 : 546.289 **1084**

Optical Studies of Injected Carriers: Part 2 — Recombination Radiation in Germanium.—R. Newman. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1313–1314.) Measurements were made of the radiation produced by direct recombination of electrons and holes in *p-n*-junction Ge diodes into which carriers were injected in pulses. The observed spectral distribution is in fair agreement with theory. The intensity of radiation is proportional to the injection current for both high- and low-resistivity material. Polarization of the radiation at oblique angles of emergence was observed.

537.311.33 : 546.289 **1085**

Surface Recombination in Germanium.—W. N. Reynolds. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406B, pp. 899–901.) The variation of the surface recombination velocity of injected minority carriers with temperature was determined for five different surfaces. The absolute values were found to be very sensitive to changes in the etching procedure.

537.311.33 : 546.289 **1086**

Electrical Conductivity of Mechanically Disturbed Germanium Surfaces.—E. N. Clarke & R. L. Hopkins. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1566–1567.) Experiments indicate that the effect of polishing, sandblasting, etc., is to produce a surface layer of relatively high conductivity.

537.311.33 : 546.289 **1087**

Microwave Observation of the Collision Frequency of Holes in Germanium.—T. S. Benedict. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1565–1566.) Using the technique previously described [2330 of 1953 (Benedict & Shockley)], measurements were made of the permittivity and conductivity of *p*-type Ge in order to determine the effective mass of the holes and the relaxation time. Results are shown graphically and discussed.

537.311.33 : 546.289 **1088**

The Conductivity of Germanium at 2·4 × 10¹⁰ c/s.—Y. Klinger. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 509–510.) The conductivity of a highly purified Ge sample over the temperature range 0–100°C was determined from the results of permittivity and loss-tangent measurements. At 100°C the h.f. conductivity is approximately half the d.c. conductivity; the h.f. and d.c. activation energies are 0·60 and $0{\cdot}77_5$ eV respectively.

537.311.33 : 546.289 **1089**

Electrical Properties of Gold-Germanium Alloys.—W. C. Dunlap, Jr. (*Phys. Rev.*, 1st Sept. 1953, Vol. 91, No. 5, p. 1282.) Au acts as an acceptor capable of taking up electrons at two distinct energy levels, the first 0·15 eV above the filled band, the second 0·2 eV below the conduction band. At 77°K resistivities up to $5 \times 10^7 \Omega$. cm have been obtained.

537.311.33 : 546.289 **1090**

The Atomic Heat of Germanium below 4°K.—P. H. Keesom & N. Pearlman. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1347–1353.)

537.311.33 : 546.289 : 537.323 **1091**

Measurement of the Thermoelectric Power of Germanium at Temperatures above 78°K.—A. E. Middleton & W. W. Scanlon. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 219–226.) An experimental investigation on pure and impure Ge over the temperature range 78°–925°K. At low temperatures, where conduction is due to impurity-introduced carriers, the sign of the thermoelectric power is the same as that of the Hall coefficient, the magnitudes of the thermoelectric power, resistivity and Hall coefficient increase with a decrease in the impurity content. With rising temperature the magnitude of the thermoelectric power increases and passes through a maximum, the value for *p*-type material subsequently passing through zero. The results are presented graphically.

537.311.33 : 546.289 : 537.323 **1092**

Theory of Thermoelectric Power in Semiconductors with Applications to Germanium.—V. A. Johnson & K. Lark-Horovitz. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 226–232.) An expression for the thermoelectric power is obtained in terms of the Fermi level, width of forbidden band, temperature, ratio of electron to hole mobility, and effective electron and hole masses. For the impurity range, the formula can be simplified to involve only the Hall coefficient and the temperature. Consideration is given to the case when charge carriage by both holes and electrons must be taken into account. The results are compared with those obtained experimentally by Middleton & Scanlon (1091 above).

537.311.33 : 546.289 : 537.323 **1093**

Thermoelectric Power of Germanium below Room Temperature.—H. P. R. Frederikse. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 248–252.) Measurements were made on *n*-type Ge samples in the range 10°–300°K. The temperature dependence at temperatures above 200°K is in good agreement with conventional theory but below this temperature the thermoelectric power rises sharply above the predicted value and reaches a maximum of several millivolts per degree (with Cu) at 15°K. This deviation is due to the disturbance of the phonon equilibrium.

537.311.33 : 546.289 : 539.3 **1094**

Germanium under Ultrasonic Stress: Part 1 — Anelastic Effects.—G. S. Baker, L. M. Slifkin & J. W. Marx. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, p. 1331.) Five samples of 30-Ω. cm single crystals, in the form of right prisms with the major axis along the [100] direction, were driven in fundamental longitudinal vibration at 111 kc/s. Young's modulus E_{100} was measured at temperatures between 26° and 876°C. Anomalies were observed in two samples.

537.311.33 : 546.289 : 539.3 **1095**

Germanium under Ultrasonic Stress: Part 2 — Dynamic Yield Point.—G. S. Baker, L. M. Slifkin & J. W. Marx. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1331–1332.) The transient and the residual effects on the yield stress were investigated at temperatures up to 614°C for mechanically normal Ge specimens of conductivity $\sim$ 20Ω. cm, cut with the major axis parallel to the [111] direction, and driven in fundamental longitudinal vibration at $\sim$ 37 kc/s.

537.311.33 : 546.472.21 **1096**

Some Electrical and Optical Properties of Synthetic Single Crystals of Zinc Sulfide.—W. W. Piper. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 23–27.) A report of measurements on hexagonal ZnS (wurtzite) to determine the energy band gap.

537.311.33 : 546.472.21 **1097**

Perfect Crystals of Zinc Sulfide.—W. W. Piper & W. L. Roth. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, p. 503.) Differences between the properties of ZnS crystals grown by sublimation in an atmosphere of hydrogen and those of ordinary ZnS crystals are discussed.

537.311.33 : 546.682.86 **1098**

Optical Properties of Indium Antimonide.—M. Tanenbaum & H. B. Briggs. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1561–1562.) Measurements indicate that the intrinsic limit of absorption lies at 7 μ, and that the presence of Ni as an impurity is at least partly responsible for anomalous transmission in the range 3–7 μ.

537.311.33 : 546.86.48 **1099**

Impurity and Intrinsic Semiconduction of Intermetallic Compounds: Part 2.—E. Justi & G. Lautz. (*Z. Naturf.*, Sept. 1952, Vol. 7a, No. 9, pp. 602–613.) An experimental investigation is made of the temperature dependence of the electrical conductivity, the variation of resistivity in a magnetic field, the differential thermoelectric power and the rectifying properties of CdSb. The results show that, as predicted by the theory presented in part 1 (3619 of 1953), CdSb is an intrinsic semiconductor in the stoichiometric state, and can be turned into an impurity semiconductor by departure from stoichiometric composition or by adding other metals.

537.311.33 : 621.396.822 **1100**

A Possible Mechanism for 1/f Noise Generation in Semiconductor Filaments.—L. Bess. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, p. 1569.) Analysis is presented based on the Brownian motion of a surface atom displaced from its equilibrium position.

538.221 **1101**

Orientational Superstructures.—L. Néel. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1613–1616.) Discussion of phenomena induced in solid solutions of ferromagnetic materials with crystals of cubic structure, when cooled so as to retain permanent anisotropy. Magnetic anisotropy of various ferromagnetic alloys is attributed to this phenomenon.

538.221 **1102**

Definition of a Ferromagnetic State with Maximum Stability.—J. Creusot & A. Langevin. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1499–1500.) B/H measurements were made on various materials with the object of finding the most stable equilibrium state corresponding to each value of H, so that B is a two-valued function of H. Superposed on the magnetizing field H is an alternating field whose strength is varied continuously down to zero; B is then measured. The formula obtained for B as a function of H is in agreement with that proposed by P. Langevin in 1911.

538.221 **1103**

Surface Anisotropy of Ferromagnetic Substances.—L. Néel. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1468–1470.)

538.221 **1104**

Study of the Ferromagnetism of Multicrystal and Single-Crystal Cementite [Fe_3C].—P. Blum & R. Pauthenet. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1501–1502.) Measurements over the temperature range 20·4°–500°K are reported.

538.221 **1105**

Theory of Saturation Magnetization in Binary Ferromagnetic Alloys.—H. Statz. (*Z. Naturf.*, Aug. 1952, Vol. 7a, No. 8, pp. 506–511.) The electron structure of the alloys Ni-Cu, Ni-Zn, Ni-Co, Fe-Ni, Fe-Co, Fe-V and Fe-Cr is investigated in relation to the saturation magnetization.

538.221 **1106**

Variation of the Magnetic Permeability of a Mild Steel subjected to a Periodic Stress.—G. Vidal & P. Lanusse. (*C. R. Acad. Sci., Paris*, 16th Nov. 1953, Vol. 237, No. 20, pp. 1213–1215.) Continuation of work noted previously (446 of February).

538.221 : 621.318.124 **1107**

Dielectric Behaviour of Granular Semiconducting Aggregates, with Special Reference to some Magnesium Ferrites.—A. Fairweather & E. J. Frost. (*Proc. Instn elect. Engrs*, Part IIA, 1953, Vol. 100, No. 3, pp. 15–22.) "Aggregated granular semiconductors can display high permittivities and dispersion effects which vary with temperature and voltage. This behaviour need not be characteristic of the granule material: it can be a consequence of its conductivity and of a particular kind of inhomogeneity of the aggregate arising from the contact structure of the intergranular boundaries. The dielectric properties of certain sintered magnesium ferrites can be accounted for in this way."

538.221 : 621.318.124 : 538.66 **1108**

On the Magnetization of Magnesium Ferrite.—N. Sakamoto, T. Asahi & S. Miyahara. (*J. phys. Soc. Japan*, Sept./Oct. 1953, Vol. 8, No. 5, pp. 677–678.) An experimental investigation of the effect of heat treatment is reported. The results are summarized in a table showing the rates of cooling from 1 100°C and the saturation magnetization per mol at room temperature. A table is also given of the characteristic temperatures, derived from Néel's chemical-equilibrium condition (3159 of 1949), corresponding to the various quenching temperatures.

538.221 : 621.318.134 **1109**

Influence of the Ionic Diameters of the Rare Earths on the Ferromagnetic Properties of their Ferrites.—G. Guiot-Guillain. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1654–1656.) The ferromagnetic Curie points for three groups of rare-earth ferrites exhibiting distinct properties are shown to be related to the ionic diameters by simple expressions. An explanation is advanced of the observations of two Curie points in one group.

538.23 **1110**

Some New Relations connecting the Magnitudes of Losses with the Coercive Force.—N. S. Akulov & T. A. Elkina. (*C. R. Acad. Sci. U.R.S.S.*, 21st March 1952, Vol. 83, No. 3, pp. 377–379. In Russian.) The irreversible magnetization (retentivity) and the losses in weak fields can be calculated by assuming ferromagnetic materials to consist of elementary regions with rectangular hysteresis loops [Preisach (3691 of 1935)], the coercive force varying from region to region. The experimental and calculated losses for several materials are in good agreement.

