WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

NOVEMBER 1956

Vol. 33 No. 11 · THREE SHILLINGS AND SIXPENCE

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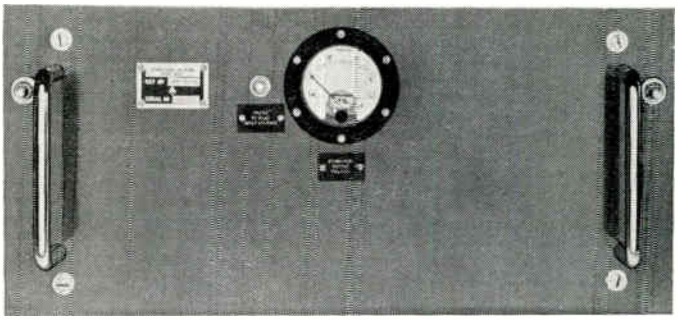

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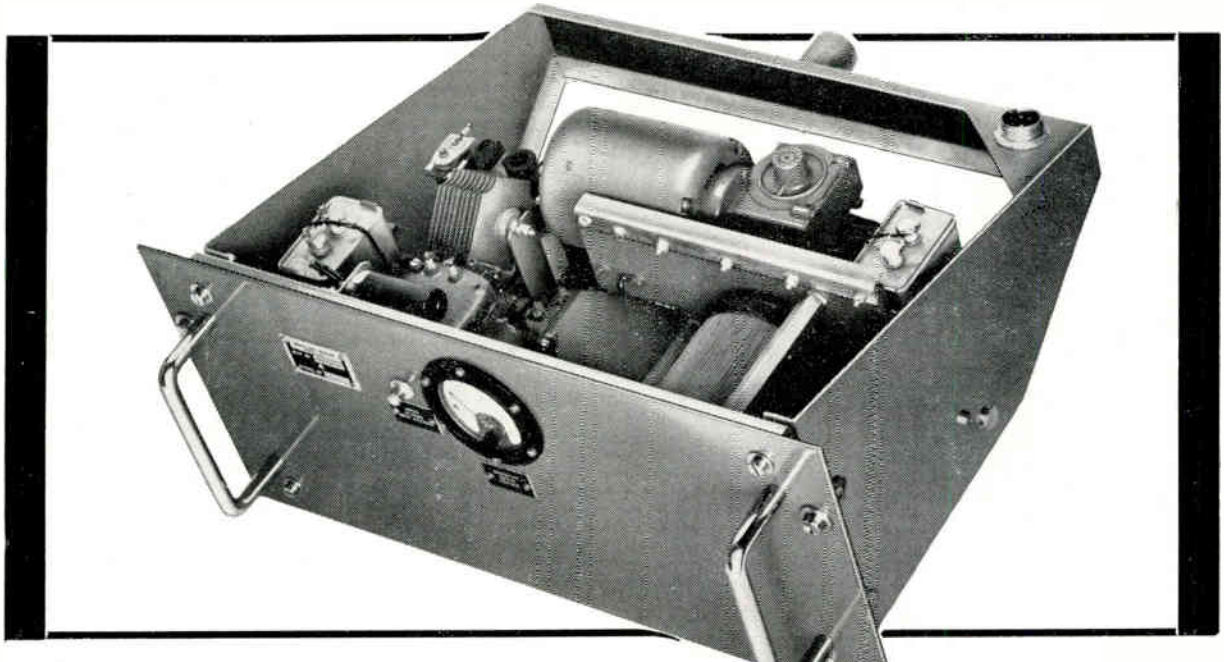

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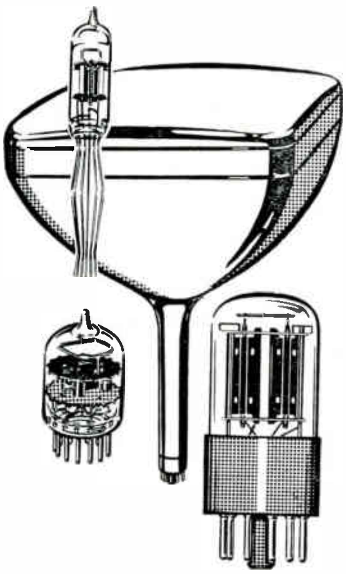

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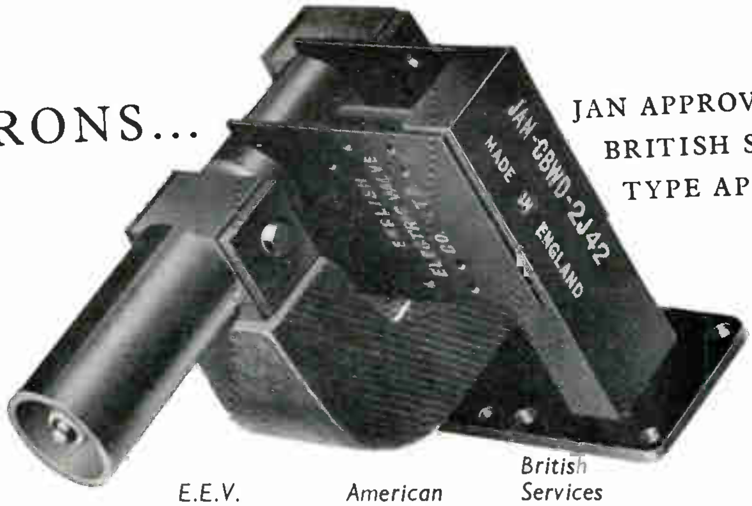

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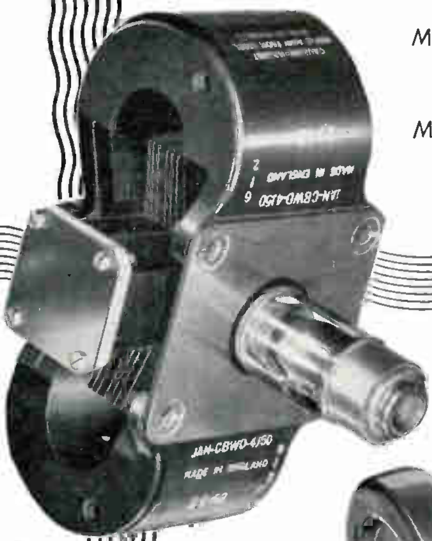
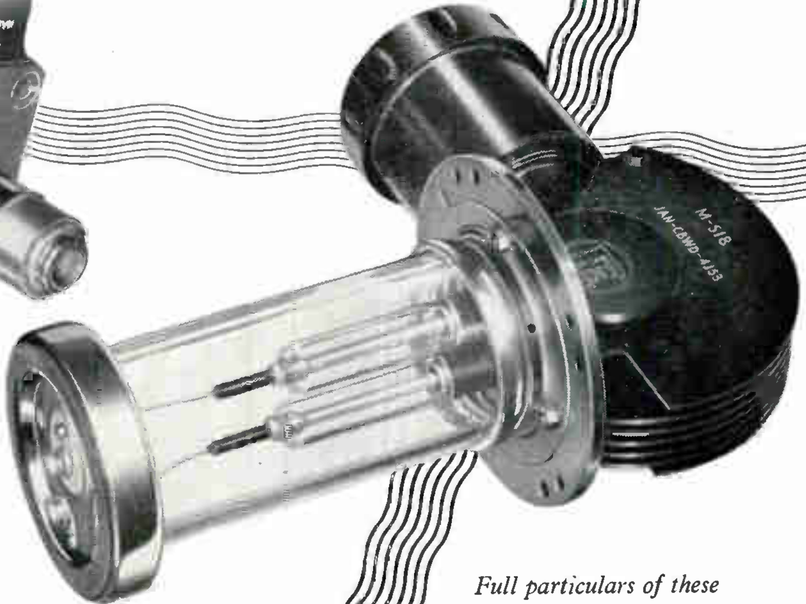
	4J32	
	4J33	C.V. 1916
	4J34	C.V. 1897
	4J35	C.V. 1898
	4J53	C.V. 513
M.526	2J42	C.V. 3676





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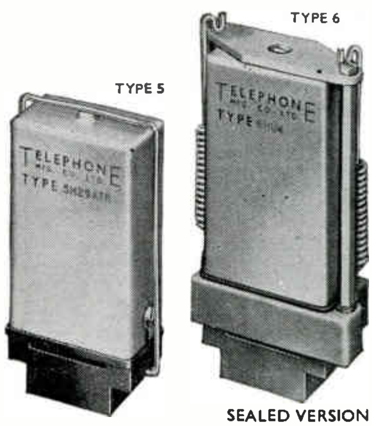

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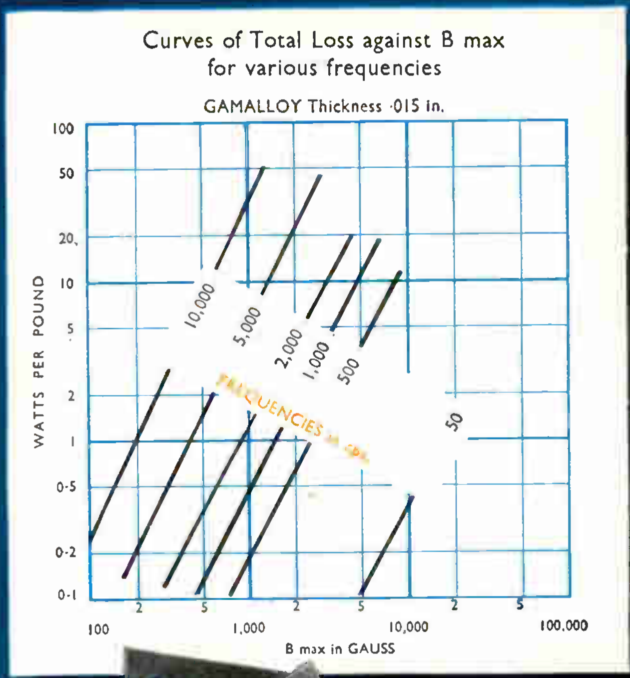

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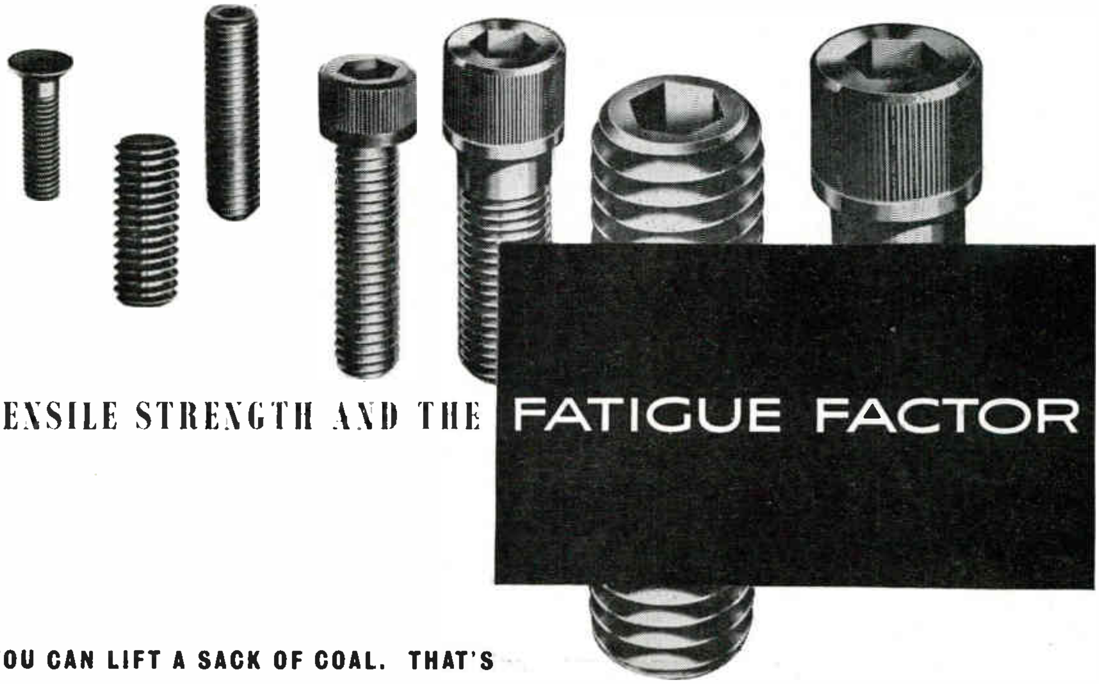

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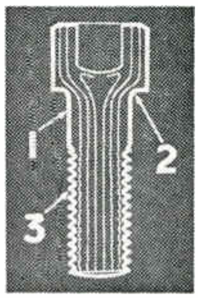

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WIRELESS ENGINEER

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SPECTRUM OF TELEVISION SIGNALS

By D. A. Bell*, Ph.D., M.I.E.E. and G. E. D. Swann†, M.Sc.

(* *University of Birmingham.* † *Formerly University of Birmingham, now with Marconi's Wireless Telegraph Co. Ltd.*)

1. Introduction

THE distribution of power over the sidebands of a television signal is of practical importance in at least three engineering problems; namely, the allocation of frequency channels to television transmitters, the development of 'compatible' colour-television systems, and the use of channels near or in the television band for other services in different geographical regions. In relation to the last, it should be pointed out that very low field-strength can be used for narrow-band communication, so that such a communication channel might suffer interference from a high-power television transmitter situated at a considerable distance, without itself being capable of causing interference in the service area of the television transmitter. Moreover, the aerials for a v.h.f. communication system will not normally be as high as those of television broadcasting stations, and this also will tend to prevent the communication signal from reaching a (low) receiving aerial in the television area but not vice versa. Following a theoretical review[1] and some sample measurements on the low-frequency sidebands[2] by one of the authors, more systematic measurements have been made on the signals broadcast from the Sutton Coldfield television station.

2. Experimental Apparatus

At the receiving site in Birmingham the signal/noise ratio was good, and a t.r.f. receiver was used with a tuned stub in the aerial circuit as rejector filter for the sound transmission. The overall response of the receiver is shown in Fig. 1: this response curve was available to correct readings of the output meter to true magnitude of signal component, but was hardly necessary since the response was within ± 1·5 dB over the range of 0–2·5 Mc/s. The standard condition adopted was a rectified output from the receiver corresponding to 0·8 V on peak white, when receiving a vision signal having a total excursion of 70% of peak-white carrier amplitude: this implied 560 mV video excursion.

MS accepted by the Editor, November 1955

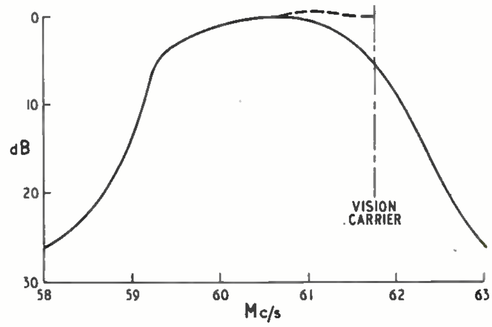

Fig. 1. *Pass-band of r.f. equipment. The full line gives the measured response and the dotted line the equivalent video response (vestigial-sideband transmission).*

In the part of the video-frequency band from zero to 11 kc/s the spectrum was analysed with a wave-analyser having a bandwidth of 4 c/s, thus making it possible to resolve the various multiples of the 25-c/s picture frequency. The difficulty remained that it was impracticable to identify individually the 25-c/s components in the kc/s range, particularly as the B.B.C. scanning system was related to 'grid' frequency so that the individual harmonics were not precisely fixed in frequency. This difficulty was overcome by fitting a slow-speed motor drive to the tuning mechanism of the wave-analyser and connecting its output to a recording meter. A 'comb' spectrum of the harmonics then appeared on the recorder chart, and individual harmonics could be identified by counting through the series either from zero frequency or from the very strong component at the line frequency (10·125 kc/s nominal). Since the component amplitudes are a function of picture content, which is a more or less randomly varying function, 20 such records were taken as a basis for averaging.

As it was not practicable to extend this process over the whole range of the signal, comprising some 10^5 harmonics of 25 c/s, the general trend of the spectrum was studied by exploring it with a communication receiver in the ranges 90 to 550 kc/s and 1·38 to 1·97 Mc/s. The receiver was set to its narrowest i.f. band, the selectivity characteristic of which is shown in Fig. 2, and this was tuned in turn to each harmonic of the 10·125-kc/s line frequency. (It follows from Fig. 2 that the receiver output would include partially the effects of a dozen or so of the components which, in practice, are spaced on either side of the line harmonic by multiples of the frame frequency.) A variable attenuator was inserted between the video output and the input to the communication receiver so that, at each frequency, the detector diode current of the latter could be set to a standard value and the attenuation compared with that required with an input of 1 mV from a signal generator. An 'average' value for each component was obtained by watching the output meter for a short period of time and estimating a mean value.

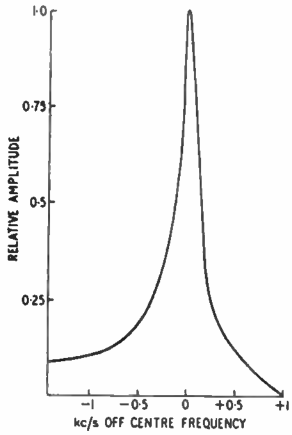

Fig. 2. *Response of narrow-band receiver used for analysis of spectrum.*

3. Analysis of Observations

The fine structure of the first 11 kc/s of the video spectrum is illustrated in Fig. 3*. The intervals between the lines are of course not completely devoid of signal, but earlier experiments[2] suggest that the residual signal is of the order of 30 dB below the lines. Since Fig. 3 represents average values, it is important to examine also the dispersion of the individual readings within the average. In the hope that the distribution might be Gaussian, the individual observations for each of several components were plotted on arithmetic probability paper[3] as shown in Fig. 4. The components at 50 c/s and 1,100 c/s

* Reproduced from "Information Theory and its Engineering Applications", 2nd Edition, Pitman, 1956.

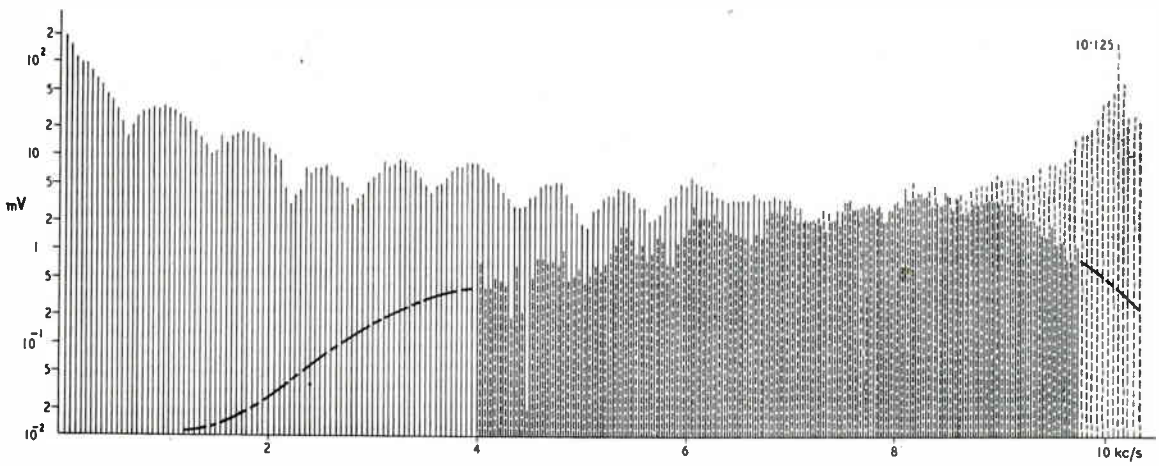

Fig. 3. *Fine structure of video spectrum in range* 0–10·2 *kc/s.*

in Fig. 4(a) can be fitted to a single straight line as well as to anything; but, in the light of the very definite shape of distribution at 9,175 c/s in 4(c), the intermediate frequencies in 4(b) have been given three-slope distributions.

For interference predictions, it is important to know the probability of occasional large values, as well as the mean values. In the absence of a simple distribution law, rough estimates have been obtained by extrapolating the distribution graphs of Fig. 4 as though they were Gaussian in the outer parts; Table 1 shows the ratio

(i) The amplitudes decrease faster than $1/n$, the products for the highest harmonics being about $\frac{1}{4}$ of the value that would be predicted from the lower components and the $1/n$ rule.

(ii) If the wave under analysis were a simple rectangular wave (of the type described in a previous paper[1] as a 'line-frequency sub-carrier') every tenth harmonic would be missing. Since these tenths were not of appreciably different amplitudes from other harmonics, the spectrum must be dominated by the picture information and not by the synchronizing pulses.

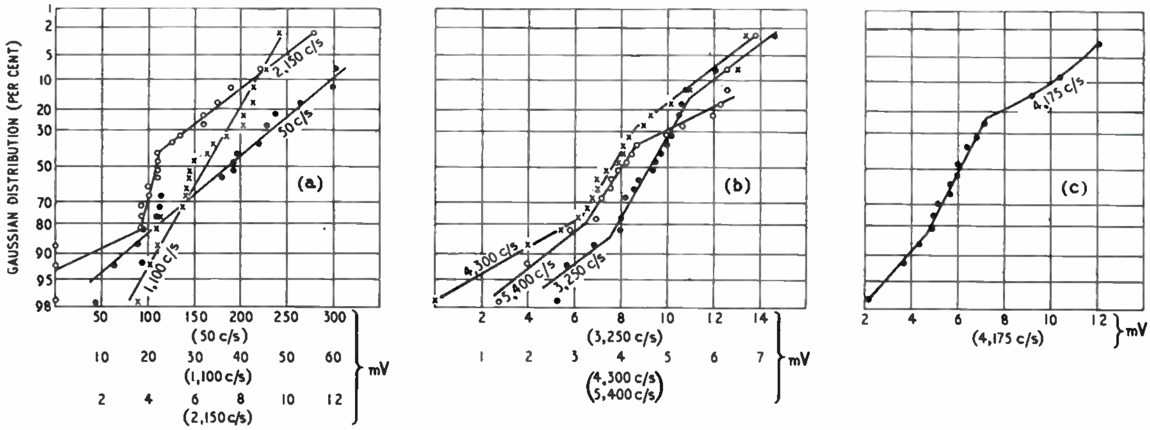

Fig. 4. *These curves show individual observations for specific frequencies plotted on arithmetic probability paper.*

to the mean of a 'peak' amplitude defined as that amplitude which would then have 0·1% probability.

TABLE 1

Frequency (c/s)	50	1,100	2,150	3,250	4,300	5,400	9,175
Peak/mean	2·5	1·8	3·7	2	2·3	2·9	2·7

It should be noted that the law is uncertain and the extrapolation is rather large—effectively from $2\frac{1}{2}$% to 0·1% probability—and these figures should be taken to indicate only an order of magnitude of peak-to-mean of say 3 : 1.

When a waveform is subjected to a Fourier-series analysis, the amplitudes of the higher harmonics are expected to show a general trend of diminution at least as fast as the order of the harmonic. In order to check the conformity of the television spectrum with the rule, the amplitudes of line-harmonic components were measured as described in Section 2 for the ranges 9 to 54 and 136 to 195 times the line frequencies. The amplitudes of the harmonics were then multiplied by their individual order numbers so that for an exact $1/n$ law of amplitudes the result would have been constant, and the results are plotted in Fig. 5. The following are the notable features of this diagram.

4. Relation between Peak-White Power and Sideband Power

From the point of view of interference with other services, it is important to be able to estimate for a given power of television transmitter the power in any designated section of the video spectrum; i.e., the power that would be radiated into a narrower frequency band which was within the sideband range of the television spectrum.

Since the picture waveform is unpredictable there is no specific answer to this question. But a reasonable limit, which is not likely to be exceeded too often, is set by first assuming a full white raster, so that the transmitter radiates peak-white power except during synchronizing pulses, and then taking the envelope of the $(\sin x)/x$ distribution which arises from the Fourier analysis of a rectangular wave. Frame sync pulses will be ignored*, and the waveform sketched in Fig. 6 can be represented by

$$s = (1 - x)\,a + \frac{2a}{\pi}\sum_{m}\frac{1}{m}\left[\sin 2\pi m\left(\frac{1-x}{2}\right)\right]\cos 2\pi mlt \qquad \text{.. (1)}$$

* See Reference 4 for a method of obtaining the exact spectrum.

B

where l is the line frequency and m the order of harmonic. On the second assumption, taking the envelope of $(\sin x)/x$, the sideband part of the series reduces to

$$\frac{2a}{\pi}\sum_{m=1}^{n}\frac{1}{m}\cos 2\pi mlt \quad .. \quad .. \quad .. \quad (2)$$

the series ending after n terms where n is the number of line harmonics in the whole video band. It is, of course, impossible for all components to appear with these amplitudes simultaneously, but the detailed structure of the picture at any moment will enhance certain harmonics at the expense of others, and the expression (2) is an estimate of the amplitudes which may occur from time to time with reasonable pictures. It would not be relevant to the transmission of a picture consisting of a single homogeneous resolution test, such as the classic but hypothetical chequer board; however, neither practical resolution test cards nor programme pictures are of this type. The power is proportional to the sum of the squared amplitudes, with the mean-square of $\cos 2\pi mlt$ replaced by $\frac{1}{2}$, so that the sideband power is

$$P_s = \frac{2a^2}{\pi^2}\sum_{m=1}^{n}\frac{1}{m^2} \quad .. \quad .. \quad .. \quad (3)$$

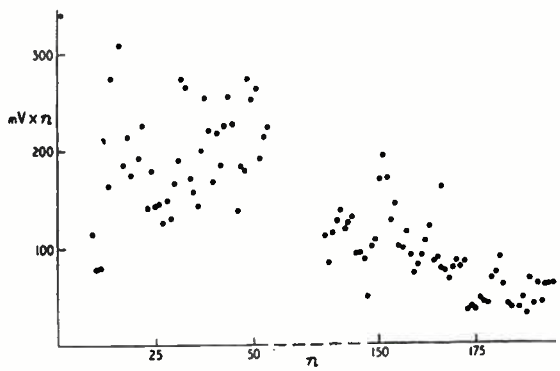

Fig. 5. *Plots of the product of harmonic amplitude and order of harmonic.*

When n is 200 the error resulting from taking the sum to infinity instead of the sum to n terms is approximately 1/200 so that, for practical purposes, it suffices to take the sum to infinity, which is $\pi^2/6$. It follows that $P_s = a^2/3$ when the peak-white power is a^2. Note that, whereas a double-sideband amplitude-modulated wave analyses into components which individually have an amplitude factor of $\frac{1}{2}$, the vestigial-sideband system doubles the amplitudes of all but the lowest components in the retained sideband, so that the amplitude of the component is equal to the amplitude of the corresponding harmonic in the analysis of the modulating waveform.