538.632 : [546.817.241 + 546.331.31 **1111**

Sensitive Hall Measurements on NaCl and on Photoconductive PbTe.—J. L. Levy. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 215–218.) Measurements were made on NaCl over the temperature range 650–795°C and on PbTe at 190°C and at 30°C. Because of the high noise level, only an upper limit for the Hall mobility could be determined for NaCl. The results for PbTe support Simpson's theory (861 of 1952) that an increase in photoconductivity is primarily due to an increase in carrier density and only secondarily to a change of mobility.

539.153 : 546.281.26 **1112**

Energy of Trapped Electrons in Ionic Solids.—K. Lehovec. (*Phys. Rev.*, 15th Oct. 1953, Vol. 92, No. 2, pp. 253–258.) The energy of an electron localized in a crystal at an impurity carrying multiple positive charges is calculated. The results are applied to a tentative interpretation of activation energies of SiC crystals observed by Busch (745 of 1947).

546.26 : 539.215.3 : 537.311.4 **1113**

The Properties of Carbon Contacts.—R. O. Grisdale. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1288–1296.) The correlation between the contact properties and the crystallographic structure of the surfaces is relatively little influenced by the intercrystal boundaries. The contact properties are determined by those of the small number of crystals in contact. The physical properties of these crystals are studied.

546.431-31 **1114**

Oxygen Vacancies in Barium Oxide.—R. L. Sproull, R. S. Bever & G. Libowitz. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 77–80.) The diffusion of the blue coloration produced when BaO crystals are heated in certain metal vapours (1115 below) was measured at temperatures between 800° and 1 300°C. Comparison of the results with those obtained by Redington (432 of 1953) indicates that the diffusion process associated with the coloration does not involve the transport of Ba, and that the principal lattice defects in BaO with excess metal are O vacancies.

546.431-31 : [535.215 + 535.343.2 **1115**

Optical Absorption and Photoconduction in the Visible and Near Infrared in Single Crystals of BaO.—W. C. Dash. (*Phys. Rev.*, 1st Oct. 1953, Vol. 92, No. 1, pp. 68–76.) Optical-absorption measurements indicate the presence of absorption bands at 0·8 and 1·4 eV, induced by ultraviolet or X-ray irradiation at about − 160°C. These bands are enhanced about fivefold on heating a crystal in air to about 1 600°C and quenching. Absorption curves for crystals heated in Ba, Al, Mg or Ca vapour all exhibit a maximum at 2 eV, which is attributed to interstitial Ba or O vacancies. Photoconduction studies indicate the presence of energy levels at 2 and 2·6 eV as well as those at 0·8 and 1·4 eV.

546.431.824-31 **1116**

Temperature Changes of Single Crystals of $BaTiO_3$.—I. N. Belyaev, N. S. Novosil'tsev, E. G. Fesenko & A. L. Khodakov. (*C. R. Acad. Sci. U.R.S.S.*, 11th April 1952, Vol. 83, No. 5, pp. 675–676. In Russian.) The temperature dependence of the dielectric constant and of the crystal cell parameters was determined for two crystals prepared from a solution and one by double decomposition. The results are shown graphically.

546.431.824-31 : 537.226.33 **1117**

Time Effects in the Hysteresis Loop of Polycrystalline Barium Titanate.—M. McQuarrie. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1334–1335.) The maximum and the remanent polarization decrease with aging by approximately the same amount until the loop shows a constriction at the centre. This effect can be partially annulled by application of a strong alternating field, and completely annulled by heating to above the Curie temperature.

621.383.49 : 546.482.21 : 535.215.5 **1118**

Photoresistivity and Photoactivation of CdS Single Crystals.—V. E. Lashkarev, V. S. Medvedev, A. I. Skopenko, G. A. Fedorus & M. K. Sheinkman. (*C. R. Acad. Sci. U.R.S.S.*, 11th Oct. 1952, Vol. 86, No. 5, pp. 905–907. In Russian.) The increase of light sensitivity due to background illumination was investigated. Graphs are shown of the variation in sensitivity (photoelectric-current/quantum) with the wavelengths of the background illumination λ_p and impulse illumination λ_i, in the visible-light range. The spectral sensitivity in the 2 100–4 000-Å range is also shown.

546.561.221 **1119**

On the Electrical Conductivity of Cuprous Sulfide: a Diffusion Theory.—I. Yokota. (*J. phys. Soc. Japan*, Sept./Oct. 1953, Vol. 8, No. 5, pp. 595–602.) Cuprous sulphide, a *p*-type semiconductor, exhibits mixed electronic and ionic conduction in the 110–470°C β phase. A theory of conduction is developed which gives values for the potential distribution in the material in good agreement with values observed by Miyatani & Suzuki (1120 below), for both transient and steady-state conditions. The temperature dependence of the ionic and hole conductivities and of the mobility of vacant copper ion lattice points is shown graphically.

546.561.221 **1120**

On the Electric Conductivity of Cuprous Sulfide: Experiment.—S. Miyatani & Y. Suzuki. (*J. phys. Soc. Japan*, Sept./Oct. 1953, Vol. 8, No. 5, pp. 680–681.) Yokota's theory of conduction (1119 above) is used to calculate the mobility and the concentration of lattice defects from the experimental results for β-phase cuprous sulphide.

546.817.831.4.03 + 546.817.824.03 **1121**

Ferroelectricity versus Antiferroelectricity in the Solid Solutions of $PbZrO_3$ and $PbTiO_3$.—E. Sawaguchi. (*J. phys. Soc. Japan*, Sept./Oct. 1953, Vol. 8, No. 5, pp. 615–629.) The phase diagram of the solid solutions was investigated by measuring the variations with temperature of the dielectric constant, thermal expansion, specific heat and lattice constants. In $Pb(Zr97\text{-}Ti3)O_3$, two antiferroelectric phases, one ferroelectric phase and one paraelectric phase were observed. The free energies in the four states are compared as functions of the temperature and the Ti ion concentration. The results are shown graphically.

548.0 : 539.378.3 **1122**

Some Predicted Effects of Temperature Gradients on Diffusion in Crystals.—W. Shockley. (*Phys. Rev.*, 15th Sept. 1953, Vol. 91, No. 6, pp. 1563–1564.) Experiments are outlined by means of which it is possible to distinguish between diffusion due to interstitial atoms and diffusion due to vacancies.

621.315.61 : 061.3 **1123**

Symposium of Papers on Insulating Materials.—(*Proc. Instn elect. Engrs*, Part IIA, 1953, Vol. 100, No. 3, pp. 1–308.) Full report of the proceedings at the symposium held in March 1953, with index.

MATHEMATICS

517.9 **1124**

The Eigenvalues of $\nabla^2 u + \lambda u = 0$ when the Boundary Conditions are given on Semi-infinite Domains.—D. S. Jones. (*Proc. Camb. phil. Soc.*, Oct. 1953, Vol. 49, Part 4, pp. 668–684.) Investigation of an equation which represents the small oscillations of many physical systems.

MEASUREMENTS AND TEST GEAR

621.317 : 537.71 (083.74) **1125**

The Accuracy of Measurement of Electrical Standards.—A. Felton. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 543–544.) Discussion on 1952 of 1952.

621.317 : 621.383.2 **1126**

The Photodianode.—Deloffre, Pierre & Roig. (See 1249.)

621.317.3 : 621.396.67.029.64 **1127**

Measurements on Aerials for Centimetre Waves.—M. Bouix. (*Ann. Télécommun.*, Oct. 1953, Vol. 8, No. 10, pp. 314–326.) Methods are discussed for the measurement of (*a*) s.w.r. (to test the matching between aerial and feeder), (*b*) phase of primary radiators, (*c*) radiation patterns both for primary radiators and complete aerial systems, (*d*) gain. Equipment described includes transmitter and sensitive receiver for the radiation-pattern and gain measurements. Attention is drawn to special requirements as regards the terrain over which the tests are made.

621.317.3.029.63/.64 + 534.62 **1128**

A New Anechoic Chamber for Sound Waves and Short Electromagnetic Waves.—Meyer, Kurtze, Severin & Tamm. (See 942.)

621.317.31 : 621.375.2 **1129**

Measurement of Weak Electric Charges by means of Pulse Technique — Study of a Fast-Acting Preamplifier with High Input Impedance and Low Noise.—H. Guillon. (*Onde élect.*, Nov. 1953, Vol. 33, No. 320, pp. 627–636.)

621.317.31 : 621.387.4 **1130**

Measurement of Weak Electric Charges by means of Pulse Technique — α-Radiation Spectrometry.—G. Valladas. (*Onde élect.*, Nov. 1953, Vol. 33, No. 320, pp. 615–626.)

621.317.32 : 537.1 **1131**

The Static and Dynamic Measurement of Electromotive Forces.—W. J. Poppelbaum. (*Helv. phys. Acta*, 15th Sept. 1953, Vol. 26, No. 5, pp. 489–498. In French.) Generalization of Meixner's equation (*Ann. Phys., Lpz.*, 1939, Vol. 35, p. 701) leads to a formulation including within its scope phenomena as varied as induction, thermoelectricity and the chemical processes in a cell. Consideration of the distinction between voltaic and galvanic potential difference results in a simple method of taking account of contact potential difference in static measurements.

621.317.335 **1132**

Precise Measurement of the Complex Dielectric Constants of Liquids by Voltage Resonance.—C. Abgrall. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1650–1652.) A substitution method is used in which either a standard capacitor or the cell containing the liquid is connected in an oscillatory circuit in series with a high impedance. Analysis of the system is based on a linear formulation, and the effect of the impedances of the connections is examined.

621.317.335.029.64 **1133**

Method for the Measurement of the Dielectric Constant of Gases at Ultrahigh Frequencies.—A. Gozzini & E. Polacco. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1497–1499.) A klystron generator, operated at about 10 kMc/s, is frequency modulated between the limiting frequencies ν_0 and ν_1 by application of a sawtooth voltage to the repeller. Two cavities tuned to different frequencies between ν_0 and ν_1 are associated with the system, one of the cavities being filled with the gas under test. The dielectric constant is determined from the time interval between the instants when the two cavities resonate.

621.317.335.029.64 **1134**

Complementary Note on the Method of Measurement of the Dielectric Constant of Gases at U.H.F.—A. Gozzini & E. Polacco. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1652–1654.) A modification of the method previously described (1133 above) to give improved sensitivity is proposed.

621.317.335.3.029.65 **1135**

A Spectrometer for Millimetre Wavelengths.—W. Culshaw. (*Proc. Instn elect. Engrs*, Part 11A, 1953, Vol. 100, No. 3, pp. 5–14. Discussion, pp. 54–60.) A free-space method is described for the measurement of permittivity at mm λ, using the microwave analogue of the optical spectrometer, horns with lenses taking the place of the optical collimator and telescope. The reflectivity of sheets of material is investigated at different angles of incidence for different polarizations; interference minima and Brewster angle are determined and accurate values of permittivity are hence deduced. The effects of dielectric loss and of diffraction are discussed. Results substantiating the theory are presented. An extension of the method to deal with liquids is described.

621.317.34.018.75 : 621.315.212 **1136**

Echo Meter with Very Short Pulse Duration for Investigation of Coaxial-Pair Television Cables.—G. Comte, M. Bouderlique & G. Thévenet. (*Câbles & Transm.*, July 1953, Vol. 7, No. 3, pp. 263–269.) A description is given, with circuit details, of an instrument designed for production testing of television cables, with application for research at higher frequencies. Features of the equipment are the short pulse duration (0·02 μs) and the use of distributed amplification in the echo amplifier to give a wide frequency band.

621.317.34.029.5/.6] : 621.315.212 **1137**

Tests at Very High Frequencies on Production Lengths of Coaxial Cable.—J. Lorrin. (*Câbles & Transm.*, July 1953, Vol. 7, No. 3, pp. 218–241.) A null method of measurement is described for determination of propagation coefficient and characteristic impedance in production testing of coaxial cables. Measurement principles are based on transmission-line theory taking account of irregularities; this is dealt with in an appendix. Bridge balance is obtained by adjustment of both reactance and frequency, and the design of an oscillator/receiver unit with a single frequency control is discussed. Illustrated descriptions are given of two instruments. Results of measurements on cables of length 100–300 m are shown.

621.317.341.029.62/.65 **1138**

A.M. System measures Microwave Attenuation.—J. Korewick. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 175–177.) See 803 of March.

621.317.35 : 621.3.018.78 **1139**

Measuring Non-linearity.—D. C. Pressey. (*Wireless World*, Feb. 1954, Vol. 60, No. 2, pp. 60–62.) A simple method is presented which is supplementary to that described by Wigan (2383 of 1953) and which uses a frequency-insensitive element to perform the subtraction of the fundamental from the composite wave.

621.317.38.029.63 **1140**

Force on a Shorted Ring in a U.H.F. Field in a Coaxial Cavity.—S. N. Kalra. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1339–1340.) The change in potential energy of a metal ring, the dimensions of which are small compared with λ, is made the basis of power measurement. Accuracy for powers of a few watts is within ∼ 1%.

621.317.44 **1141**

Dynamic Measurements on Electromagnetic Devices.—M. A. Logan. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1413–1467.) An electronic timing system controlling mercury-contact relays is used to switch in the measuring instrument (e.g., fluxmeter) for a very short period only at a preselected instant of each cycle of operation of the device tested. The system and the circuits required for the dynamic measurement of magnetic flux, current, displacement and velocity response are described.

621.317.444 **1142**

A Small Sensitive Magnetometer.—T. M. Palmer. (*Proc. Instn elect. Engrs*, Part 11, Oct. 1953, Vol. 100, No. 77, pp. 545–550.) The measuring head contains a solenoid through which is passed a d.c. balancing out the field under test. A saturating current of frequency 5 kc/s is passed through a fine mumetal wire within the solenoid, causing its effective longitudinal permeability to alternate, so that a field along the wire produces an alternating e.m.f. in the solenoid; this e.m.f. serves as an indication of the field. A change of 2×10^{-5} oersted can be detected. The measurement range is limited to about 50 oersted due to the heating of the solenoid.

621.317.7 **1143**

Device for Measurement of the Time Constants of Indicating Instruments.—J. Mey & H. Thibert. (*Ann. Télécommun.*, Oct. 1953, Vol. 8, No. 10, pp. 327–334.) The time constant for indication, the time for restoration to zero, and the 'integrating' time are considered, particularly in relation to volume and modulation meters for telephone testing. Apparatus devised for measuring these time constants comprises an electro-optical system for marking the passage of a galvanometer needle through a predetermined position, an electronic chronometer, and a 'chronotome' relay.

621.317.7.088 **1144**

Performance Limits in Electrical Instruments.—A. H. M. Arnold. (*Proc. Instn elect. Engrs*, Part 11, Oct. 1953, Vol. 100, No. 77, pp. 543–544.) Discussion on 1971 of 1952.

621.317.714.024 **1145**

Non-Contact D.C. Ammeter.—W. H. Bailey. (*Elect. Rev., Lond.*, 21st Aug. 1953, Vol. 153, No. 8, pp. 397–400.) Description of a device which permits remote indication and recording of the current in a cable.

621.317.729 **1146**

The Accurate Mapping of Electric Fields in an Electrolytic Tank.—K. F. Sander & J. G. Yates. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 569–570.) Discussion on 2739 of 1953.

621.317.756 + 621.317.77 **1147**

A Harmonic-Response-Testing Equipment for Linear Systems.—D. O. Burns & C. W. Cooper. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, p. 467.) Discussion on 3374 of 1953.

621.317.76 + 531.771] : 621.387 **1148**
A High-Speed Precision Tachometer.—Bland & Cooper. (See 1153.)

621.373.43 : 621.317.3 **1149**
High-Voltage Sawtooth and Rectangular-Wave Pulse Generator.—W. D. Edwards. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, pp. 36–39.) Descriptions are given of a square-wave generator giving an output of 0–20 kV with pulse duration continuously variable between 0·05 and 80 μs, and of a sawtooth generator giving a peak output of 18 kV with rise time of 15 μs–10 ms. The generators are specially designed for measurements of dielectric strength.

621.397.5 : 535.623].001.4 **1150**
Methods of Verifying Adherence to the N.T.S.C. Color Signal Specifications.—A. C. Luther, Jr. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 235–240.) The composition of the colour signal is determined by measuring the amplitudes and relative phases of a group of bar signals corresponding to saturated primary colours and their complements. The use of a simple demodulator for accurate measurement of phase at the 3·58-Mc/s subcarrier frequency is described.

621.397.5 : 535.623].001.4 **1151**
A Versatile Approach to the Measurement of Amplitude Distortion in Color Television.—J. A. Bauer. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 240–246.) The importance of system linearity for maintaining the selected value of gamma is emphasized, and an instrument developed for checking the degree of nonlinearity is described.

621.397.5 : 535.623].001.4 **1152**
Test Instruments for Color Television.—W. C. Morrison, K. Karstad & W. L. Behrend. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 247–258.) Equipment for use in measuring frequency response, differential gain and differential phase, and sound-to-picture frequency separation is described.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.771 + 621.317.76] : 621.387 **1153**
A High-Speed Precision Tachometer.—W. R. Bland & B. J. Cooper. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, pp. 2–8.) An integrating-type electronic tachometer with ranges of 0–8 000 and 10–80 000 r.p.m. and a reading accuracy within 0·01% uses cold-cathode glow-discharge tubes to give a visual display. The instrument can be used with a variety of pickups, and can also be used as a frequency meter.

551.508.1 : 621.396.91 **1154**
The Ground Equipment for the F-Type Radiosonde.—B. B. Huddar, K. Nagarajan, N. C. Dhar & S. P. Venkiteshwaran. (*Indian J. Met. Geophys.*, Oct. 1953, Vol. 4, No. 4, pp. 347–352.) Equipment in use at Poona is described; the receiver is of superregenerative type, and the recorder is of moving-coil type.

621-52 : 621.389 **1155**
An Electronic Process Controller.—J. R. Boundy & S. A. Bergen. (*Proc. Instn elect. Engrs*, Part II, Oct. 1953, Vol. 100, No. 77, pp. 561–562.) Discussion on 1386 of 1952.

621.316.722 : 621.383.27 : 621.387.464 **1156**
Device for the Stabilization of Photomultipliers.—R. Ascoli. (*Nuovo Cim.*, 1st July 1952, Vol. 9, No. 7, pp. 615–617.) A stabilizer for scintillation counters makes use of the constancy of the emission from a radioactive source.

621.385.832/.833] : 538.691 **1157**
Image Distortion due to Pole-Piece Asymmetry in Electron Lenses.—W. Glaser & P. Schiske. (*Z. angew. Phys.*, Sept. 1953, Vol. 5, No. 9, pp. 329–339.)

621.385.833 **1158**
Electron-Optical Properties of Electrostatic Lenses: Part 2.—W. Lippert & W. Pohlit. (*Optik, Stuttgart*, 1953, Vol. 10, No. 9, pp. 447–454.) Further results are given of the work on unipotential lenses previously noted (795 of 1953).

621.385.833 **1159**
Trajectories in the Symmetrical Electron Lens.—L. Jacob & J. R. Shah. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1261–1266.) Numerical evaluation of trajectories in a strong unipotential lens. See also 1396 of 1952 (Shah & Jacob).

621.387.464 **1160**
The Efficiency of the Anthracene Scintillation Counter—D. K. Butt. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406A, pp. 940–944.) Investigation of a counter having a crystal about 1 cm^2 × 2 mm placed on the end of an uncooled E.M.I. Type-5060 photomultiplier tube.

621.387.464 : 550.835 **1161**
A Scintillation Counter for Radioactivity Prospecting.—D. H. Peirson & J. Pickup. (*J. Brit. Instn Radio Engrs*, Jan. 1954, Vol. 14, No. 1, pp. 25–32.) A simple and compact arrangement is obtained by using a scintillation counter in conjunction with a cold-cathode valve in the counting-rate meter circuit and a specially designed recording microammeter.

PROPAGATION OF WAVES

538.566 + 621.372.2 **1162**
The Effect of the Radiation Condition in the case of Complex Wave Number, and its Significance in the Problem of Surface Waves.—A. Haug. (*Z. Naturf.*, Aug. 1952, Vol. 7a, No. 8, pp. 501–505.) It is shown that Sommerfeld's radiation condition (i.e., that the wave vanishes at infinity) guarantees the uniqueness of the solutions of the wave equation $\Delta u + k^2 u = 0$ in the whole space, not only for real but also for complex values of the wave number k. It follows from the treatment presented that the existence of Sommerfeld's surface wave is not inconsistent with the radiation condition.

538.566 + 621.372.2] : 621.3.012 **1163**
New Chart for the Solution of Transmission-Line and Polarization Problems.—Deschamps. (See 965.)

621.396.11 **1164**
Nonstandard Radio Propagation.—P. G. Forsyth. (*Nature, Lond.*, 21st Nov. 1953, Vol. 172, No. 4386, p. 966.) Brief report of long-range reception observed at Ottawa on frequencies between 60 and 72 Mc/s.

621.396.11 : 551.5 **1165**
Ultra-short-Wave Field Strength in a Ground-Based Radio Duct.—R. S. Unwin. (*Nature, Lond.*, 7th Nov. 1953, Vol. 172, No. 4384, pp. 856–857.) Discussion of field-strength observations at λ 3 cm, 9 cm, and 60 cm, made at various heights over the sea under widely differing superrefractive conditions. A rough estimate can be made of the maximum field strength in the duct at

distances up to 100 km from the transmitter, if the average width of the ground-based duct can be assumed from meteorological data to be greater than a critical value for the particular wavelength. See also 1471 of 1953 (Hay & Unwin) and back references.

621.396.11 : 551.510.535 **1166**

Coupling and Conditions for Reflection of the Ordinary and Extraordinary Electromagnetic Waves in an Inhomogeneous Anisotropic Plasma (Ionosphere).—R. Jancel & T. Kahan. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1657–1659.) The propagation equations are solved, taking the plasma as characterized by a dielectric tensor which does not vary with height except in so far as the electron concentration varies, and taking acccunt of the earth's magnetic field. The conditions giving rise to triple splitting are established.