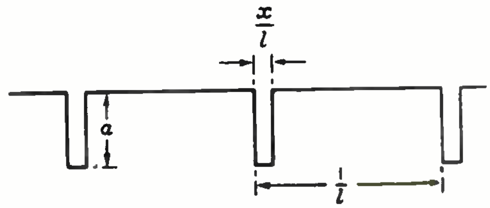

Fig. 6. *Rectangular waveform.*

When a limited channel in the upper part of the spectrum is to be considered, it should be a fair approximation to multiply the power in the central harmonic within the band by the number of line harmonics within the band. For example, in a channel extending from 1·6 to 1·75 Mc/s from the carrier frequency of a B.B.C. transmitter, the central harmonic of 10·125 kc/s will be the 165th and the number of harmonics will be 14 if the channel is very closely defined or, more probably, 15 with the rate of cut-off likely in practical receiving apparatus. The power in this channel will then be estimated as

$$15 \times \frac{2}{\pi^2} \times \frac{1}{165^2} \times \text{peak-white power}$$

or about 40 dB below peak-white power.

On the basis of equation (1) and the argument used above, the maximum ordinate to be expected in Fig. 6, based on 800 mV, for peak white, would be 510. It appears that, in practice, this argument gives a factor of safety of 6 to 10 dB over *typical* values of the sideband power but, since instantaneous values may be 10 dB above the mean value (cf. Table 1, for fine-structure components, in Section 3) the result obtained seems to provide a reasonable basis for design.

5. Acknowledgments

The experimental work was carried out in the Electrical Engineering Department, University of Birmingham, and the authors wish to acknowledge the facilities placed at their disposal by Professor A. Tustin, some time head of the Department.

REFERENCES

[1] D. A. Bell, "Economy of Bandwidth in Television", *J. Brit. Inst. Radio Engrs*, 1953, Vol. 13, p. 447.
[2] D. A. Bell, discussion on L. C. Jesty, "Television as a Communication Problem", *Proc. Instn elect. Engrs*, 1952, Vol. 99, Pt. IIIA, p. 761.
[3] W. R. Hinton, "Graphical Statistical Methods", *Wireless Engineer*, 1949, Vol. 26, p. 400.
[4] W.T.C., "Television Sync-Pulse Spectrum", *Wireless Engineer*, December 1955 Vol. 32, p. 313.

ATTENUATORS WITH MISMATCHED TERMINATIONS

By J. Altshuler, E.E.(Havana)

THE loss of power in a four-terminal network is known as attenuation and is often expressed in decibels. If the four-terminal network is wholly made up of resistive elements, it is called an attenuator and this, in turn, is said to operate under nominal conditions when used to couple two resistance levels which match its image resistances. A formula for the attenuation introduced by an attenuator under non-nominal conditions will be developed here.

To begin with, consider a resistive, dissymmetrical attenuator, defined by (a) its image resistances, R_1, R_2, and (b) its image attenuation constant, α, such that

$$e^{\alpha} = \sqrt{\frac{E_{1i}I_{1i}}{E_{2i}I_{2i}}} \quad \ldots \quad \ldots \quad \ldots \quad (1a)$$

where, with reference to Fig. 1, E_{1i} and E_{2i} represent, respectively, the input and output r.m.s. voltages to the attenuator. I_{1i} and I_{2i} are the corresponding r.m.s. currents, while the subscript i emphasizes the fact that all the voltages and currents in (1a) are those produced under image-operation conditions.

If we make

$$N = e^{\alpha} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1b)$$

then the nominal attenuation in decibels is given by

$$10 \log \left(\frac{E_{1i}I_{1i}}{E_{2i}I_{2i}}\right) = 20 \log N \quad \ldots \quad (1c)$$

Since $E_{1i} = I_{1i}R_1$ and $E_{2i} = I_{2i}R_2$, we can write

$$N = \frac{I_{1i}}{I_{2i}}\sqrt{\frac{R_1}{R_2}} \quad \ldots \quad \ldots \quad \ldots \quad (1d)$$

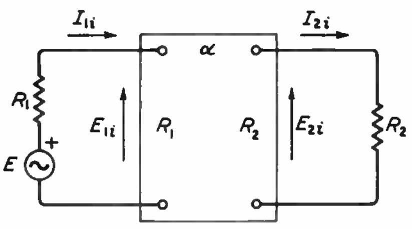

Fig. 1. *Attenuator connected between source and load.*

Input Resistance

Fig. 2 represents the network as defined above connected between a source of internal (resistive) impedance sR_1 and a resistive load of value rR_2, s and r being any two positive numbers whatsoever.

Following the classical treatment by Shea[1] we can substitute parts of the source- and receiving-end impedances by equivalent generators with zero internal impedances and internal e.m.fs of magnitudes and polarities as shown in Fig. 3. This new arrangement does not alter the situation so far as currents and voltages at the terminals of the attenuator are concerned. An important advantage is gained, however, since now image conditions prevail and it is easy to apply the superposition theorem.

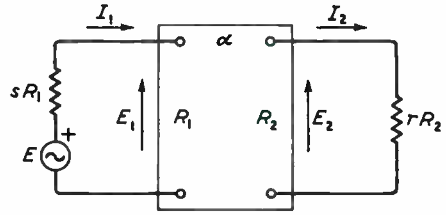

Fig. 2. *Attenuator with mismatched terminating resistances.*

Let I_1' and I_2' be the values which I_1 and I_2 would take if the output generator in Fig. 3 were short-circuited, and let I_1'' and I_2'' be the values which the same currents would take if the input generators were short-circuited.

We have

$$I_1' = \frac{E - I_1(s-1)R_1}{2R_1}$$

and, recalling (1d),

$$I_2' = \frac{E - I_1(s-1)R_1}{2N\sqrt{R_1R_2}}.$$

Also

$$I_2'' = \frac{-I_2(r-1)R_2}{2R_2}$$

and again, from (1d) and the fact that N is independent of the direction of power flow, it follows that

$$I_1'' = \frac{-I_2(r-1)R_2}{2N\sqrt{R_1R_2}}$$

The application of the superposition theorem yields

$$I_1 = I_1' + I_1'' = \frac{E - I_1(s-1)R_1}{2R_1} - \frac{I_2(r-1)R_2}{2N\sqrt{R_1R_2}}$$

$$I_2 = I_2' + I_2'' = \frac{E - I_1(s-1)R_1}{2N\sqrt{R_1R_2}} - \frac{I_2(r-1)R_2}{2R_2}$$

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and solving for I_1 and I_2 we get

$$I_1 = \frac{E}{R_1}\left[\frac{1 - m}{s(1 - m) + (1 + m)}\right] \quad \ldots \quad (2a)$$

where

$$m = \frac{r - 1}{N^2(r + 1)} \quad \ldots \quad \ldots \quad \ldots \quad (2b)$$

and

$$I_2 = \frac{2\sigma E}{\sqrt{R_1 R_2}\,(s + 1)(r + 1)N} \quad \ldots \quad (3a)$$

where

$$\sigma = \left[1 - \frac{(s - 1)(r - 1)}{(s + 1)(r + 1)N^2}\right]^{-1} \quad \ldots \quad (3b)$$

The input resistance of the attenuator, R_{in}, is obtained immediately since

$$R_{in} = E/I_1 - sR_1$$

and hence, making use of (2a),

$$R_{in} = \left[\frac{1 + m}{1 - m}\right] R_1 \quad \ldots \quad \ldots \quad (4)$$

m being given by (2b).

Attenuation

Let P_{in} be the power flowing into the attenuator and P_{out} that flowing out of it. By definition

Attenuation in decibels $= 10 \log P_{in}/P_{out}$ (5a)

With reference to Fig. 2

$$\text{Attenuation in decibels} = 10 \log \frac{I_1^2 R_{in}}{I_2^2 r R_2} \quad (5b)$$

Now,

$$I_1 = \frac{E}{sR_1 + R_{in}} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

and substituting this relation and (2b), (3) and (4) into (5) we get, after some algebraic manipulation,

$$\text{Attenuation in dB} = 10 \log \frac{(1 + r)^2}{4r} + 10 \log (1 - m^2) + 20 \log N \quad \ldots \quad (7)$$

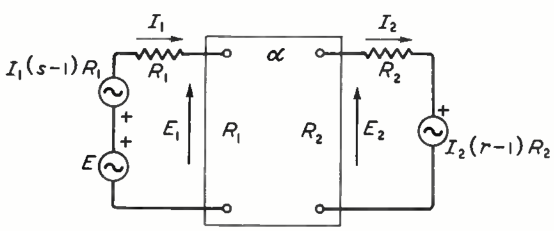

Fig. 3. *Equivalent circuit of Fig. 2.*

Formula (7) shows that the attenuation is independent of the matching conditions at the input terminals of the attenuator. In Fig. 4 the first two terms on the right-hand side of (7) have been plotted against a logarithmic r scale for a number of values of nominal attenuation, as indicated in decibels on the curves. It becomes evident that the relative importance of the second term diminishes very rapidly as $20 \log N$ increases; i.e. for a given value of r and a sufficiently large nominal attenuation, the attenuation in dB is equal to $20 \log N$ plus the reflection loss at the load end

$$10 \log (1 + r)^2/4r \quad \text{dB.}$$

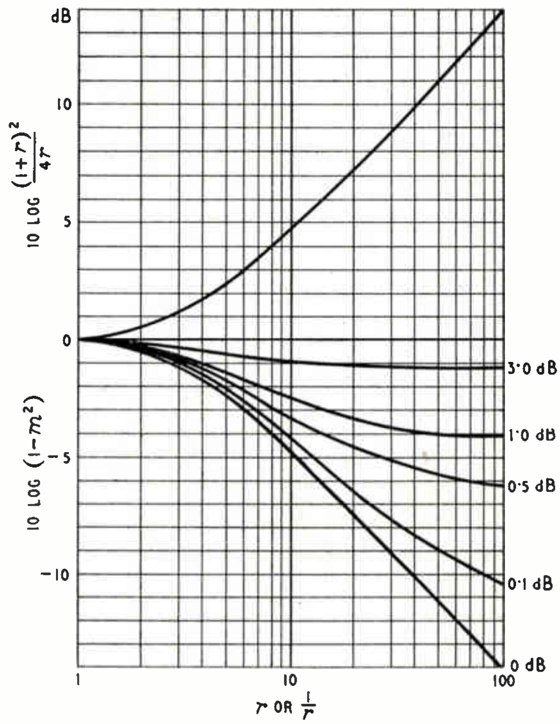

Fig. 4. *Curves of actual attenuation for various amounts of nominal attenuation.*

It is remarkable that (7) is not simplified in the slightest if the attenuator happens to be symmetrical. This should be contrasted with the fact that the often-quoted formula for the insertion loss[1] does contain a symmetry factor.

Acknowledgment

The author is greatly indebted to Mr. M. Estrada for stimulating discussions.

REFERENCE

[1] T. E. Shea, "Transmission Networks and Wave Filters", Chap. IV, van Nostrand, New York.

SCATTERING OF MICROWAVES BY LONG DIELECTRIC CYLINDERS

By Albert W. Adey, Ph.D.

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SUMMARY.—The paper presents near-field results for the scattering of 3-cm waves by dielectric rods of circular, square and rectangular cross-section.

Measured results obtained by the use of a parallel-plate transmission line are in good agreement with calculations of the scattering due to circular polystyrene cylinders having radii comparable with the wavelength. The effect of the material of the cylinder on the scattering is investigated experimentally. The resonances caused by scattering by dielectric cylinders are discussed.

Experimental results are given for square and rectangular polystyrene rods.

Introduction

ALTHOUGH the problem of the scattering of an electromagnetic wave by a circular dielectric cylinder was studied many years ago by Rayleigh[1], the present author knew of only one previous attempt[2,3] to compare calculated with experimental results under reasonably comparable conditions when the work discussed in this paper was begun. The study referred to above considered the case of damped waves scattered by thin cylinders. More recently, other calculated and experimental results have been announced[4]. The recent development of the parallel-plate transmission line has permitted better controlled microwave experiments with cylindrical obstacles, for some cross-sections of which theoretical scattering solutions are not yet available.

In a recent paper[4] where he presented results for metal cylinders, the author described such a transmission line operating at a wavelength of 3·275 cm. In the present paper corresponding results for dielectric rods of circular, square and rectangular cross-section will be given.

In contrast to scattering by metal cylinders, it is shown that resonances can occur when the scattering is by dielectric cylinders, because of the field's penetration of the material. These effects are illustrated by calculated and experimental results. Measurements of the scattered fields of cylinders of various dielectric materials show the damping effect resulting from the loss in the dielectric.