621.396.11 : 551.510.535 **1167**

A New Phenomenon of Interaction between Waves and Free Electrons subjected to the Terrestrial Magnetic Field.—M. Cutolo. (*Nuovo Cim.*, 1st Aug. 1952, Vol. 9, No. 8, pp. 687–698.) Experiments indicate that modulated waves of carrier frequency equal to the frequency of rotation of free electrons suffer appreciable demodulation in traversing the ionosphere, due to the action of the terrestrial magnetic field. The magnitude of the effect increases with the modulation frequency. Various names, e.g., self-demodulation, are suggested for the effect. The physical process involved is discussed and the importance of the effect in broadcasting and in the study of the ionosphere E layer is indicated. A long summary in English is included. See also 1758 of 1951.

621.396.11 : 621.317.353.3 : 551.510.535 **1168**

Experimental Determination of the Resonance Curves in the Motion of the Slow Electrons in the Upper Atmosphere.—M. Cutolo. (*Nuovo Cim.*, 1st May 1952, Vol. 9, No. 5, pp. 391–407.) Theory of gyrointeraction between waves in an ionized medium is reviewed. Double-hump or single-hump resonance curves are obtained, depending on the experimental conditions. Experiments made in Italy in 1950 are described, when by varying the frequency of the unmodulated wave the transition from the double-hump to the single-hump curve was observed. See also 720 of March.

621.396.812 : 621.396.621.59 **1169**

Long-Range Communication Trends.—Crosby. (See 1172.)

RECEPTION

621.396.62/.63 **1170**

Conelrad Receiver with Built-In Alarm.—R. E. Quenstedt. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 156–157.) Description of a f.m. broadcast receiver with carrier-failure alarm, for use in controlled broadcast stations required to monitor a regional parent station of a civil defence scheme.

621.396.621 + 621.397.621 **1171**

Radio and Television at the 16th Salon National.—P. A. François. (*TSF et TV*, Nov. & Dec. 1953, Vol. 29, Nos. 301 & 302, pp. 359–364 & 393–394.) General report of the Paris exhibition, 25th Sept.–5th Oct. 1953, with tabulated details of the television receivers shown. Reports of the exhibition are also given in *Toute la Radio*, Nov. 1953, Vol. 20, No. 180, pp. 410–413, and *Télévision*, Nov. 1953, No. 38, pp. 264–266.

621.396.621.59 : 621.396.812 **1172**

Long-Range Communication Trends.—M. G. Crosby. (*Trans. Inst. Radio Engrs*, July 1953, Vol. CS-1, No. 1, pp. 41–53.) Various types of fading due to multipath ionospheric transmission are reviewed and methods of reducing fading effects are discussed. The interference rejection and i.f. a.f. selectivity transfer obtained with exalted-carrier detection are noted. The advantage of frequency-shift keying for telegraphy is pointed out. The application of exalted-carrier and s.s.b. methods in a triple-diversity system is illustrated.

STATIONS AND COMMUNICATION SYSTEMS

621.376.2 : 621.396.5 : 621.396.822 **1173**

Noise and Radiotelephony with Amplitude Modulation.—P. Marcou. (*Ann. Télécommun.*, Oct. 1953, Vol. 8, No. 10, pp. 339–351.) D.s.b. and s.s.b. a.m. systems are compared, using as criterion the signal/noise ratio at the receiver output when white noise is mixed with the r.f. signal. The effect of different detecting processes on the signal/noise ratio is analysed. The s.s.b. system makes better use of available power inasmuch as (*a*) the carrier is suppressed or reduced, (*b*) the r.f. noise is halved, and (*c*) reception is linear; the advantage due to the this last feature only becomes significant, however, for output signal/noise ratios too low to give good intelligibility even with this improvement. With s.s.b. transmissions, the ear accepts quasi-synchronous demodulation, not necessarily in phase.

621.39.001.11 : 621.376 **1174**

Comparative Study of Modulation Methods.—R. M. Page. (*Trans. Inst. Radio Engrs*, July 1953, Vol. CS-1, No. 1, pp. 13–22.) To express the results of information theory in practical terms, direct, coded and modulated-carrier coded transmission systems are analysed on the basis of Shannon's equation. Basic transformer theory is applied to the action of coding and an expression is derived relating power ratio to bandwidth ratio in terms of the dynamic range of the information. Curves showing signal/noise ratio at a receiver output as a function of signal input power for s.s.b. a.m., d.s.b. a.m., wide-band f.m. and binary-code p.c.m. systems are compared.

621.39.001.11 : 621.394 + 621.396.3 **1175**

The Transmission of Intelligence in Typescript.—I. S. Coggeshall. (*Trans. Inst. Radio Engrs*, July 1953, Vol. CS-1, No. 1, pp. 4–13.) Practical aspects of the application of communication theory in telegraphy are reviewed.

621.396.41 **1176**

Properties of a Multiplex Signal with Pulses of Alternate Sign.—L. Le Blan. (*C. R. Acad. Sci., Paris*, 21st Dec. 1953, Vol. 237, No. 25, pp. 1662–1664.) Analysis of a two-channel system in which one channel uses positive a.m. pulses while the other uses negative a.m. pulses. Simple methods can be used to separate the two signals at the receiver; in general, arrangements must be provided for eliminating crosstalk.

621.396.44 **1177**

Simplified Carrier-Current System for Short Distances.—G. H. Bast & J. L. Hurault. (*Câbles & Transm.*, July 1953, Vol. 7, No. 3, pp. 185–217.) The paper is based on an investigation made for the Netherlands Administration. A detailed study is made of design requirements for a multiplex system operating over distances of 20–300 km on any suitable existing lines. In a discussion of economic aspects, the attenuation required to avoid crosstalk is calculated for different channel widths, and the choice of a 6-kc/s bandwidth is explained. Full descriptions are given of terminal equipment for a 32-channel system on symmetrical-pair cables and the main oscillators and control circuits at the central station.

621.396.662.029.5/.6 1178

Design Trends in Communication Equipment.—L. M. Craft. (*Trans. Inst. Radio Engrs*, July 1953, Vol. CS-1, No. 1, pp. 22–30.) General discussion of omnichannel operation of u.s.w. and s.w. equipment. Outline descriptions are given, with illustrations, of automatic tuning and channel-selection units incorporated in Collins transmitters and receivers.

621.396.712 1179

La Maison de la Radio, Paris.—H. Testemale. (*Télév. franç.*, Nov. 1953, No. 100, pp. 23–25.) A competition has been held for the design of a building to serve as a comprehensive broadcasting centre; the winning design is described.

621.396.712.029.62 : 621.396.81 1180

U.S.W. Planning in Austria.—J. Burgstaller. (*Radio Tech., Vienna*, Oct. 1953, Vol. 29, No. 10, pp. 340–345.) Formulae and curves for the theoretical field strength of horizontally polarized waves received at a height 30 ft above ground, and for the correction factor for the attenuation due to diffraction in mountainous districts are given and discussed. The frequency considered is 98 Mc/s. Maps show the estimated area coverage provided by six 25-kW transmitting stations and, in the case of the Klagenfurt transmitter, the effects of different aerial heights and radiated powers.

621.396.932 1181

Aspects of Naval Communications Systems.—J. A. Krcek. (*Trans. Inst. Radio Engrs*, July 1953, Vol. CS-1, No. 1, pp. 54–58.) General review of problems and developments in the design and arrangement of radio equipment aboard a communications vessel which may carry about 150 receivers and 60 transmitters.

621.396.933 1182

A Discussion of United Air Lines V.H.F. Network Developments.—K. J. Rhead. (*Trans. Inst. Radio Engrs*, June 1953, No. PGAE-8, pp. 9–11.) The network comprises five transmitter-receiver stations, with automatic locking out of either transmitter or receiver when the other unit is in operation. Preliminary experience indicates that intermodulation effects are considerably reduced by using a stable oscillator, by sub-channelling arrangements, and by restriction of the speech band to the range 200–2 500 c/s.

SUBSIDIARY APPARATUS

621-526 1183

Analogue Methods for Optimum Servomechanism Design.—F. C. Fickeisen & T. M. Stout. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 244–250. Discussion, p. 250.)

621-526 1184

Feedback Control Systems with Dead-Time Lag or Distributed Lag by Root-Locus Method.—Y. Chu. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 291–296.) Generalization and application of the method originated by Evans (2337 of 1952).

621-526 1185

Synthesis of Feedback Control System by Phase-Angle Loci.—Y. Chu. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 330–339.) A modification of Evans' root-locus method (2337 of 1952).

621-526 1186

The Use of Nonlinear [tachometric] **Feedback to Improve the Transient Response of a Servomechanism.**—J. B. Lewis. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 449–453. Discussion, p. 453.)

621-526 : 621.3.016.35 1187

Stabilization of a Servomechanism subject to Large Amplitude Oscillation.—E. S. Sherrard. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 312–324.) The frequency-response method of analysis developed by Kochenburger (224 of 1951) is applied to a system containing a saturable amplifier and in determining the required nonlinear stabilizing filter.

621-526 : 621.3.016.35 1188

Stability Limits for Third-Order Servomechanisms.—T. J. Higgins & J. G. Levinthal. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 459–466. Discussion, pp. 466–467.) Curves are derived giving directly the roots and coefficients of specified cubic characteristic equations. Their use in facilitating analysis and design of servo systems is explained and illustrated.

621-526 : 621.316.7 1189

The Analysis of Sampled-Data Systems.—J. R. Ragazzini & L. A. Zadeh. (*Trans. Amer. Inst. elect. Engrs*, 1952, Vol. 71, Part II, pp. 225–232. Discussion, pp. 232–234.) Full paper; summary abstracted in 1801 of 1953.

621.311.6 1190

Stable Power Supplies for Microwave Standards.—W. P. Ernst. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 168–171.) A description of the power-supply system for operating the klystron frequency standards at the National Bureau of Standards.

621.314.634.004 1191

Selenium Rectifiers — Factors in their Application.—J. Gramels. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1469–1492.)

621.318.5 1192

Design of Relays.—(*Bell Syst. tech. J.*, Jan. 1954, Vol. 33, No. 1, pp. 1–259.) A symposium of papers, dealing with design, production, service and measurements.

TELEVISION AND PHOTOTELEGRAPHY

621.397.2 : 535.623 1193

The Colorplexer — a Device for Multiplexing Color Television Signals in accordance with the N.T.S.C. Signal Specifications.—E. E. Gloystein & A. H. Turner. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 204–212.) The functions of matrixing, band limiting, delay correction, modulating, burst generating, and mixing are described in detail. Waveforms photographed at several points in the colorplexer are shown for one standard colour-bar signal.

621.397.2 : 535.623 1194

Transmission of Color over Inter-City Television Networks.—J. R. Rae. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, No. 1, pp. 270–273.) The additional gain and delay equalizers required for colour transmission and the method for shifting the colour information within the pass band of coaxial cable are discussed.

621.397.24 : 621.315.212.4 1195

The Birmingham-Manchester-Holme-Moss Television-Cable System.—R. J. Halsey & H. Williams. (*P.O. elect. Engrs' J.*, Oct. 1953 & Jan. 1954, Vol. 46, Parts 3 & 4, pp. 118–121 & 171–176.) Shortened version of paper noted in 1147 of 1953.

621.397.24 : 621.372.55 1196

Adjustment of Bridged-T Phase-Correction Networks used in Television Equipment.—H. Martin. (*Câbles &*

E

Transm., July 1953, Vol. 7, No. 3, pp. 175–184.) Properties of equalizing networks for television cables are reviewed. A practical method is described, based on measurement of impedance at a frequency for which the phase shift is 180°, by which network impedance can be adjusted to within ± 2Ω of the correct value throughout the pass band. Propagation-time frequency characteristics are shown for two types of network.

621.397.5 **1197**

Fundamental Problems of Subscription Television: the Logical Organization of the Telemeter System.—L. N. Ridenour & G. W. Brown. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1953, Vol. 61, No. 2, pp. 183–194.) The basic principles of a satisfactory 'pay-as-you-view' system are considered. Essential requirements are (*a*) provision of a coin-actuated mechanism controlling a signal decoder, (*b*) programme sales on a variable-price basis, the unit being a single programme rather than a unit of time, (*c*) announcement of details of the available programme on the channel carrying the programme, for the benefit of anyone tuning in to that channel, and (*d*) an accurate record of each show purchased.

621.397.5 **1198**

Camera Adapter for TV Receivers.—L. E. Flory, W. S. Pike & G. W. Gray. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 141–143.) A complete television system for domestic or business use comprises a vidicon camera unit, the picture signals from which are transmitted to the receiver on a v.h.f. carrier via cable; operating voltages for the camera tube are derived from the receiver circuits.

621.397.5 : 535.623 **1199**

Second Color Television Issue.—(*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 1–348.) The whole of this issue is devoted to an account of developments in colour television since 1951. The first group of papers comprises 22 contributions from the National Television System Committee; the titles of these papers, with the page references and the authors' names, are listed below. The second group comprises 27 contributions from individual workers on various branches of the subject; these papers are abstracted separately.

The Future of Color Television (pp. 5–7).—W. R. G. Baker.

Basic Concepts and Evolution of Color Television (pp. 7–9).—E. W. Engstrom.

Psychophysical and Electrical Foundations of Color Television (pp. 9–11).—A. V. Loughren.

The N.T.S.C.—An Exercise in Technical Coordination (pp. 11–14).—D. B. Smith.

N.T.S.C. Signal Specifications (pp. 17–19).

N.T.S.C. Color Television Field Test (pp. 20–43).—R. DeCola, R. E. Shelby & K. McIlwain.

The N.T.S.C. Monographs (pp. 43–45).—D. G. Fink.

The N.T.S.C. Color Television Standards (pp. 46–48).

Colorimetry in Television: Parts 2 & 3 (pp. 48–57).—F. J. Bingley.

The Choice of Axes and Bandwidths for the Chrominance Signals in N.T.S.C. Color Television (pp. 58–59).—G. H. Brown.

The Constant Luminance Principle in N.T.S.C. Color Television (pp. 60–66).—W. F. Bailey.

Mathematical Formulations of the N.T.S.C. Color Television Signal (pp. 66–71).—G. H. Brown.

Transfer Characteristics in N.T.S.C. Color Television (pp. 71–78).—F. J. Bingley.

Choice of Chrominance Subcarrier Frequency in the N.T.S.C. Standards (pp. 79–80).—I. C. Abrahams.

The 'Frequency Interleaving' Principle in the N.T.S.C. Standards (pp. 81–83).—I. C. Abrahams.

Quadrature Cross Talk in N.T.S.C. Color Television (pp. 84–90).—W. F. Bailey & C. J. Hirsch.

Narrow-Band Transmission of the N.T.S.C. Color Signal (pp. 90–91).—J. G. Reddeck.

System Delay Characteristics in N.T.S.C. Color Television (pp. 92–95).—R. C. Palmer.

Effect of Transmitter Characteristics on N.T.S.C. Color Television Signals (pp. 95–105).—G. L. Fredendall & W. C. Morrison.

Color-Carrier Reference Phase Synchronization Accuracy in N.T.S.C. Color Television (pp. 106–133).—D. Richman.

621.397.5 : 535.623 **1200**

The Concept of Transmission Primaries in Color Television.—P. W. Howells. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 134–138.) The concept of colour space is discussed. The location of the three transmission primaries of the N.T.S.C. system (namely, the monochrome signal and the two colour signals) in the C.I.E. colour space is indicated.

621.397.5 : 535.623 **1201**

Colorimetric Analysis of the N.T.S.C. Color Television System.—D. C. Livingston. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 138–150.) Formulae are developed which enable colour fidelity, compatibility, and adherence to the constant-luminance principle to be assessed. Three different forms of the N.T.S.C. system are compared; the superiority of the standard form is indicated. See also *Convention Record Inst. Radio Engrs*, 1953, Part 4, pp. 51–55.

621.397.5 : 535.623 **1202**

Quantitative Spectral Measurements in Color Television.—J. A. Rado & W. L. Hughes. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 151–156.) Measurements of the spectral sensitivities of the pickup devices and of the colorimetric characteristics of the display devices are discussed. Techniques are described using narrow-band optical-interference filters in conjunction with 'red-pass' gelatin filters.

621.397.5 : 535.623 **1203**

Wide-Range Chromaticity Measurements with Photoelectric Colorimeter.—J. B. Chatten. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 156–160.) Detailed description of a tristimulus colorimeter sufficiently accurate for general work in colour television.

621.397.5 : 535.623 **1204**

Reproduction of Colors in Outdoor Scenes.—D. L. MacAdam. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 166–174.) Available spectrophotometric and colorimetric data on the colours of skin, hair, grass, foliage, sky and earth are summarized and measurements of typical colour-film reproductions are presented. Subjective assessments of colour-reproduction quality are discussed on the basis of these data.

621.397.5 : 535.623 **1205**

The Use of Electronic Masking in Color Television.—R. P. Burr. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 192–200.) A discussion of the use of electrical networks for reducing the effects of photographic cross-coupling introduced when using subtractive colour transparencies as material for television transmission.

621.397.5 : 535.623 **1206**

Matrix Networks for Color TV.—W. R. Feingold. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 201–203.) Summation-type circuits required for colour-television transmitters and receivers are described.

621.397.5 : 535.623 **1207**

Transients in Color Television.—P. W. Howells. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 212–220;

Convention Record Inst. Radio Engrs, 1953, Part 4, pp. 24–34.) When a colour transient occurs, the three components of the transmitted signal respond in a manner determined by the characteristics of the individual channels. The system response is characterized by the resulting path along which the reproduced colour point moves through the colour space from its initial to its final location. An analysis is made of such paths, and the corresponding subjective effects are discussed.

621.397.5 : 535.623 1208
Transition Effects in Compatible Color Television.—J. B. Chatten. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 221–228.) An experimental video-frequency television system is described for investigating the best choice of the three independent colour-signal components to be transmitted. A description is given of an arrangement for predistorting the luminance signal to compensate for luminance variations arising in the reproduction of colour transients.

621.397.5 : 535.623 1209
Reproduction of Luminance Detail by N.T.S.C. Color Television Systems.—D. C. Livingston. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 228–234.) Three different forms of the N.T.S.C. system are compared to determine the relative merits of different methods of gamma correction. The system using a luminance corrector in the transmitter is judged to be the best.

621.397.5 : 535.623 1210
Delay Equalization in Color Television.—G. L. Fredendall. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 258–262.) An equalizer designed by the potential-analogue method consists of four conventional all-pass filter sections.

621.397.5 : 535.623 : 778.5 1211
Brightness Modification Proposals for Televising Color Film.—W. L. Brewer, J. H. Ladd & J. E. Pinney. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 174–191.) It is recommended that (*a*) the effective luminance range should be modified, either in the film or in the television system, to conform to that available on the kinescope, and (*b*) kinescope reproductions of film colours should be made lighter with increasing saturations. Alternative methods of achieving the colour-dependent brightness compensation are discussed.

621.397.5 : 535.623].001.4 1212
Methods of Verifying Adherence to the N.T.S.C. Color Signal Specifications.—Luther. (See 1150.)

621.397.5 : 535.623].001.4 1213
A Versatile Approach to the Measurement of Amplitude Distortion in Color Television.—Bauer. (See 1151.)

621.397.5 : 535.623].001.4 1214
Test Instruments for Color Television.—Morrison, Karstad & Behrend. (See 1152.)

621.397.61 : 535.623 1215
Alignment of a Monochrome TV Transmitter for Broadcasting N.T.S.C. Color Signals.—J. F. Fisher. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 263–270.) A detailed account of the procedure used to adapt the WPTZ (Philadelphia) station.

621.397.611 : 535.623 1216
Image Orthicons for Color Cameras.—R. G. Neuhauser, A. A. Rotow & F. S. Veith. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 161–165.) Operating conditions and performance characteristics of the R.C.A. Type-1854 tube are given.

621.397.611.2 1217
The Flying-Spot Scanning System by means of the MC 13-16.—J. J. P. Valeton & F. H. J. van der Poel. (*Electronic Applic. Bull.*, June/July 1953, Vol. 14, Nos. 6/7, pp. 77–90.) A detailed description is given of the flying-spot scanning system for deriving a picture signal for modulating a television transmitter from transparent positives or negatives. The MC 13-16 c.r. tube used has magnetic focusing and deflection systems. Circuit means are indicated for correcting the signal for the afterglow of the fluorescent screen.

621.397.62 + 621.396.621 1218
Radio and Television at the 16th Salon National.—François. (See 1171.)

621.397.62 1219
Technical Description of a Television Receiver.—A. Bilotti. (*Rev. telegr. Electronica, Buenos Aires*, Sept. 1953, No. 492, pp. 555–560.) Detailed circuit diagram and component values are given for a receiver operating on the intercarrier system, to suit the Argentina television standards, namely, negative picture signal, line frequency 15 625 per sec, frame frequency 50 per sec, aspect ratio 3:4, f.m. sound, separation of 4·5 Mc/s between picture and sound carriers, channel width 6 Mc/s. Reception on all twelve v.h.f. channels is possible.

621.397.62 1220
The D.C. Component in Television.—W. T. Cocking. (*Wireless World*, Feb. 1954, Vol. 60, No. 2, pp. 63–66.) Birkinshaw's views (552 of February) are generally supported, but criticism is made of the well-known circuit in which the cathode of the c.r. tube is fed from the anode of the video stage through a voltage divider. The low input resistance of the tube thus connected may lead to a 50% reduction of the d.c. component. Various modifications of the coupling circuit are suggested for eliminating this defect.

621.397.62 1221
A Printed-Circuit Television Receiver.—G. Székely. (*Télévision*, Oct. 1953, No. 37, pp. 230–232.) Brief description of a new French receiver. All circuits, excepting timebases and supply, but including deflection coils, are printed.

621.397.62 : 535.623 1222
Improving the Transient Response of Television Receivers.—J. Avins, B. Harris & J. S. Horvath. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 274–284.) An examination is made of the delay distortion produced in the i.f. amplifier, and of the extent to which this is compensated by the peaking circuits of the video detector and amplifier. Factors determining cross-talk between the two colour-difference signals in the N.T.S.C. system are discussed. The use of a standard transmission monitor throughout the industry is recommended.

621.397.62 : 535.623 1223
Theory of Synchronous Demodulator as used in N.T.S.C. Color Television Receiver.—D. C. Livingston. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 284–287.) See 3129 of 1953.