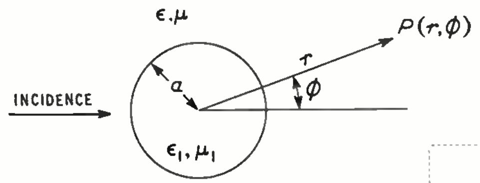

Fig. 1. *Section through the cylindrical co-ordinate system.*

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Scattering by a Circular Cylinder

A cylinder of radius a permittivity ϵ_1 and permeability μ_1 is illuminated by a plane wave, of amplitude unity for convenience, which is travelling in the direction $\phi = 0$ and which has its electric vector polarized parallel to the cylinder axis. Fig. 1 shows the arrangement, for a cylindrical system of co-ordinates (r,ϕ,z). The medium external to the cylinder is considered to be characterized by a permittivity ϵ and permeability μ. A time factor $e^{-j\omega t}$ is assumed and rationalized m.k.s. units are used.

Following a standard procedure, the incident, scattered and internal fields may be written in the respective forms—

$$E_{inc}(r,\phi) = e^{jkr} = \sum_{0}^{\infty} e_n (j)^n \, J_n(kr) \cos n\phi \quad (1)$$

$$E_{sc}(r,\phi) = \sum_{0}^{\infty} e_n B_n \, H_n^{(1)}(kr) \cos n\phi \quad (2)$$

$$E_{int}(r,\phi) = \sum_{0}^{\infty} e_n A_n \, J_n(k_1 r) \cos n\phi \quad (3)$$

where the J_n are the Bessel functions of the first kind, the $H_n^{(1)}$ are the Hankel functions of the first kind and e_n is Neumann's number ($e_o = 1$; $e_n = 2$, $n = 1, 2 \ldots$)

$k = 2\pi/$external wavelength

$k_1 = 2\pi/$internal wavelength

$$= \sqrt{\frac{\mu_1 \epsilon_1}{\mu \epsilon}}\, k = k_r k$$

From Maxwell's equation for the magnetic field H_ϕ —

$$H_\phi(r,\phi) = \frac{j}{\omega\mu} \frac{\partial}{\partial r} E(r,\phi) \quad \ldots \quad \ldots \quad (4)$$

and from the continuity of the tangential electric and magnetic fields at the boundary $r = a$, the amplitude of the scattered field can be obtained as

$$B_n = -(j)^n \frac{\dfrac{k}{\mu} J_n(k_1 a)\, J_n'(ka) - \dfrac{k_1}{\mu_1} J_n(ka)\, J_n'(k_1 a)}{\dfrac{k}{\mu} J_n(k_1 a)\, H_n^{(1)\prime}(ka) - \dfrac{k_1}{\mu_1} H_n^{(1)}(ka)\, J_n'(k_1 a)} \quad (5)$$

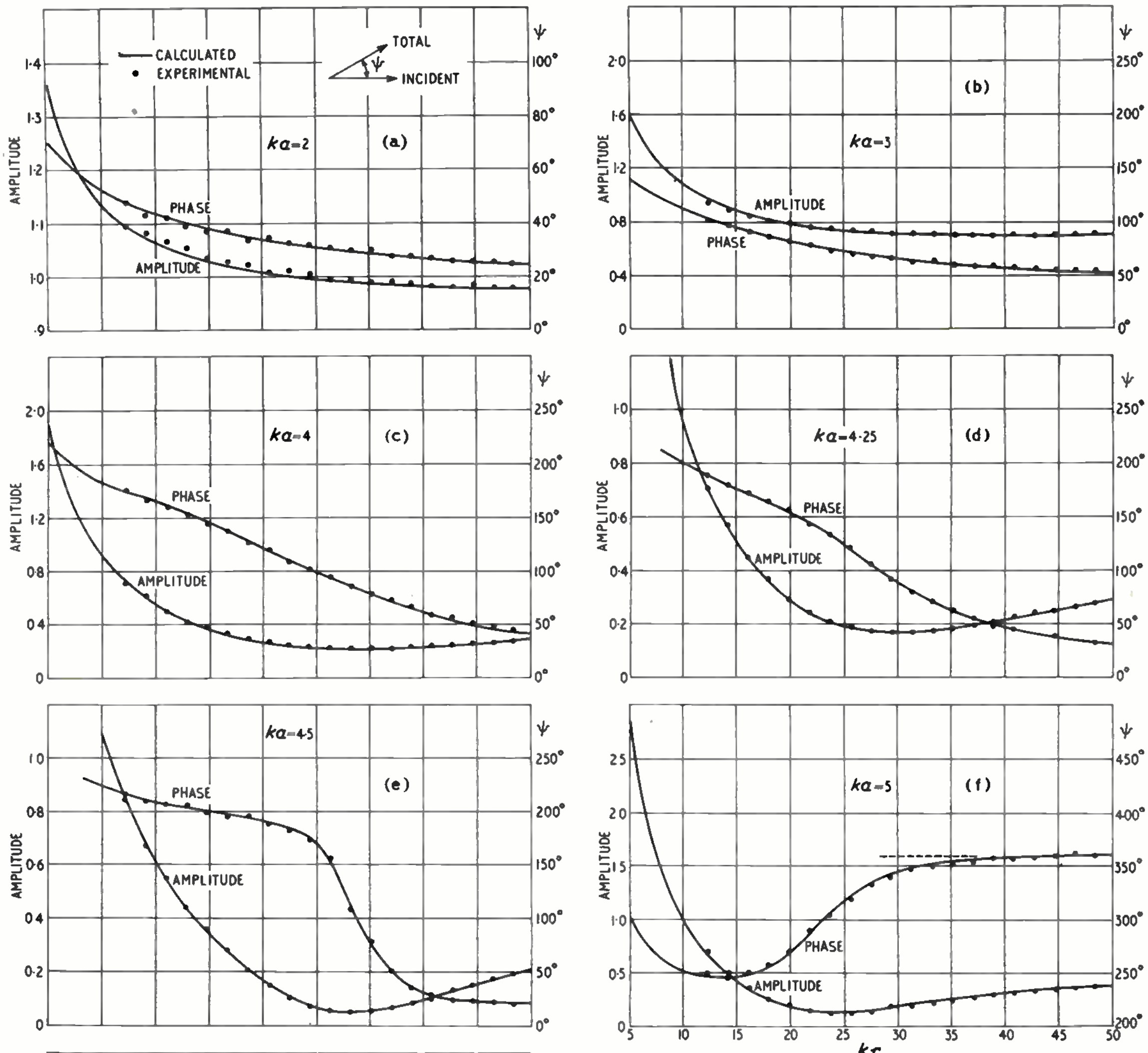
where the prime indicates differentiation with respect to the argument. When $\mu = \mu_1$ this can be reduced to—

$$B_n = -(j)^n \frac{C_n}{C_n + jD_n} \quad \ldots \quad (6)$$

where

$$\left.\begin{aligned} C_n &= J_n(k_1a)\ J_{n+1}(ka) - k_r J_{n+1}(k_1a)\ J_n(ka) \\ D_n &= J_n(k_1a)\ Y_{n+1}(ka) - k_r J_{n+1}(k_1a)\ Y_n(ka) \\ k_r &= \sqrt{\epsilon_1/\epsilon} \end{aligned}\right\} \quad (7)$$

Similarly, the coefficient A_n of Equ. (3) is found



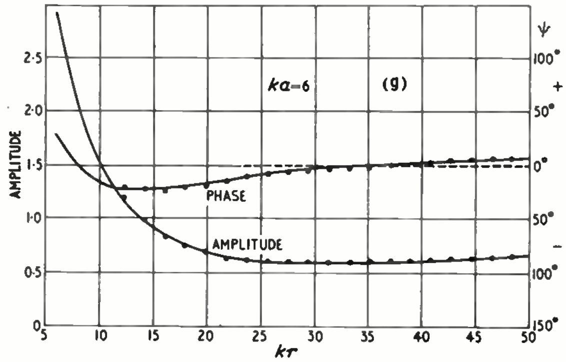


Fig. 2. *Comparison of measured and calculated shadow fields for a series of values of ka.*

to be—

$$A_n = (j)^n \frac{\dfrac{k}{\mu}\left[J_n(ka)\ H_n^{(1)\prime}(ka) - J_n'(ka)\ H_n^{(1)}(ka)\right]}{\dfrac{k}{\mu} J_n(k_1a)\ H_n^{(1)\prime}(ka) - \dfrac{k_1}{\mu_1} J_n'(k_1a)\ H_n^{(1)}(ka)} \quad \ldots \quad (8)$$

which reduces, for $\mu = \mu_1$, to—

$$A_n = (j)^{n-1} \left(\frac{2}{\pi ka}\right) \Big/ \left(C_n + jD_n\right) \quad \ldots \quad (9)$$

The total external field is then given as the sum of the incident and scattered fields by Equs. (1), (2) and (5) or (6).

(a) Scattering by a Circular, Polystyrene Cylinder

Calculations have been made of the near forward-scattered ($\phi = 0$) and back-scattered ($\phi = \pi$) fields for several values of *ka*, for $\mu = \mu_1$ and $k_r = 1{\cdot}60$. The total shadow fields are compared with experimental results in Fig. 2.

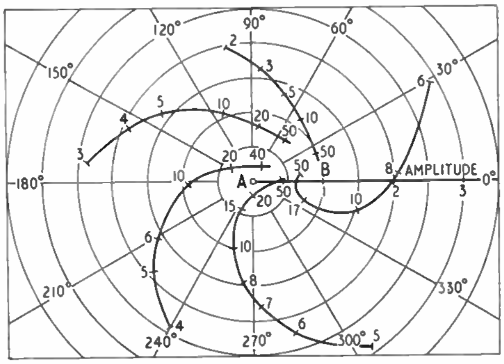


Fig. 3. *Vector diagram illustrating the trend of the curves of Fig. 2. The numbers on the curves refer to values of kr, those at their ends to values of ka.*

The reference for amplitude is the incident field (essentially plane). The plotted phase for a particular value of *kr* is the shift in phase at the point corresponding to that value of *kr* on introducing the cylinder into the field.

Three points of difference between the shadow fields presented here and those given previously for metal cylinders are immediately evident—

(1) While the field amplitude approached zero as the field point approached the surface of the metal cylinder, it showed a sharp rise above the incident field value near the polystyrene cylinder surface.

(2) While the amplitude increased monotonically up to the incident field value for increasing values of *kr* in the metal cylinder case, for the polystyrene cylinders it first decreased before finally increasing to the incident field value.

(3) For the *ka* values above about 4·6 there appears to be a discontinuity of 2π in the phase for the larger *kr* values.

The trends indicated by these curves can best be illustrated by combining, for each cylinder, the amplitude and phase into a vector diagram. This has been done for several values of *ka* in Fig. 3. The numbers on each curve indicate the *kr* value of the field points, the number at the outer

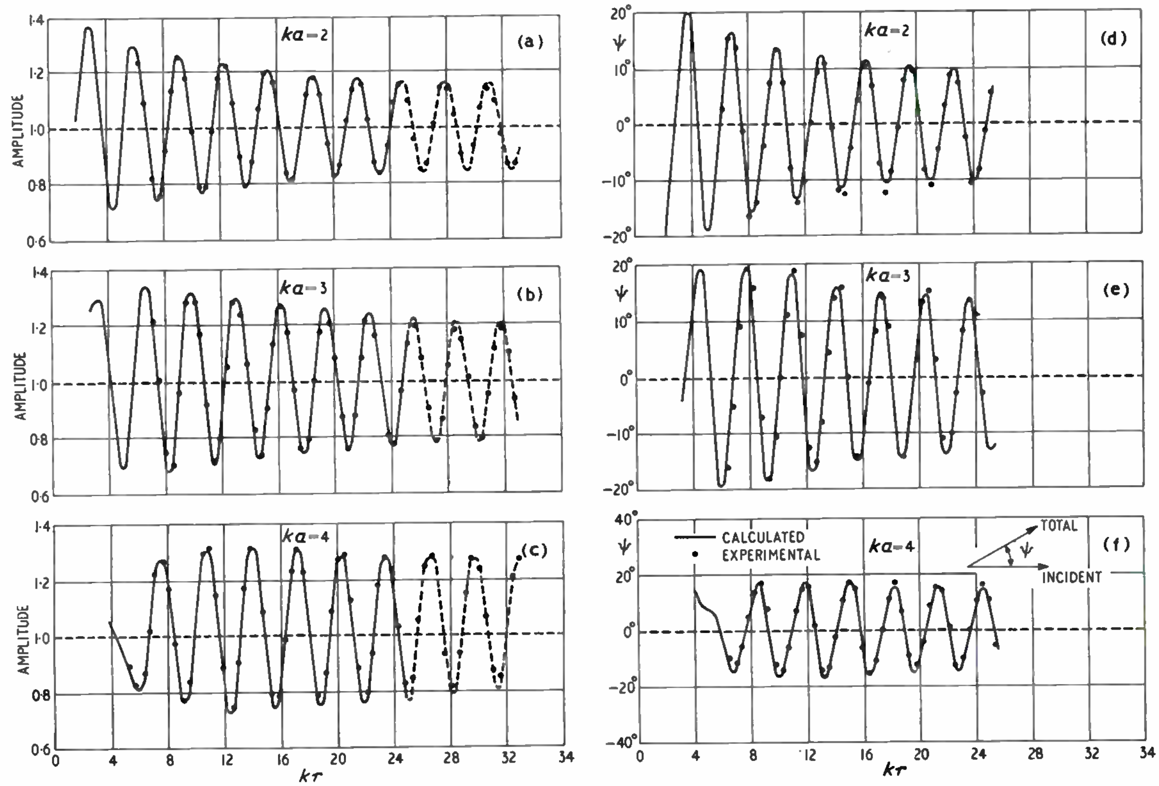


Fig. 4. *Field on the illuminated side of cylinders.*

extremity of each curve indicating the *ka* value of the cylinder. The shadow deepens until that value of *ka* is reached for which the curve passes through the origin, after which it decreases. For that value of *kr* and *ka* the amplitude is zero and the phase indeterminate. The zero-field region is very localized with respect to *ka* and *kr*. For *ka* values less than the critical the phase decreases with increasing *kr*. For greater *ka* values the phase first decreases and then increases, tending toward 2π instead of zero. This behaviour was suspected by Kodis[5] in his experiments on dielectric cylinders, although he doubted whether it would occur on the shadow axis.

corresponding calculations were not done, however, mainly because of the lack of tables of Bessel Functions with complex argument. The results have been presented in polar form, rather than in field-point detail, in Fig. 5 for the following materials respectively—polyethylene, graphite, and two resin-base plastics.