621.397.62 : 535.623 1224
The D.C. Quadricorrelator: a Two-Mode Synchronization System.—D. Richman. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 288–299.) A description is given of an automatic-phase-control circuit adapted for colour synchronization in the N.T.S.C. system. The arrangement is simple, reliable and noise-immune. The pull-in and hold-in modes of operation are made indepen-

dent of each other by means of an automatic switch. See also *Convention Record Inst. Radio Engrs*, 1953, Part 4, pp. 13–23.

621.397.62 : 535.623 1225

Processing of the N.T.S.C. Color Signal for One-Gun Sequential Color Displays.—B. D. Loughlin. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 299–308.) Receiver arrangements of two types are described, namely those in which the colour subcarrier signal is modified, and those in which the luminance signal is modified. Circuits of the latter type generally demodulate the colour signal to some extent and correct the luminance signal to produce constant luminance.

621.397.62 : 535.623 1226

Compatible Color Picture Presentation with the Single Gun Tricolor Chromatron.—J. D. Gow & R. Dorr. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 308–315.) Techniques are discussed for operating the tube previously described [3131 of 1953 (Dressler)]. Circuit nonlinearity is corrected so as to ensure colour balance at different brightness levels.

621.397.62 : 535.623 1227

Improvements in the R.C.A. Three-Beam Shadow-Mask Color Kinescope.—M. J. Grimes, A. C. Grimm & J. F. Wilhelm. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 315–326.) Advances made since the original design [844 of 1952 (Law)] are described.

621.397.62 : 535.623 1228

The C.B.S.-Colortron: a Color Picture Tube of Advanced Design.—N. F. Fyler, W. E. Rowe & C. W. Cain. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 326–334.) Full details are given of a three-gun tricolour tube in which the phosphor dots are applied directly to the curved end-plate, and a self-supporting curved mask is provided. See also *Tele-Tech*, Nov. 1953, Vol. 12, No. 11, pp. 73, 150, 165.

621.397.62 : 535.623 1229

A Laboratory Receiver for Study of the N.T.S.C. Color Television System.—C. Masucci, J. J. Insalaco & R. Zitta. (*Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1, pp. 334–343.)

621.397.62 : 621.314.632 1230

Some High Frequency Effects in Germanium Diodes with Special Reference to Television Sound Detectors.—D. D. Jones & B. C. Brodribb. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, pp. 33–35.) The measured performance of Ge diodes at h.f. may differ appreciably from that predicted from the static characteristics. The deviations, which may give rise to highly nonlinear detection, are shown to be consistent with hole-storage effects in the Ge; these effects can be eliminated by production techniques designed to reduce the lifetime of the holes. An indication is given of suitable test methods.

621.397.62 : 621.375.2 1231

Video Amplifier Design Charts.—W. K. Squires & H. L. Newman. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 190–192, 194.) Charts based on transient-response analysis are presented.

621.397.8 1232

Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems: Part 2 — The Grain Structure of Motion Picture Images — An Analysis of Deviations and Fluctuations of the Sample Number.—O. H. Schade. (*J. Soc. Mot. Pict. Telev. Engrs*, March 1952, Vol. 58, No. 3, pp. 181–222.) A treatment of aperture-response theory as applied to the evaluation of relative deviation in motion-picture processes. Part 1: 2293 of 1951.

621.397.8 1233

Image Gradation, Graininess and Sharpness in Television and Motion-Picture Systems: Part 3 — The Grain Structure of Television Images.—O. H. Schade. (*J. Soc. Mot. Pict. Telev. Engrs*, Aug. 1953, Vol. 61, No. 2, pp. 97–164.) An adequate description of granularity in television and motion-picture frames requires specification of the sine-wave spectrum and signal deviation ratio in the retinal image as a function of luminance and for a specified viewing distance. An assessment of the perception of deviations can be made by introducing the characteristic of threshold signal/deviation ratios as the reference level. Part 2: 1232 above.

621.397.8 1234

Note on the Influence of Phase in Television.—A. Dubec. (*Onde élect.*, Nov. 1953, Vol. 33, No. 320, pp. 606–614.) Methods of calculating phase frequency characteristics are reviewed in relation to the design of television receivers.

621.397.8 1235

Eye Movements in Connexion with Television Viewing.—M. P. Lord. (*Nature, Lond.*, 21st Nov. 1953, Vol. 172, No. 4386, pp. 964–965.) A comparison of movements made when viewing interlaced and sequentially scanned pictures indicates little difference; hence instability and 'crawling' associated with interlaced scan cannot be immediately explained in terms of the pattern of eye movements.

TRANSMISSION

621.375.227.029.4 : 621.3.018.783 1236

Nonlinear Distortion in a Class-B Push-Pull Amplifier with Transformer Output.—F. Böttcher. (*Telefunken Ztg*, Aug. 1953, Vol. 26, No. 101, pp. 313–322.) Expressions for the distortion, up to the 4th harmonic, are derived for the case of imperfect magnetic coupling between the halves of the primary winding of the output transformer. An approximate numerical calculation is made for the modulator output stage of an anode-modulated transmitter.

621.396.664 1237

Speech Clippers and their Operation.—W. Schreuer. (*Short Wave Mag.*, Oct. 1953, Vol. 11, No. 8, pp. 465–469.) Average modulation depth is increased without introducing overmodulation on voice peaks by using an amplitude limiter followed by a low-pass filter, with a cut-off frequency $\sim$3 kc/s. High-level and low-level systems are discussed.

VALVES AND THERMIONICS

621.314.63 : 546.289 1238

Recovery Currents in Germanium *p-n* Junction Diodes.—R. G. Shulman & M. E. McMahon. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1267–1272.) When a diode biased in the forward direction has a reverse voltage suddenly applied, a large transient ('recovery') current flows. Values of this current based on a proposed mechanism involving diffusion of stored minority carriers to the barrier are compared with experimental results. The application to variable time-delay devices is discussed.

621.314.632 : 546.289 1239

Theory of the Forward Characteristic of Injecting Point Contacts.—P. C. Banbury. (*Proc. phys. Soc.*, 1st Oct.

1953, Vol. 66, No. 406B, pp. 833–840.) The voltage/current relation for forward voltages across a metal/semiconductor point contact is derived for the case when the current is carried by injected minority carriers. Unit injection ratio is assumed and recombination effects are neglected. Results of measurements on contacts under illumination and experimentally determined forward-voltage/current characteristics of a Ge-W rectifier are in satisfactory agreement with theory.

621.314.632 : 546.289 **1240**

Forward Characteristic of Injecting Area Contacts on Germanium.—H. K. Henisch & F. D. Morten. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406B, pp. 841–844.) Measurements were made on 4·2-Ω.cm *n*-type and on 12-Ω.cm *p*-type Ge illuminated with white light. Au or Ag rectifying electrodes were used. The results found for the floating potential, the contact capacitance and the derived current/voltage barrier characteristic are given and compared with those derived from theory.

621.314.632 : 546.289 : 537.312.6 **1241**

Thermal Effects at Point-Contact Diodes.—P. M. Tipple & H. K. Henisch. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406B, pp. 826–832.) Measurements, by a thermoelectric method, have been made of the contact temperature of a Ge diode, at several points on the voltage/current characteristics. The voltage turnover occurs at a critical contact temperature, which is constant for a given specimen. Also, the temperature gradients in the vicinity of a hot point contact may increase the contact resistance. This observation is discussed.

621.314.632 : 546.289 : 537.312.6 **1242**

Thermal Effects in Point-Contact Rectifiers.—H. L. Armstrong. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1332–1333.) The relation between thermal effects and the shape of the reverse characteristic is investigated for a Type-1N34 Ge rectifier.

621.314.632 : 621.397.62 **1243**

Some High Frequency Effects in Germanium Diodes with Special Reference to Television Sound Detectors.—Jones & Brodribb. (See 1230.)

621.314.7 **1244**

Design Theory of Junction Transistors.—J. M. Early. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1271–1312.) "The small signal a.c. transmission characteristics of junction transistors are derived from physical structure and bias conditions. Effects of minority carrier flow and of depletion layer capacitances are analyzed for a one-dimensional model. The ohmic spreading resistance of the base region of a three-dimensional model is then approximated. Short-circuit admittances representing minority carrier flow, depletion layer capacitances, and ohmic base resistance elements are then combined into an equivalent circuit. Theoretical calculations are compared to observations for two typical designs."

621.314.7 : [546.28 + 546.289 **1245**

A Study of Carrier Injecting Properties of Emitter Contacts and Light Spots at Normal and Moderately Elevated Temperatures.—C. A. Hogarth. (*Proc. phys. Soc.*, 1st Oct. 1953, Vol. 66, No. 406B, pp. 845–858.) "The method of determining the injection efficiency γ of an emitter contact [described previously by Shockley, Pearson & Haynes (380 of 1950)] is discussed and some of the difficulties of the method and the interpretation of experimental results are described. The effects of a fine spot of white light when used as an emitter and hence as a conductivity modulator are investigated and an equivalent minority carrier current for a given optical assembly can be determined. This procedure suggests an experimental method for the determination of γ as a function of temperature. A simple theory for γ in terms of forbidden energy gap, depth of Fermi level, and barrier height ϕ is given and applied to the determination of barrier heights at room temperature, at elevated temperatures, and when an emitter contact on germanium is illuminated. Theoretical curves relating γ and ϕ are presented for Ge and Si of various impurity concentrations. The experiments carried out at elevated temperatures suggest that the surface states on germanium lie at the top of the filled band and that their density is of order 10^{10}–10^{11} cm^{-2}."

621.314.7 : 546.28 **1246**

Forming Silicon Point-Contact Transistors.—H. Jacobs, F. A. Brand & W. Matthei. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, p. 1340.) Particles of a suitable impurity material were pressed between a pointed tungsten electrode and the Si sample, and a high-density current was passed through the junction in a N_2 atmosphere. Best results were obtained using Sb to form *p-n-p* transistors and Al to form *n-p-n* transistors. Some test results are tabulated.

621.314.7 : 621.375.4.029.3 **1247**

Power Transistors for Audio Output Circuits.—L. J. Giacoletto. (*Electronics*, Jan. 1954, Vol. 27, No. 1, pp. 144–148.) Junction transistors cooled by liquids and by metal radiators are described. Analysis previously developed for small-signal operation is adapted to power operation, and the influence of finite base-lead resistance, temperature, frequency and source resistance is examined. Biasing arrangements for typical audio output circuits are discussed.

621.314.7 : 621.396.822 **1248**

Shot Noise in Junction Transistors.—H. C. Montgomery & M. A. Clark. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1337–1338.) The noise figure calculated from Montgomery's formula (643 of 1953) is in fair agreement with the values measured in a *p-n-p* alloy transistor at frequencies above those for which the noise is inversely proportional to frequency.

621.383.2 : 621.317 **1249**

The Photodianode.—G. Deloffre, É. Pierre & J. Roig. (*C. R. Acad. Sci., Paris*, 9th Dec. 1953, Vol. 237, No. 23, pp. 1507–1509.) The 'photodianode' is a tube with a plane photoemissive cathode and two linear anodes arranged parallel to and equidistant from the cathode. The anodes are connected via separate equal resistors to the positive supply terminal, thus there is a potential difference between them depending on the position of the illuminated area; this potential difference is determined by measuring the current through a galvanometer connected between the anodes. The arrangement responds to variations of the direction of a light beam, and can be used for accurate measurements of displacement and rotation.

621.383.4 **1250**

On the Relation between the Speed of Response and the Detectivity of Lead Sulfide Photoconductive Cells.—R. C. Jones. (*J. opt. Soc. Amer.*, Nov. 1953, Vol. 43, No. 11, pp. 1008–1013.)

621.383.5 : 546.23 **1251**

A New Type of Fatigue of Photocells.—G. Blet. (*C. R. Acad. Sci., Paris*, 11th Jan. 1954, Vol. 238, No. 2, pp. 228–230.) The impedance of a Se barrier-layer cell was found to drop immediately on illumination, returning to its original value only very slowly when the illumination was cut off. The suggested explanation is that the liberated photoelectrons suffer collisions which reduce their energy and hence delay their return to their original positions.

621.385 : 681.142 1252
Valve Reliability in Digital Calculating Machines.—Knight. (See 984.)

621.385.029.6 1253
Instabilities in the Smooth-Anode Cylindrical Magnetron.—L. A. Harris. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, p. 1335.) Correction to paper noted in 3293 of 1952. An error in equation (38) invalidates the previous conclusions. The system is stable, with a set of real characteristic frequencies.

621.385.032.213 1254
The Motion of Idealized Vacuum Tube Filaments under Shock.—H. S. Thomas. (*J. appl. Phys.*, Nov. 1953, Vol. 24, No. 11, pp. 1341–1342.) An analysis is made of the motion of an ideal clamped-end string; approximate formulae are derived for the maximum displacement for accelerations of the supports corresponding to three different types of shock. The results are applicable to the investigation of filament-to-grid shorting.

621.385.032.216 1255
Molded Thermionic Cathodes.—D. MacNair, R. T. Lynch & N. B. Hannay. (*J. appl. Phys.*, Oct. 1953, Vol. 24, No. 10, pp. 1335–1336.) The cathodes are made of sintered mixtures of Ni powder and (Ba, Sr)CO_3 on a Ni base. Test results indicate a very high resistance to deactivation by gases and ion bombardment. A comparison with sprayed oxide and other cathodes is made.

621.385.032.216 1256
Deterioration of Valve Performance due to Growth of Interface Resistance.—G. H. Metson & M. F. Holmes. (*P.O. elect. Engrs' J.*, Jan. 1954, Vol. 46, Part 4, pp. 198–199.) Results of measurements on a high-slope pentode indicate that the development of interface resistance between core and coating of the oxide cathode [2378 of 1952 (Child)] can be eliminated by replacing the usual Ni core by a material free from Si, e.g. commercially pure Pt. The lifetime of common receiving valves might thus be doubled.

621.385.032.216 : 546.831 1257
Thermionic Emission and Optical Emissivity of Zirconium.—G. Mesnard. (*Le Vide*, July/Sept. 1953, Vol. 8, Nos. 46/47, pp. 1392–1399.) Measurements were made of the properties of cathodes prepared by coating W or Mo wires with zirconium oxide. The activation by thermal treatment and the development of emission with time were studied. Spectral emissivity, resistance and required heating power are discussed. Similarities are noted between these cathodes and those using other materials, particularly thoria.

621.385.032.216 : 546.841.4-31 1258
Thermionic Properties of Thoria Coatings on Thoriated Molybdenum.—G. Mesnard. (*Le Vide*, July/Sept. 1953, Vol. 8, Nos. 46/47, pp. 1377–1383.) Measurements of the emission from (*a*) thoriated molybdenum, (*b*) thoria coatings on nonthoriated molybdenum, and (*c*) thoria coatings on thoriated molybdenum indicated that no appreciable advantage is obtained by thoriating the molybdenum base. The effects of treatment at high and at medium temperatures are discussed.

621.385.032.24 1259
Gold as a Grid Emission Inhibitor in the Presence of an Oxide-coated Cathode.—B. O. Baker. (*Brit. J. appl. Phys.*, Oct. 1953, Vol. 4, No. 10, pp. 311–315.) "Emission measurements have been made on gold-plated molybdenum and gold-plated manganese-nickel grids in the presence of an oxide-coated cathode. For grids which cannot be designed to operate below 350°C a minimum thickness of 1 μ of gold will suppress grid emission. Silver is not so reliable, but is effective in some cases."

621.385.2 : 621.316.722.1 1260
Characteristics of the Temperature-Limited Diode Type 29C1.—V. H. Attree: F. A. Benson & M. S. Seaman. (*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, p. 42.) Comment on 595 of February and authors' reply.

621.385.3 : 621.396.822 1261
Experimental Investigation of Grid Noise.—N. Houlding & A. E. Glennie. (*Wireless Engr*, Feb. 1954, Vol. 31, No. 2, pp. 35–42.) "Results are given of a detailed investigation of triode noise factor, with particular reference to correlation of induced grid noise with shot noise. It is deduced that correlation is very slight and that, although the optimum value of noise factor can be calculated fairly accurately from the values of shot noise and optimum source resistance, the latter must be found by experiment and therefore the theory is not of major practical importance."

621.385.832 1262
Theory of the Triode Electron Gun with Cylindrical Symmetry.—É. Labin. (*Onde élect.*, Nov. & Dec. 1953, Vol. 33, Nos. 320 & 321, pp. 597–605 & 713–719.) Systems with nonrotational symmetry are considered, such as those used for producing ribbon beams. The method of conformal representation is used and formulae are derived based on purely electrostatic conditions; the validity of these formulae for operating conditions is examined.

621.385.832 : 681.142 1263
Recent Advances in Cathode-Ray-Tube Storage.—Williams, Kilburn, Litting, Edwards & Hoffman. (See 985.)

621.387 1264
Investigation of the use of Caesium Vapour in Thyratron-Type Gas-Filled Valves.—R. Coquerel. (*Le Vide*, July/Sept. 1953, Vol. 8, Nos. 46/47, pp. 1384–1391.)

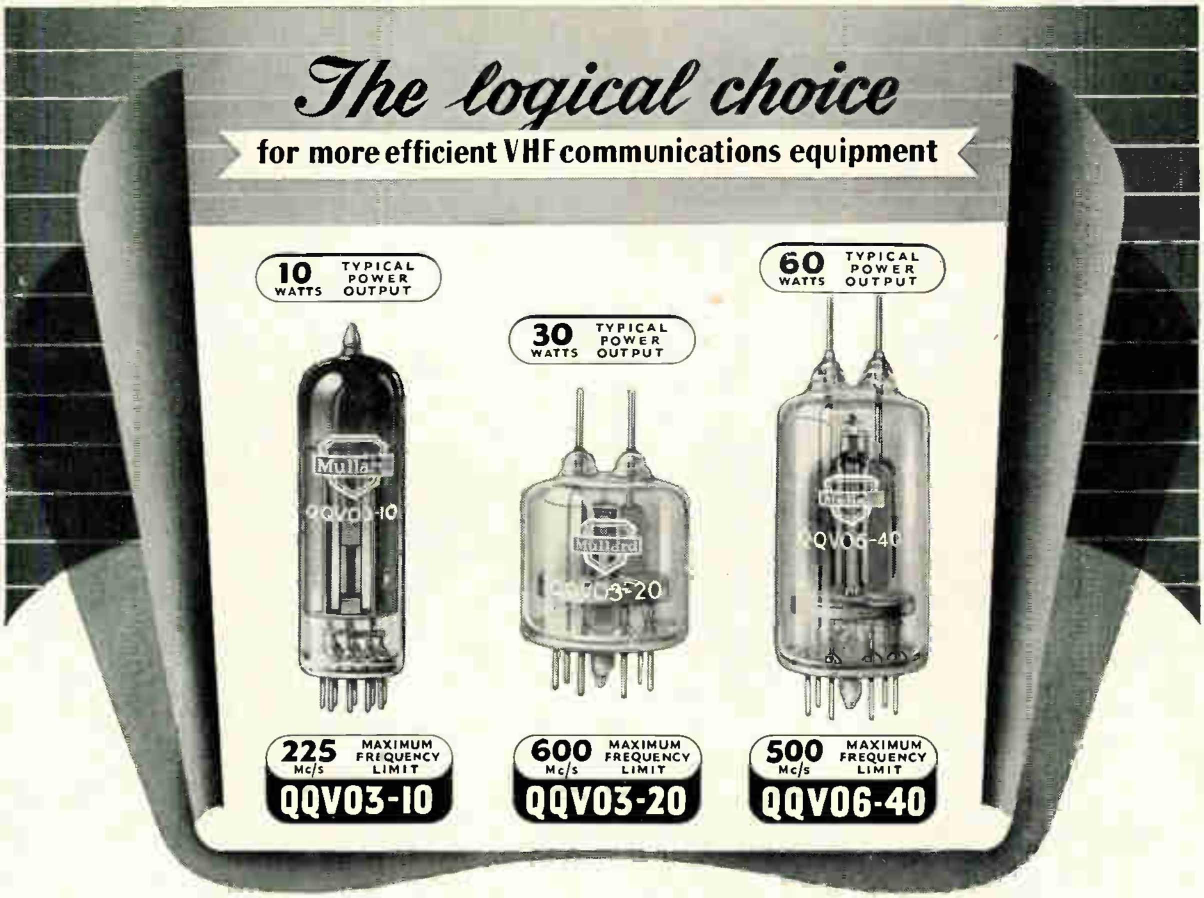
621.387 : 621.318.572 1265
A New Cold-Cathode Decade Counter Tube.—H. v. Gugelberg. (*Helv. phys. Acta*, 16th Nov. 1953, Vol. 26, No. 6, pp. 586–588. In German.) Counting rates up to 10^5 pulses/sec have been obtained with experimental tubes using asymmetrical molybdenum cathodes.

621.387 : 621.318.572 1266
Cold-Cathode Tubes for Transmission of Audio-Frequency Signals.—M. A. Townsend & W. A. Depp. (*Bell Syst. tech. J.*, Nov. 1953, Vol. 32, No. 6, pp. 1371–1391.) The desirable transmission properties are discussed of tubes for use as switching elements in series with telephone circuits; performance curves for an experimental diode are given.

MISCELLANEOUS

621.39 1267
Some Recent Developments in Electronic Engineering.—(*Electronic Engng*, Jan. 1954, Vol. 26, No. 311, pp. 20–26.) Developments discussed include telemetering in guided missiles, radar and navigation aids and associated equipment for radio communication, equipment for meteorological investigations, computers, and apparatus for electromedical and industrial uses.

621.39 : 061.4 1268
Radio Industries at the 20th Salon de l'Aéronautique (26th June to 5th July 1953).—(*Onde élect.*, Nov. 1953, Vol. 33, No. 320, pp. 652–655.) A brief survey of equipment exhibited.



The introduction of this group of double tetrodes marks an outstanding advance in power and driver valves for V.H.F. mobile and fixed communications equipments. The principal design feature of all three valves is the use of a common cathode and common screen-grid for their two tetrode sections. As a result, they are characterised by high efficiencies, high power gain and heater economy. These characteristics permit the use of small driver valves and lead to low power consumption, thus enabling considerable savings in space to be made.

Other important features of these double tetrodes include built-in neutralising capacitors, which enable circuitry to be simplified; and low inter-electrode capacitances, which allow wide tuning ranges and high circuit efficiencies.