Because of the lower value of relative permittivity of polyethylene, the curves of Fig. 5 (a) lie at lower angles than the corresponding ones of Fig. 3 for polystyrene. A higher value of *ka* is thus required of the polyethylene cylinder to give the zero-field phenomenon than was found for polystyrene.

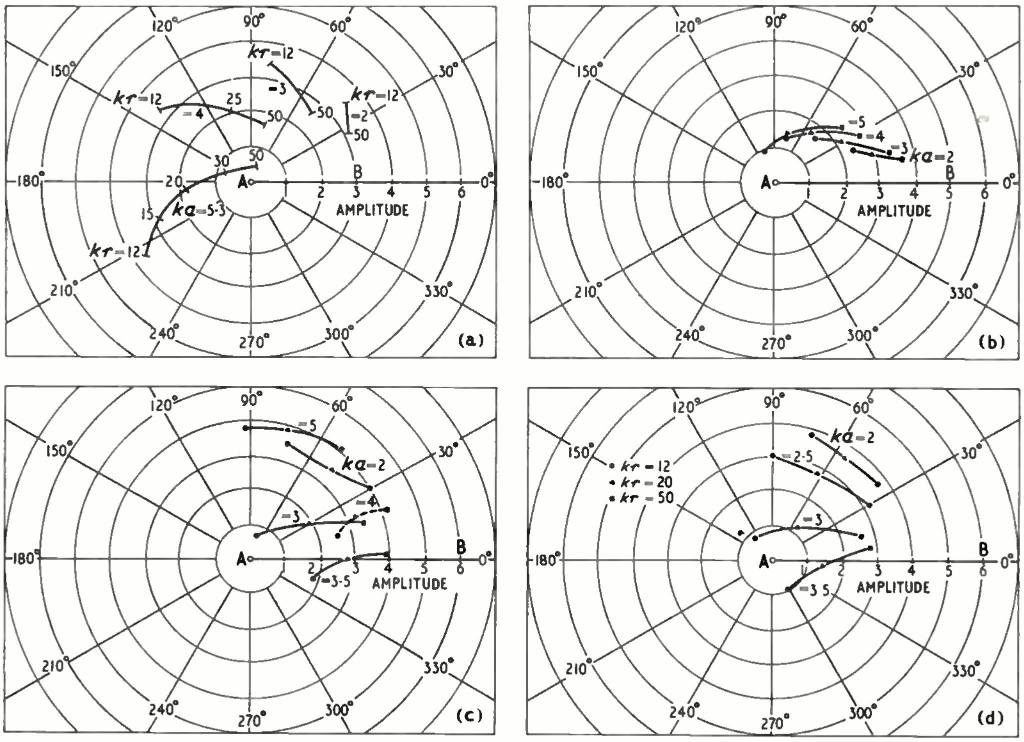


Fig. 5. *Shadow fields for cylinders of polyethylene* (*a*), *graphite* (*b*) *and resin-based plastics* (*c and d*).

The curves of Fig. 4 for the field on the illuminated side of the cylinders follow, in the main, the pattern for the metal cylinders. However, the amplitude of the standing wave does not always fall off monotonically with increasing *kr* as was found in the metal case, but can actually rise, initially.

(*b*) *Measurements on Miscellaneous Materials*

The shadow measurements were repeated for families of cylinders of several other readily-available materials, to determine the effect on the scattering of the change of permittivity together with the presence of appreciable loss. The

The results for graphite cylinders show that the graphite and metal cylinders behave similarly for scattering. The scattered field increases with cylinder radius and the left-hand terminal of each curve tends toward the origin.

The effect on the scattering of increasing both the relative permittivity and the loss is illustrated by Figs. 5 (c) and (d). The curve passing through the origin corresponds to a lower value of *ka* than for polystyrene, because of the higher relative permittivity. The higher loss, since it decreases the scattered field amplitude by damping, has the effect of moving the pattern to the right—toward point B.

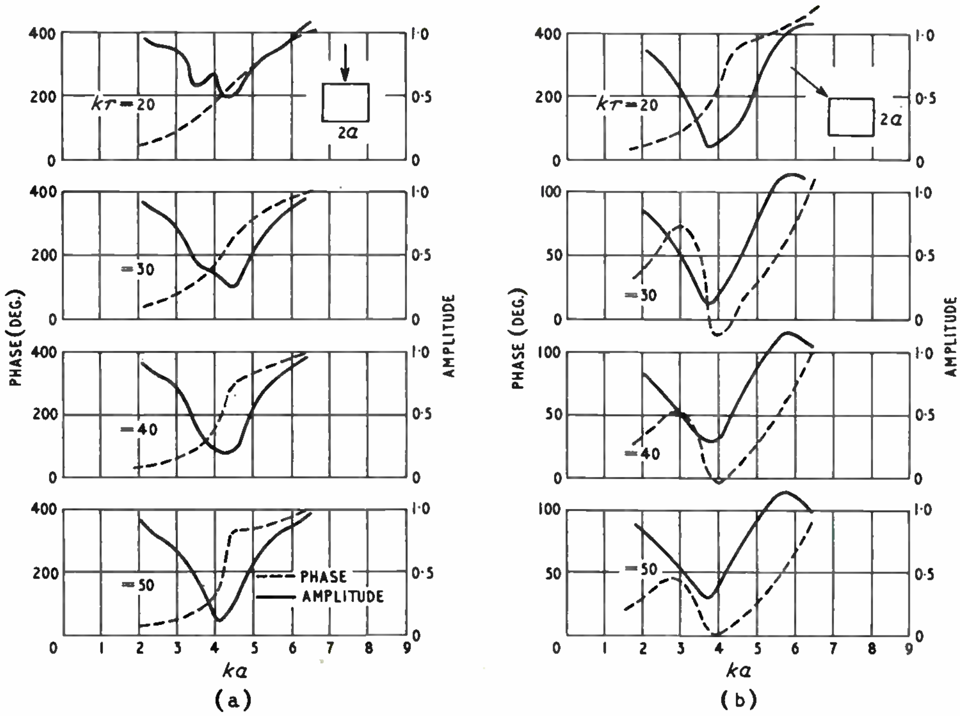


Fig. 6. *Shadow fields for square polystyrene rods.*

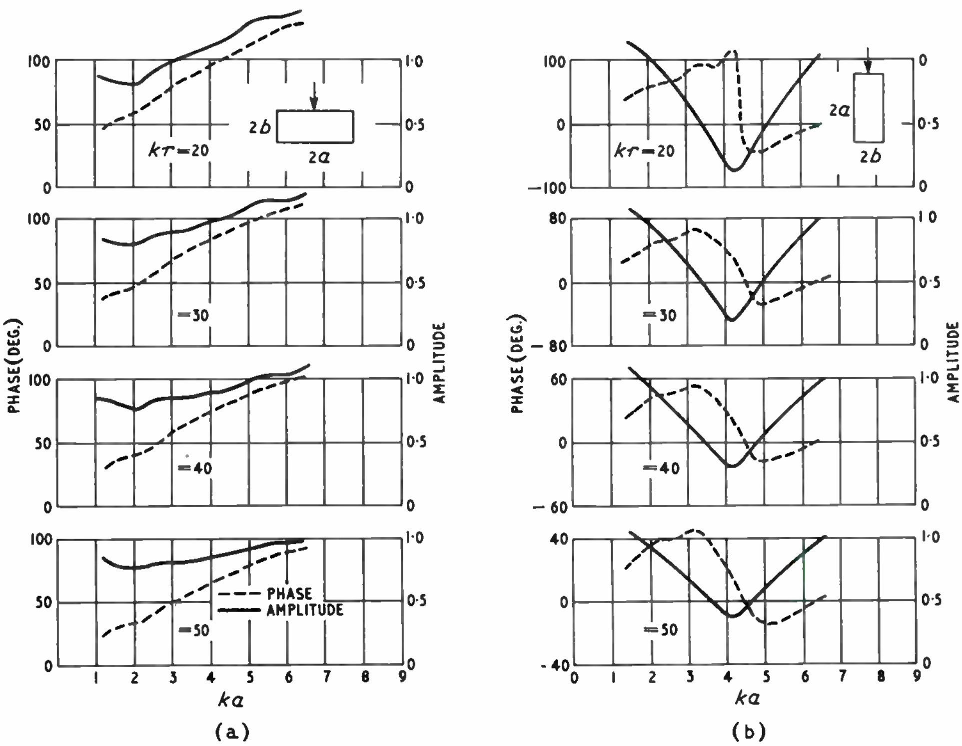


Fig. 7. *Shadow fields for polystyrene rods of rectangular section.*

Scattering by Square and Rectangular Polystyrene Rods

(a) Square Rods

Shadow field measurements were made on a family of ten polystyrene rods in the *ka* range 2·18–6·43, where " *a* " is the half-side.

To save space, the results were first plotted in detail as for the circular polystyrene cylinders and then consolidated in Fig. 6 for several values of *kr*.

For both orientations there is a tendency—observed in the case of the circular cylinders—for the amplitude to have a zero value and the phase a change of form for a particular combination of *ka* and *kr*. The field complexity that can be encountered in the near region is well illustrated by the curve for $kr = 20$ for normal incidence.

For normal incidence, the detailed curves indicated that the critical radius-distance combination would be approximately 4·2 and 55 respectively. The *ka* value is a little smaller than for the circular cylinders, indicating a higher effective relative permittivity.

For diagonal incidence the corresponding values are in the region of 3·7 and 23 respectively.

For convenience the angles on the higher *kr* curves for diagonal incidence are shown in a different form than for the smaller ones, because of the rapid increase in phase after passing the critical *kr* value.

(b) Rectangular Rods

Shadow measurements were made on a family of eleven rectangles of dimensions $2a \times 2b$ for $kb = 2{\cdot}37$ and *ka* in the range 1·52–6·44. The results are given in Fig. 7.

The curves for a constant dimension in the direction of incidence are fairly smooth, although less so than for the metal rectangles treated previously. One would expect the curves of both amplitude and phase to tend, in the limit of large *ka*, to the values corresponding to the transmission coefficient of a polystyrene slab.

For the other orientation the trend of the curves is again similar to that for the circular and square rods. From the detailed curves the critical combination of *ka* and *kr* appeared to be approximately 4·2 and 18 respectively. Thus, as for the squares, a higher value of effective relative permittivity is indicated than for the circular cylinders.

The physical optics aspect of the results (e.g., an analysis based on Fresnel Zone Theory) has not been discussed since, for the largest transverse dimension considered, the field point was always in the first Fresnel Zone.

Conclusions

The study has shown the dielectric, circular cylinders to be resonant structures, their scattering properties varying widely with the cylinder radius and material. This is in contrast with the scattering behaviour of metal rods, which is comparatively smooth as a function of radius. The damping effect of the loss in the cylinder material has been illustrated. The shadow field of the square rods has been shown to be similar to that for the circular cylinders, as has that for the rectangles when the dimension in the direction of incidence is varied.

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REFERENCES

[1] Lord Rayleigh, (a) "On the EM Theory of Light", *Phil. Mag.*, 1881, Vol. 12, p. 81. Also *Sc. Papers*, Vol. 1, p. 533. (b) "On the Dispersal of Light by a Dielectric Cylinder", *Phil. Mag.*, 1918, Vol. 36, p. 365. Also *Sc. Papers*, Vol. 6, p. 554.

[2] C. L. Schaefer and F. Grossman, "Diffraction of EM Waves by a Dielectric Cylinder", *Ann. Phys., Leipzig*, 1910, Vol. 31, p. 455.

[3] – Kobayashi, – Iwao, "Diffraction of Electric Waves at a Dielectric Cylinder", *Ann. Phys., Leipzig*, 1914, Vol. 43, p. 861.

[4] A. W. Adey, "Diffraction of Microwaves by Long, Metal Cylinders", *Canad. J. Phys.*, to be published.

[5] R. Kodis, "An Experimental Investigation of Microwave Diffraction", *J. Appl. Phys.*, 1952, Vol. 23, p. 249.

ERRORS IN BRIDGE MEASUREMENTS

By C. G. Mayo, M.A., B.Sc., M.I.E.E. and J. W. Head, M.A.

(Research Department, B.B.C. Engineering Division)

SUMMARY.—Any linear network used as a bridge can be regarded as subject to three errors which are independent of the unknown and standard impedances (or admittances) being compared. These errors (which may be complex quantities having any argument) are: (a) a ratio error, (b) an error impedance in series with the standard, (c) an error admittance in parallel with the unknown. One of these errors can be reduced to zero by adjustment; the other two can be determined by measuring two known impedances (or admittances) of different orders of magnitude.

1. Introduction

At high frequencies, the presence of stray capacitances, etc., may cause the condition of balance to depart appreciably from the expected condition that the ratio of the unknown impedance to the standard impedance is a constant, usually real or purely imaginary, when the bridge is balanced. Here therefore we determine the conditions of balance ab initio in the general case, assuming only that various self and mutual impedances exist within the bridge network which are constant at any one frequency; we shall show that the bridge can be regarded as subject to three errors independent of each other and of the standard and unknown impedances being measured.

At first sight, it would appear that, in order to investigate bridge errors, we should make calculations based upon the known values of the elements composing the bridge. This procedure, however, involves two difficulties. At high frequencies there will be a number of elements such as stray capacitances and inductances which are not easily measured and, even if their values were completely known, the computation from such a complex arrangement of elements would be unnecessarily difficult. The second difficulty is that we wish to establish a general theorem, and to do so from particular circuits is difficult.

A new approach is required, analogous to 'ignoration of co-ordinates' in dynamics; we must refuse to find out anything we do not need to know. The relevant question is not "What causes this phenomenon?" but "What is its effect?". We should not ask "What are the electrical elements contained within this system?", but rather "What does this system do?".

In our particular problem, we do not need to know the elements forming the bridge network; we only need to know how the bridge behaves. We should think of the bridge network as enclosed within an unbreakable 'black box', accessible to the outside world only through four pairs of terminals; the only relevant data are those obtained from measurements at those terminals. The orderly tabulation of the results of such measurements leads us to the primary concept associated with this new 'black box' approach—the matrix.

We first observe that the terminals have no significance unless current can flow between them. If we provide external connections between the terminals of a pair, these connections will determine the geometrical path of the resultant current and will, in fact, give arbitrary additional elements to the original network which is indeterminate. A possible way of counteracting this indeterminacy would be to short-circuit all terminal pairs; if this is done, the bridge network would be completely determined but also completely useless. Suppose now, however, that each short-circuiting link has a 'narrow' gap across which a voltage is injected from a zero-impedance source in series with a zero-impedance ammeter as in Fig. 1. 'Narrow' means that the ratio of the gap width to the wavelength at the operating frequency is of the same order of magnitude as the ratio expressing the required precision. We are, under these circumstances, able to apply a voltage across any terminal pair and to measure the resulting current in the same or another

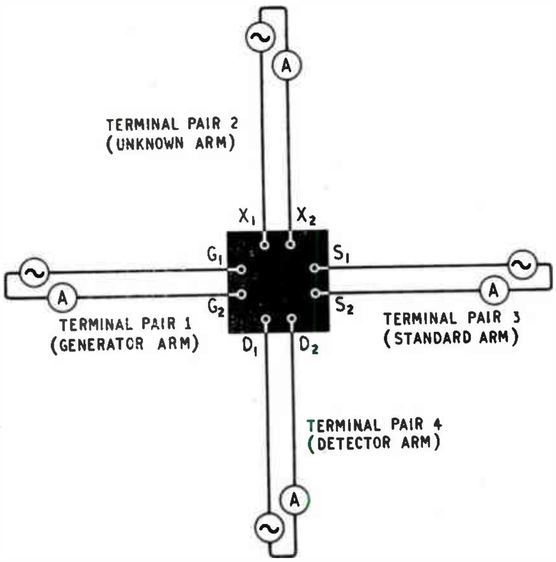

Fig. 1. *A bridge network with determinate current paths.*

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terminal pair without in any way altering the 'black box'. If now a voltage V_α is applied to the terminal pair T_α and the resulting current at the terminal pair T_j is $i_{\alpha j}$, we denote by $Y_{\alpha j}$ the quotient* $i_{\alpha j}/V_\alpha$, which is a constant of the network; $Y_{\alpha\alpha}$ is the current at terminal pair T_α per volt applied there, or the admittance at the terminal pair T_α, while $Y_{\alpha j}$ is similarly the mutual admittance between terminal pair T_α and terminal pair T_j, or the current measured at terminal pair T_j per volt applied at terminal pair T_α. By applying voltages in turn at each terminal pair and measuring the resultant $Y_{\alpha j}$, we determine the essential properties of the network, which may be conveniently tabulated in matrix form:

$$A = \begin{pmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{pmatrix} \quad .. \quad (1a)$$

If the principle of reciprocity applies (as it usually does) we shall have $Y_{jk} = Y_{kj}$, but this is not important from our present point of view. If the system is linear, the principle of superposition applies, so that if voltages V_1, V_2, V_3 and V_4 are applied simultaneously at the four terminal pairs

$$\left.\begin{aligned} i_1 &= Y_{11}V_1 + Y_{12}V_2 + Y_{13}V_3 + Y_{14}V_4 \\ i_2 &= Y_{21}V_1 + Y_{22}V_2 + Y_{23}V_3 + Y_{24}V_4 \\ i_3 &= Y_{31}V_1 + Y_{32}V_2 + Y_{33}V_3 + Y_{34}V_4 \\ i_4 &= Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3 + Y_{44}V_4 \end{aligned}\right\} \quad (1b)$$

At this stage we may, if we please, try to find some circuit which has the properties thus established and think in the familiar terms of the elements of that circuit. In fact, however, it is much easier to think entirely in terms of the Y_{ij} as the basic entities and resist the temptation to visualize them as circuit elements, since this visualization merely confuses the issue. It will be seen later that we ultimately need only three quantities to specify the behaviour of the bridge. These can be deduced from the Y_{ij} but, in practice, it is easier to measure them directly; the evaluation of the whole matrix (1a) is then unnecessary.

2. The Three Error Constants

The foregoing remarks apply generally to any network with four terminal pairs. If the network is used as a bridge, it has also the following special properties:

(i) We shall suppose that only terminal pair 1 is connected through a generator, so that V_1 and i_1 are arbitrary. The conditions for zero output from the detector terminals are independent of the magnitude of the input or the sensitivity of the detector. It follows that shunt or series elements associated with detector or source terminals have no effect on precision, but only on sensitivity. Further, the geometrical arrangement of the standards is determined a priori, so that the terminal pair where the unknown admittance is connected is the only one where the precise nature of the geometrical arrangement for the flow of current may be important.

(ii) If an unknown admittance Y_x is connected to terminal pair 2 and a standard admittance Y_s to terminal pair 3, we have, in addition to (1b)

$$i_2 = Y_xV_2; \quad i_3 = Y_sV_3 \quad .. \quad (2)$$

As we are only concerned with the conditions under which no current flows through the detector (assumed to have finite impedance Y_d), we have also

$$i_4 = Y_dV_4 = 0 \quad .. \quad .. \quad .. \quad (3)$$

The legitimacy of adding equations (2) and (3) to (1) is more fully discussed in the Appendix. Eliminating i_2 and i_3 by means of (2), we therefore have that, when no current flows through the detector,

$$\begin{aligned} Y_{21}V_1 + (Y_{22} - Y_x)\,V_2 + Y_{23}V_3 &= 0 \\ Y_{31}V_1 + Y_{32}V_2 + (Y_{33} - Y_s)\,V_3 &= 0 \\ Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3 &= 0 \end{aligned} \quad .. \quad (4)$$

These equations are inconsistent unless

$$\begin{vmatrix} Y_{21} & Y_{22} - Y_x & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} - Y_s \\ Y_{41} & Y_{42} & Y_{43} \end{vmatrix} = 0 \quad (5)$$

This determinant can be expanded in the form

$$Y_{41}\,Y_xY_s + \lambda\,Y_x + \mu\,Y_s + \nu = 0 \quad (6)$$

where

$$\lambda = Y_{31}Y_{43} - Y_{41}Y_{33}\,; \quad \mu = Y_{21}Y_{42} - Y_{41}Y_{22}$$

and

$$\nu = \begin{vmatrix} Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \\ Y_{41} & Y_{42} & Y_{43} \end{vmatrix} \quad .. \quad .. \quad (7)$$

so that λ, μ, ν are constants of the network and independent of Y_x, Y_s. The importance of (6) is its form, bilinear in Y_x, Y_s.

Now consider the relation

$$Y_x + Y_e = \frac{\xi}{\dfrac{1}{Y_s} + Z_e} \quad .. \quad .. \quad (8)$$

It is the same as (6) (when cleared of fractions) provided we choose the, as yet unspecified, constants Y_e, Z_e and ξ so that

$$Y_{41}/Z_e = \lambda = \mu/(Z_eY_e - \xi) = \nu/Y_e \quad (9)$$

or

$$Z_e = Y_{41}/\lambda; \quad Y_e = \nu/\lambda; \quad \xi = (Y_{41}\nu - \mu\lambda)/\lambda^2 \quad (10)$$

The relations (6) and (8) specify that the network

* This assumes that all quantities involved are expressed in operational form.

behaves as if it were an ideal bridge with an error impedance Z_e in series with the standard and an error admittance Y_e in parallel with the unknown, the ratio of the bridge being ξ, where Z_e, Y_e and ξ are given by (10) and may be complex quantities having arguments of any value. It does not mean that the bridge network actually contains such elements, but that its errors can be corrected as if these elements were present.

If we have actually carried out the measurement of all the Y_{ij}, (10) specifies Z_e, Y_e and ξ completely. But, in order to determine the behaviour of the bridge, even measurement of the Y-matrix (1a) gives us more information than we need; it is sufficient to determine by measurement the quantities Y_e, Z_e and ξ on the assumption that a relation of the form (8) exists. For an admittance bridge, we first consider open-circuit conditions; that is to say, we have the standard side open-circuited ($Y_s = 0$) and provide an adjustable impedance in parallel with the unknown which is used to balance the bridge. When the bridge is balanced, the value of the adjustable admittance is $-Y_e$. We can, if we wish, note the value of Y_e thus obtained and then, by measurement on the bridge of two known impedances, obtain simultaneous equations for Z_e and ξ, but it is simpler to leave the adjustable impedance permanently at the value which secured balance on open circuit. By doing this we have, in effect, replaced the original bridge by a similar bridge free from the error impedance in parallel with the unknown. If the admittance $-Y_e$ has a negative real part, we shall find that we cannot balance the bridge on open circuit with our adjustable admittance unless a suitable fixed admittance is permanently incorporated in the bridge in parallel with the standard. This admittance does not need to be adjustable; its purpose is merely to make the effective value of $-Y_e$ have a positive real part. We assume that the adjustable admittance, and if necessary the fixed admittance, once determined, are added permanently to the structure of the bridge within the ' black box '; the relevant values of the elements of the matrix (1a) are henceforward those obtained after this change.

Having determined Y_e, or adjusted it to an effective value zero in the manner just described, we measure two known admittances, preferably of different orders of magnitude, with the bridge. (8) then gives us linear simultaneous equations for Z_e and ξ, and (8) can thereafter be used with these values of Z_e and ξ to determine any Y_x, given Y_s.

For an impedance bridge, the procedure is similar except that we first consider short-circuit conditions (Y_x infinite). An adjustable impedance is now required in series with the standard, and its value for balancing the bridge is $-Z_e$. A fixed impedance in series with the unknown may also be required if $-Z_e$ has a negative real part, so that the bridge cannot be balanced under short-circuit conditions otherwise. Having determined or removed Z_e, ξ and Y_e are determined by applying (8) to measurements of two known impedances of different orders of magnitude on the bridge; this gives linear simultaneous equations for ξ and Y_e.

We thus find that any admittance bridge can be regarded as subject to three errors which are independent of the standard and unknown impedances, namely

(a) an error impedance in series with the standard

(b) an error admittance in parallel with the unknown

(c) a ratio error.

The error (b) can be eliminated by adjustment, while (a) and (c) can be determined by measuring two known admittances, preferably of different orders of magnitude.

Similar remarks apply to impedance bridges, but now it is the error (a) which can be eliminated by adjustment.

Acknowledgment

The authors wish to thank the Chief Engineer of the British Broadcasting Corporation for permission to publish this paper.

APPENDIX

Assessing the Effect of Adding External Impedances Across the Terminals of a Network: Deduction of Thévenin's Theorem

Consider an arbitrary linear network A having terminal pairs T_j. Suppose a generator system G is connected to A so as to inject currents i_j into terminal pairs T_j. These currents are of the same frequency but supposed arbitrary in phase and amplitude; they are to be regarded as independent variables. In theory they should, therefore, be supplied from infinite-impedance sources. In practice, any generator may be considered as an infinite-impedance source shunted by a finite admittance, and these finite admittances Y_j shunted across the T_j would be such that the given network A could be regarded as equivalent to a network A' different from A but now connected to infinite-impedance sources. If we assume that the generators G are infinite-impedance sources, the currents i_j are to be regarded as injected into A without altering A or being altered by it.

If now the voltage across T_j is V_j then

$$V_j = \sum Z_{jr} i_r \qquad \text{(A1)}$$

The quantities Z_{jr} form the network impedance matrix and (A1) is in fact merely a statement that the system is linear.

We now connect across any one terminal pair T_α a new impedance Z_α.