Of special interest to designers of battery-operated equipments is the fact that whilst optimum performance of these double tetrodes is obtained with a heater supply of nominally 6.3V, good operating characteristics are maintained if, for any reason, the valves are slightly under-run for short periods. Full technical details of these and other types in the Mullard range of valves for communications equipments will be gladly supplied on request.

PRINCIPAL CHARACTERISTICS

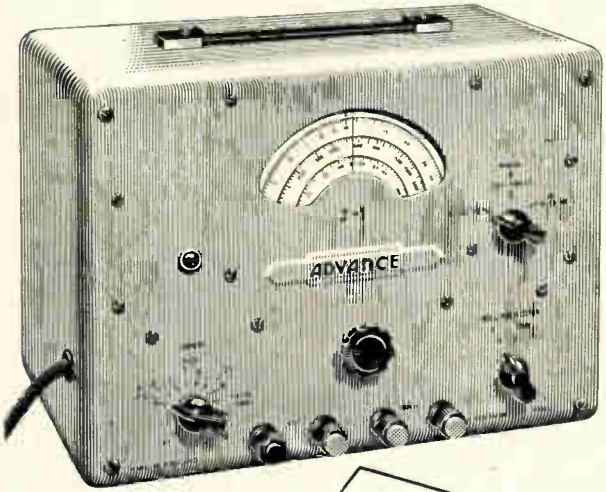
TYPE	DESCRIPTION	BASE	HEATER		LIMITING VALUES				
			SERIES	PARALLEL	Va max (V)	pa max (W)	Vg2 max (V)	pg2 max (W)	Ik max (mA)
QQV03-10	Miniature R.F. Power Double Tetrode	B9A	12 0.4	6.0V 0.8A	400	2×5	250	2×1.5	2×40
QQV03-20	R.F. Power Double Tetrode	B7A	12.6 0.65	6.3V 1.3A	600	2×10	250	2×1.5	2×55
QQV06-40	R.F. Power Double Tetrode	B7A	12.6 0.9	6.3V 1.8A	600	2×20	250	2×3	2×120

Mullard

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, W.C.2

MVT.146

Advance audio signal generator



COVERS
15 c/s TO 50,000 c/s

ACCURACY
PLUS/MINUS 2%
PLUS/MINUS 1 c/s

LOW DISTORTION

1 WATT OUTPUT
INTO 600 OHMS
OVER ENTIRE
RANGE

THE TYPE "J.1."

This new model completely covers the wide range of 15 c/s to 50,000 c/s in three ranges, with an accuracy of ± (2% + 1 c/s). Output (continuously variable) into 600 ohms, 0·1 mW.- 1w (0·25 - 25 v) ± 2 db, the output impedance approxim-ating to 600 ohms over the whole range. Max. output into 5 ohms is greater than ½ watt. A 20 db attenuator may be switched into use when a very accurate output impedance is required. The total harmonic and hum content as compared with fundamental above 100 c/s is better than 34 db down (2%) at full output, and better than 40 db down (1%) at 0·1 watt.

Weight 20 lb. Size 13½" x 10½" x 8¼"

Full technical data on leaflet V17

LIST PRICE (IN U.K.)
£35. 12s.

The Type 'J2' similar to the Type 'J1', but with output voltage meter.
LIST PRICE (IN U.K.) £45

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THE UNIVERSITY OF SOUTHAMPTON
Scholarship in Electronics

Applications are invited for a joint Post-graduate course in Electronics at the University of Southampton and at Vickers-Armstrongs, Ltd., Weybridge. The graduate selected will attend the Diploma course in Electronics at the University during the first year, and will spend the second year training in special projects in the Electronics Laboratory of the firm. The value of the scholarship will be that appertaining to the firm's graduate training scheme, approximately £400 per annum. Applications should be made to the Professor of Electronics, University of Southampton.

APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order, 1952.

Ferranti, Ltd., Edinburgh, have a number of vacancies in their Applications Laboratory in connection with the development and production of equipment for important new field in industrial control. The work is interesting and offers full scope for initiative.

Engineer, Physicists:—For development work involving pulse technique and servo-mechanisms. A degree or equivalent is essential and previous experience desirable. (Ref. EP/AL.)

Electronic Engineers:—For work involving the design and testing of electronic equipment for pre-production. A degree or equivalent is desirable and previous experience essential. (Ref. EE/AL.)

The appointments are permanent and offer excellent prospects in an expanding organization in Edinburgh. A salary commensurate with the qualifications required for these positions will be paid. Staff Pension Scheme. Apply, giving full details of training, qualifications and experience, and quoting Reference, to the Personnel Officer, Ferranti, Ltd., Ferry Road, Edinburgh, 5.

Telecommunications Installers required by the Nigeria Government Posts and Telegraphs Department for one tour of 12-24 months in the first instance. Salary, etc., £1,270 a year. Gratuity £150 a year. Outfit allowance £60. Free passages for officer and wife. Assistance towards cost of children's passages or grant of up to £150 annually for maintenance in U.K. Liberal leave on full salary. *(a)* Very High Frequency Radio (M2C/30360/WJ). Candidates must have a sound knowledge of radio principles with particular knowledge of V.H.F. radio and preferably some knowledge of telephone terminal equipment. They should have had experience of commercial radio installation work and must be prepared to travel extensively in Nigeria. *(b)* High Frequency Radio (M2C/30364/WJ). Candidates must have a sound knowledge of radio principles and of modern H.F. radio. They should have had considerable experience of radio installation work, including the installation of transmitters up to 5 kW output, receivers, radio telephone terminals, frequency shift keying and teleprinter equipment.

Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote the reference number shown against the appointment applied for.

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for the specialized equipment designer

Approx. actual size.

Where small size and stability of characteristic, unaffected by repeated cycles of humidity, are of first importance choose STC diodes, which will give you complete reliability. The five types described below are available from stock, and others are in course of development.

Abridged Data at 20°C	TYPE NUMBERS				
	2X/102G	2X/103G	2X/104G	2X/105G (CV448)	2X/106G (CV425)
Peak Inverse Voltage (V)	85	30	30	100	70
Minimum Reverse Resistance (kilo-ohms)	500 (at 70V)	100 (at 20V)	100 (at 20V)	500 (at 50V)	50 (at 50V)
Maximum Forward Resistance (ohms)	500 (at 1V)	250 (at 1V)	1000 (at 1V)	333 (at 1V)	250 (at 1V)

Comprehensive data sheets may be obtained from:

Standard Telephones and Cables Limited

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Radio Division

OAKLEIGH ROAD, NEW SOUTHGATE, LONDON, N.11

Cottage Laboratories, Ltd., have the following vacancies:—

Development Engineer

A physical and experimental outlook is desirable. The applicants should be capable of designing modern electronic circuits. A degree, or equivalent qualification, is desirable. There are good prospects of promotion in an expanding organisation.

Assistant Development Engineers interested in electronics. H.N.C., or equivalent, is desirable.

The positions are permanent and pensionable. Five-day week, good canteen, sports ground and social club. The premises are on the main bus route between Kingston and Guildford.

Applicants must be of British nationality and should submit details of age, qualifications, etc., to the Technical Director, Cottage Laboratories, Ltd., Fairmile Cottage, Portsmouth Road, Cobham, Surrey.

ELECTRONIC ENGINEERING

Engineer required for the developing of H.F. transmitting equipment.

The applicant filling this post will be responsible for the supervision of projects to the production stage and will work under the general direction of the Senior Engineer.

Junior Engineers. Duties will include development work on communication equipments in the H.F., V.H.F. and U.H.F. fields.

These vacancies will call for men with design experience and with training to Higher National Certificate level.

Good working conditions in modern factories at Cambridge and Lowestoft. Excellent opportunities for further study. Single board available.

Apply to Personnel Manager, Pye Telecommunications, Ltd., Ditton Works, Cambridge.

Mullard, Ltd., have a vacancy in the Industrial/Telecommunications Valve Division for an Electronic Telecommunications Engineer able to assimilate, analyse and evaluate all technical and applicational aspects of problems and products in this field and to *express himself in writing*. This is, in fact, a requirement for a high grade technical writer, but is a key technical engineering appointment with great opportunity. The successful applicant will be required, among other duties, to originate high grade technical and applicational material and publications. He should also be capable of writing articles and papers for publication based on his work and on information reaching him in the course of his duties. This post could probably be filled by a schoolmaster with adequate Service telecommunication or radar experience or by a development engineer with good field experience of telecommunication/electronic equipment. University or professional qualifications will be an asset and the starting salary will be appropriate to the age, qualifications and experience of the successful applicant. Write, giving age and full details, to the Personnel Officer, Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Technical Staff are required by **The English Electric Co., Ltd.**, Luton, for the following vacancies on work of national importance.

(1) **Technical Assistants** with sound knowledge of physics and electrical theory and experience in Electronics Industry, to assist on ground testing.

(2) **Laboratory Technicians** for repair and calibration of electronic laboratory test equipment. Must have wide experience in this work.

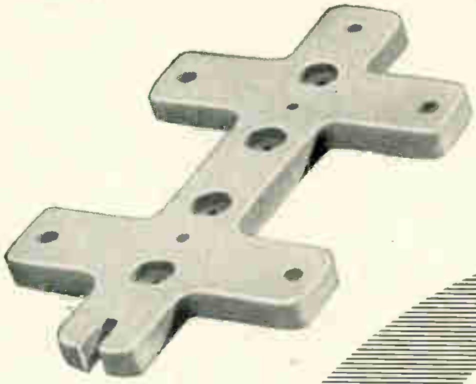
(3) **Computor** must be to G.C.E. standard in mathematics, but advanced or higher level preferred.

These positions are permanent and progressive, with attractive salaries. A Staff Pension Scheme is in operation. Applications to Dept. C.P.S., 336/7 Strand, W.C.2, quoting Ref. S.A.42.

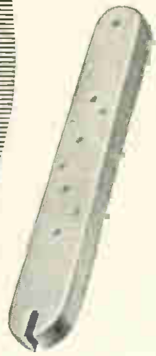
Mullard, Ltd., have a vacancy in the Industrial/Telecommunications Valve Division for a Technical/Commercial Engineer to conduct technical survey and applicational advisory duties in the receiving field. This will require, amongst other duties, liaison with telecommunications and radar equipment manufacturers Knowledge and experience of V H.F./U.H.F. centimetric spectrum and systems of communication, navigation and radar and/or experience in receiver development would be major assets in this post, whilst a degree or equivalent is desirable but not essential. Service experience would be an advantage. This appointment will satisfy an enthusiastic engineer of ambition, and will carry an attractive and progressive salary appropriate to the age, experience and qualifications of the successful applicant. Write, giving age and full details, to the Personnel Officer, Mullard, Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Technical Instructor (Broadcasting) required by the **Nigerian** Government on contract for two tours of 12-15 months. Possibilities of permanency. Salary, etc., according to experience in scale £1,170 rising to £1,269 a year. Outfit allowance £60. Free passages for officer and wife and assistance towards cost of children's passages or grant up to £150 annually for their maintenance in this country. Liberal leave on full salary. Candidates should have had instructional experience at the B.B.C., and must have reached Grade C minus, or above.

Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/30305/WJ.





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