We can, if we like, regard the network having this additional impedance as an entirely new network and obtain equations of the form (A1) ab initio with an impedance matrix changed because of the addition of the new element Z_α.

Alternatively, the new voltages can be found by a method analogous to the principle of virtual work in dynamics. Suppose that the current in Z_α is i_α. Let the impedance Z_α be replaced by an additional infinite-impedance generator linked to the system G and delivering a current i_α into the terminals T_α.

We now have one more input current and the new voltages will be

$$V'_j = \sum Z_{jr} i_r + Z_{j\alpha} i_\alpha \quad \ldots \quad \ldots \quad \ldots \quad (A2)$$

for all terminal pairs including T_α.

Also $V'_\alpha = - Z_\alpha i_\alpha \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A3)$

The new current i_α does not differ in kind from any of the other i_j and, like them, it does not change A. These equations (A2) and (A3) determine all the V'_j. They are, in fact, a generalized form of the equations (1) and (2) used in the main text (with the parts played by current and voltage interchanged) and can clearly be generalized still further, for we could proceed as above if there had been any number m of external impedances Z_α instead of only one. If the network had n terminal pairs, we should obtain n linear equations like (A2) involving the currents i_r in the original network as well as the m currents like i_α in the external impedances, and we should also have m equations like (A3). The equations like (A3) could be used to replace each i_α by a multiple of V'_α, so that we should finally have n linear simultaneous equations for the V'_j in terms of the known currents i_r in the original network.

If in (A2) and (A3) we make Z_α tend to infinity, i_α will tend to zero and the voltage V'_α obtained across the terminals T_α is the open circuit voltage V_α so that

$$V_\alpha = \sum Z_{\alpha r} i_r \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A4)$$

Hence for terminal pair T_α, (A2) can be written

$$V'_\alpha = V_\alpha + Z_{\alpha\alpha} i_\alpha \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A5)$$

Combining (A3) and (A5)

$$(Z_\alpha + Z_{\alpha\alpha}) i_\alpha = - V_\alpha \quad \ldots \quad \ldots \quad \ldots \quad (A6)$$

If in (A6) we put $Z_\alpha = 0$, i_α becomes the short-circuit current $i_\alpha{}^*$ at T_α

and $Z_{\alpha\alpha} = - V_\alpha / i_\alpha{}^* \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (A7)$

Also if all the i_j except i_α are reduced to zero

$$V''_\alpha = Z_{\alpha\alpha} i_\alpha$$

so that $Z_{\alpha\alpha}$ is the impedance of the network A from the terminals T_α.

Thus (A7) is in fact Thévenin's Theorem obtained by specialization of (A2) and (A3).

OPTIMUM *RC* FILTERS

For Separating Sinusoidal Signals from Noise

By J. W. R. Griffiths, B.Sc., A.M.I.E.E.

Introduction

It is sometimes necessary in practice to separate a sinusoidal signal from unwanted fluctuations and, if very low frequencies are involved, normal band-pass filter techniques cannot be used. This problem arises in the detection of a noise source, such as a radio star, by interferometer techniques[1,2,3]. In brief, these consist of two receiving systems the outputs of which are either multiplied together or, in the older systems, added and rectified, the resultant in either case being passed through a low-pass filter. In the multiplier type, the d.c. output from the filter effectively measures the correlation between the outputs of the two receiving systems and, hence, the single point noise source whose signal at the two receiving systems is correlated, produces a d.c. output: the background and receiver noise, however, being uncorrelated in the two systems, produces a fluctuating output which can, to some extent, be reduced by lowering the cut-off frequency of the low-pass filter.

In the additive type a d.c. is present even when the signal is absent, and the presence of the signal is indicated by an increase in this d.c.; this means that in order to decide that a source has been detected, it is necessary to observe the background with and without the star present. This restriction does not apply to the multiplier type since d.c. is only present when a signal is being received.

If there is relative angular motion between the receiving system and the signal source, the signal output oscillates according to the interferometer pattern, so turning the d.c. output into a quasi-sinusoid and giving the signal a characteristic signature. This makes detection possible in the additive type, and considerably enhances detection in the multiplier type. The relative motion when searching for a radio star is conveniently achieved simply by the movement of the aerial system due to the earth's rotation. The frequency of the quasi-sinusoid sets a lower limit to the reduction of the background fluctuation by the low-pass filter, and it is with this point that this paper is mainly concerned.

In theoretical calculations of the minimum detectable input signal/noise ratio[2,3], it is usually assumed that the low-pass filter used is ideal; i.e., it is a low-pass filter which passes the wanted frequency without attenuation, but rejects all noise whose frequency components exceed this. However, since the frequency involved is extremely low—a typical figure is one cycle/hour—the realization of such a filter is impracticable, and normally an *RC* network of one or more sections is used. It is shown below that in such

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a case there is an optimum time constant for the *RC* network which is dependent on the number of sections but, even using this optimum, the signal/noise ratio is still inferior to that obtained with an ideal filter.

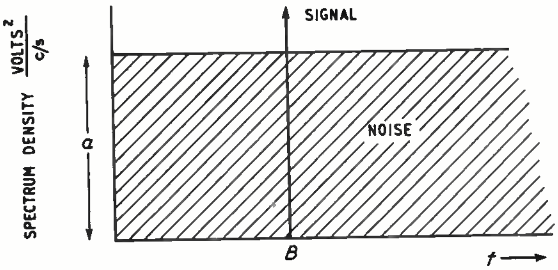


Fig. 1. *Spectrum assumed for noise and signal at the output of the system.*

Calculation of Optimum Conditions

Fig. 1 shows the spectrum assumed for the noise and signal at the output of the multiplier. The wanted frequency is assumed sinusoidal and the noise spectrum flat over the relevant frequency band. The noise spectrum is in fact triangular, but if the bandwidth of the receiving systems is much greater than B—as is usually the case—then the lower portion of the spectrum can be assumed uniform. The noise output from an ideal filter of cut-off frequency B is aB, a being the spectrum density of the noise in units of (voltage)^2 per c/s and, since the signal is unattenuated, the signal-to-noise power ratio

$$\frac{S}{N} = \frac{A^2}{aB} \quad A = \text{Signal amplitude (r.m.s.)}$$

For n identical *RC* circuits isolated from each other as in Fig. 2(a) the ratio of the output to the input voltage for any one frequency is given by

$$\frac{v_o}{v_i} = \frac{1}{(1+jx)^n}$$

where $x = \frac{f}{f_o}$ and $f_o = \frac{1}{2\pi RC}$

$$\therefore \left|\frac{v_o}{v_i}\right|^2 = \frac{1}{(1+x^2)^n}$$

Noise power in band $df = a.df$. [Unit resistance is assumed for convenience in working.]

Total noise power at output of filter

$$N = \int_0^\infty \frac{a.df}{(1+x^2)^n}$$

Putting $x = \tan\theta$ we obtain

$$N = a\int_0^{\pi/2} (\cos\theta)^{2(n-1)}\, d\theta$$

The integrand can be expanded into a series containing one term which is a function of n only; the remaining terms contain a function of n and a cosine of an even multiple of θ and when integrated between 0 and $\pi/2$, contribute nothing to the final integral.

Hence we find the noise output

$$N = K.a.f_o$$

where $$K = \frac{\pi}{2}\cdot\frac{[2(n-1)]!}{2^{2(n-1)}[(n-1)!]^2}$$

$$\text{Signal output} = \frac{A}{\left\{1+\left(\frac{B}{f_o}\right)^2\right\}^{n/2}}$$

$$\therefore \frac{S}{N} = \frac{A^2}{K.a.f_o.\left\{1+\left(\frac{B}{f_o}\right)^2\right\}^n}$$

This can be shown to have a maximum when

$$\left(\frac{B}{f_o}\right)^2 = \frac{1}{2n-1}$$

and substituting we find

$$\left(\frac{S}{N}\right)_{opt} = K_o\,\frac{A^2}{a.B}$$

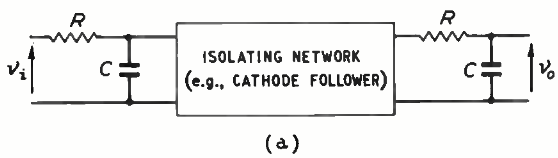
where $$K_o = \frac{\left(1-\frac{1}{2n}\right)^n}{K}$$

Considering Fig. 2(b) in which the *RC* circuits are not isolated, we find for two sections,

$$\frac{v_o}{v_i} = \frac{1}{1-x^2+3jx}$$ x being defined as before.

$$\left|\frac{v_o}{v_i}\right|^2 = \frac{1}{1+7x^2+x^4}$$

$$\text{Total noise power } N = a.f_o\int_0^\infty \frac{dx}{1+7x^2+x^4}$$



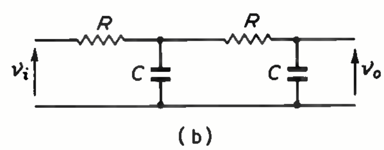


Fig. 2. *RC filter networks.*

By the substitution $y = \frac{1}{x}$ it can be shown that

$$N = a.f_o\int_0^\infty \frac{dx}{\frac{1}{x^2}+7+x^2}$$

and adding gives

$$2N = a.f_0 \int_0^\infty \frac{\left(1 + \frac{1}{x^2}\right) dx}{\frac{1}{x^2} + 7 + x^2}$$

Putting $u = x - \frac{1}{x}$ we obtain

$$N = a.f_0 \int_0^\infty \frac{du}{u^2 + 9}$$

$$= \frac{a.f_0.\pi}{6}$$

$$\therefore \frac{S}{N} = \frac{6A^2}{\pi.a.f_0\left\{1 + 7\left(\frac{B}{f_0}\right)^2 + \left(\frac{B}{f_0}\right)^4\right\}}$$

which is a maximum when

$$\frac{B}{f_0} \simeq \frac{1}{\sqrt{7{\cdot}4}}$$

$$\therefore \left(\frac{S}{N}\right)_{opt} = 0{\cdot}36 \frac{A^2}{aB}$$

Discussion

Table 1 summarizes the results. Column 4 assumes that there is a square-law relationship between the input and output S/N ratios, an assumption valid for all input S/N ratios in the case of the multiplier types, but only valid for S/N ratios much less than unity in the additive types.

In making a decision as to the best RC filter for any particular system an important point for consideration is the question of the total RC product of the network. The resistance R is limited by leakage currents, and therefore the value of the product RC determines the required value of the capacitance C, and so the size and weight of the filter. As very long time constants are required, this becomes a limiting factor to the design of the filter.

When two isolated sections are used under optimum conditions, each section has an RC product only $1/\sqrt{3}$ of the single section, so that the total is increased to $2/\sqrt{3}$. In the case of cascaded sections each RC product is reduced to $1/\sqrt{7{\cdot}4}$ so that the total RC product $2/\sqrt{7{\cdot}4}$ is less than the original.

Conclusions

When RC circuits are used to reduce the background fluctuations and so facilitate the detection of a weak sinusoidal signal, there is an optimum time constant which depends on the number of sections, and whether or not the sections are isolated from one another. Even using the optimum values, an RC filter of any number of sections still falls short of the performance of the ideal filter.

REFERENCES

[1] M. Ryle, "A New Radio Interferometer and its Application to the Observation of Weak Radio Stars", *Proc. Roy. Soc. A*, 1952, Vol. 211, p. 351.

[2] D. G. Tucker, "Signal/Noise Performance of Multiplier (or Correlation) and Addition (or Integrating) Types of Detector", *I.E.E. Monograph No.* 120*R*, February 1955.

[3] S. J. Goldstein, Jr, "A Comparison of Two Radiometer Circuits", *Proc. Inst. Radio Engrs*, 1955, Vol. 43, p. 1663.

TABLE 1

1 Filter	2 $(S/N)_{opt}$ (power ratio)	3 Loss compared with ideal filter (decibels)	4 Increase of input S/N to give same output S/N as ideal filter (decibels)	5 Optimum conditions
Ideal	$1{\cdot}00 \frac{A^2}{a.B}$	0	0	Cut-off of filter $= B$
One RC section	$0{\cdot}32 \frac{A^2}{a.B}$	5	2·5	$f_0 = B$
Two isolated RC sections	$0{\cdot}41 \frac{A^2}{a.B}$	4	2	$f_0 = \sqrt{3}\, B$
A large number of isolated RC sections	$0{\cdot}51 \frac{A^2}{a.B}$	3	1·5	$f_0 = \sqrt{2n}\, B$
Two cascaded RC sections	$0{\cdot}36 \frac{A^2}{a.B}$	4·4	2·2	$f_0 = \sqrt{7{\cdot}4}\, B$

FLUCTUATION NOISE

Direct Measurement at Very Low Frequencies

By F. J. Hyde, M.Sc., A.M.I.E.E.

(Official communication from D.S.I.R. Radio Research Station, Slough)

SUMMARY.—A method of measuring the current noise generated in temperature-sensitive solid-state devices, in narrow bandwidths about frequencies chosen between 5×10^{-3} and 10^{-1} c/s is described. The central feature of the equipment is a resistance-capacitance coupled amplifier of the type originally described by Schneider (1945). Spurious electrical fluctuations arising from the circuitry and thermal fluctuations of the ambient oil surrounding the specimen were shown not to cause any error. Specification of the noise necessitates determination of the impedance of the specimen at the frequencies in question: this may be derived from measurements of the limiting small-signal resistances of the specimen at very low and very high frequencies and its thermal time-constant.

1. Introduction

It has been of interest to measure the spectral density of fluctuation noise, at very low frequencies, associated with current-carrying germanium devices, as a means of investigating the fundamental noise-generation process. One method used elsewhere (Rollin and Templeton 1953, 1954) was to record the noise in a broad bandwidth on a magnetic tape running at slow speed. This was then played back at normal speed and selective amplification of the recorded noise effected in the audio-frequency range. From the ratio of recording to play-back speed the noise density was referred back to the appropriate low frequencies at which it was generated. By this means it proved possible to measure noise down to frequencies as low as $2{\cdot}5 \times 10^{-4}$ c/s.

With the equipment to be described here, noise has been measured *directly* in a narrow bandwidth at frequencies down to 5×10^{-3} c/s, being displayed as a pen recording on a chart. Measurements at lower frequencies could be made if sufficient recording time were allowed. The essential feature of the equipment is an amplifier, resonant at the frequencies at which recordings are to be made, with a Q-factor of about eight for each resonance. The type of resonant system used was originally described by Schneider (1945), although it is believed that the present is the lowest frequency range of application of the system so far reported.

2. Resonant Amplifier for Very Low Frequencies

A schematic diagram of the selective amplifier is shown in Fig. 1. The transmission is given by

$$\frac{e_o}{e_i} \propto \frac{1}{1 + jQ\left(\dfrac{\omega}{\omega_0} - \dfrac{\omega_0}{\omega}\right)} \quad \ldots \quad \ldots \quad (1)$$

as for an ideal tuned circuit. The angular resonant frequency is given by

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$$\omega_0 = 1/(mR_1C_1R_2C_2)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad (2)$$

and the Q-factor by

$$Q = \frac{m_1^{\frac{1}{2}}}{g}\left(\frac{R_2C_2}{R_1C_1}\right)^{\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

if the leakage resistances r_1 and r_2 of C_1 and C_2 can be ignored; i.e., if $\omega_0C_1r_1$, $\omega_0C_2r_2 > 10$ say. Here m is the aperiodic gain of the amplifier with the feedback capacitor C_2 removed,

$$m_1 = \left(m + 1 + \frac{R_3}{R_2} + \frac{R_3}{R_1}\right),$$

$$g = \left(1 + \frac{R_2}{R_1} + \frac{R_2 + R_3}{R_1} \cdot \frac{C_2}{C_1}\right)$$

and R_3 is the output resistance of the amplifier and is equal to the parallel combination of the anode load of V_3 (see Fig. 2) and the slope resistance of V_3.

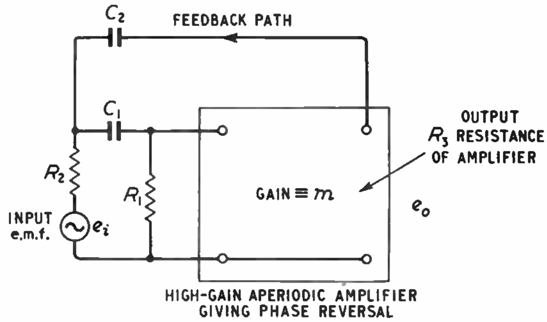


Fig. 1. *Schematic circuit of selective amplifier.*

The Q-factor may be maximized for a given gain m by a suitable choice of ratios C_2/C_1 and R_2/R_1 with respect to R_3/R_1. These are $C_2/C_1 = (R_1/R_3)^{\frac{1}{2}} = R_1/R_2$. It will be noted that the resonant frequency is inversely proportional to the square root of the aperiodic gain m of the amplifier, so that very low resonant frequencies can be obtained with quite ordinary values of R_1, R_2, C_1, C_2. The optimum value of Q is

C

$$Q_{opt} = \frac{m^{\frac{1}{2}}}{2\left[1 + \left(\frac{R_3}{R_1}\right)^{\frac{1}{2}}\right]} \quad \ldots \quad \ldots \quad (4)$$

A detailed circuit diagram of the amplifier is given in Fig. 2. Valves 1–3 form a direct-coupled amplifier giving the required phase reversal with a voltage gain m of about 1000. Bias voltages are supplied mainly by potentiometers between h.t. and earth. By ganged switching of C_2 and C_1, maintaining their ratio approximately constant to preserve optimum Q, five resonant frequencies ($f_0 = \omega_0/2\pi$) were obtained as shown in Table 1.

TABLE 1

Switch Position	1	2	3	4	5	6
C_2 μF	2	1	0·5	0·25	0·1	–
C_1 μF	1	0·5	0·25	0·1	0·05	1
f_0 c/s (approx.)	0·005	0·01	0·02	0·04	0·10	Broad Band

The 0·001-μF capacitor across the final anode load suppresses oscillation at high frequencies. It was found necessary to use a separate stabilized h.t. supply for the cathode follower V_4, to avoid instability at low frequencies. Decoupling is not a practicable proposition at the low frequencies we are concerned with here. The heaters were d.c. supplied at 6·3 volts from two 6-volt accumulators with barretter stabilization. When the unit was preceded by a commercial d.c. amplifier, flicker noise was not troublesome at full gain, and drift of the output current through the pen recorder was not more than 0·1 mA in eight hours, which was the longest continuous recording period used. The resonant frequency may be varied slightly by changing the heater voltage of the valves, thereby altering the gain m.

3. Parameters of the Amplifier

In order that a measured noise current output may be referred to a noise voltage at the input of the amplifier, it is necessary to know the transfer conductance K of the unit at the resonant frequency f_0, and also the noise bandwidth $\frac{\pi}{2} \cdot \frac{f_0}{Q}$. A convenient way to determine these parameters is to record the transient response of the system to a unit step of voltage applied at the input terminals. The response of the amplifying section can be shown, with negligible approximation if $Q > 5$ say, to be

$$V(t) = \frac{G_0}{Q} \exp.\left(-\frac{\omega_0}{2Q}t\right) \sin \omega_0 t \quad \ldots \quad (5)$$

where $V(t)$ is the voltage developed at the anode of V_3, and $G_0 = m/g$ is the gain of the amplifier at resonance. If it is assumed that the pen-recorder response may be specified by a single time-constant $\tau_R < 2Q/\omega_0$ then it follows that the overall transient response is

$$I(t) = \frac{K}{Q} \exp.\left(-\frac{\omega_0}{2Q}t\right) \sin \omega_0 t \quad \ldots \quad (6)$$

where $K = G_0 K_c$, K_c being the transfer conductance of the output cathode-follower. The attribution of a single time-constant to the pen-recorder is a reasonable approximation if about 6 volts r.m.s. of 50-c/s excitation from a high-impedance source is superimposed on the

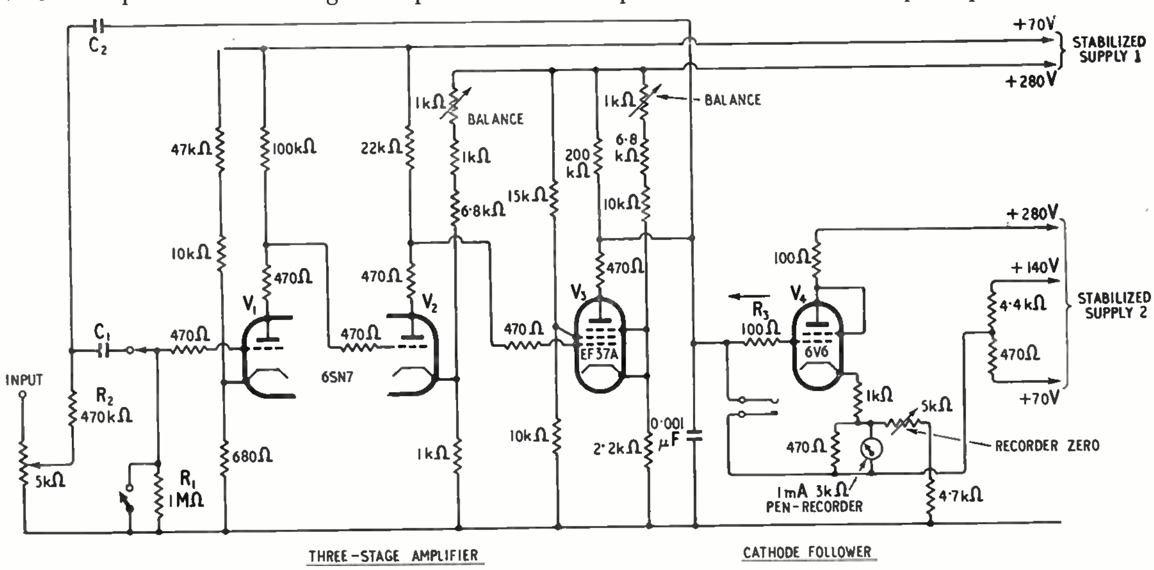


Fig. 2. *Circuit of very-low-frequency resonant amplifier.*

low-frequency noise applied to the pen-recorder movement, so that pen–paper friction is minimized: τ_R was about 0·1 sec for the recorder used here. A typical transient record resulting from a step of 0·279 volt applied at $t = 0$, and a plot of the dependence of the amplitude of the peaks of the transient waveform on the number of periods is shown in Fig. 3. The resonant frequency is determined by timing periods with a stop-watch.

a cut-off frequency of 10 c/s and a maximum sensitivity of 25 volts output for 1 mV input across 1000 ohms. The amplified broad-band noise is then further amplified selectively by the resonant amplifier, and the noise output of this is applied to the pen recorder. A section of a typical noise record for $f_0 = 0{\cdot}01$ c/s, noise bandwidth 0·002 c/s and paper speed of twelve inches per hour is shown in Fig. 5.

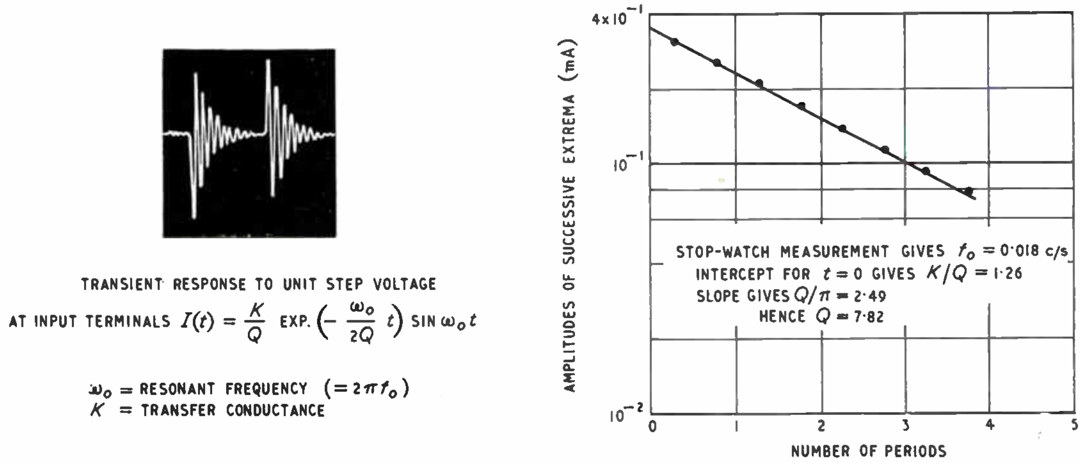


Fig. 3 (above). *Typical transient record and analysis.*

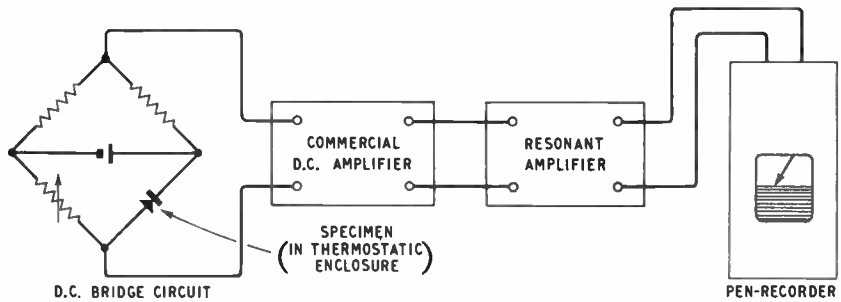


Fig. 4 (right). *Schematic circuit for measurement of noise.*

4. Complete Measuring Circuit for Noise

This is shown schematically in Fig. 4. The specimen under examination, shown as a rectifier biased in the reverse direction, is immersed in an oil-bath, the temperature of which is controlled to an accuracy of about ± 0·001 °C. It comprises one arm of a d.c. bridge circuit, the other arms of which are wire-wound resistances generating only thermal noise, even when carrying current. The bridge is adjusted so that the required direct current flows through the specimen and there is no direct voltage output at the bridge terminals.

The excess noise generated in the specimen, when current is passed through it, does, however, produce a *noise* voltage at the bridge output terminals (the total thermal noise at the bridge output is always very much smaller than the excess noise generated in the specimen at the low frequencies we are concerned with here). This is amplified by a commercial d.c. amplifier having

5. Analysis of the Noise Records

It was shown by Rice (1945) that the envelope curve $A(t)$ of a noise current contained in a narrow band of frequencies Δf centred on f_0 has a Rayleigh distribution of amplitude: that is, the probability of the instantaneous amplitude of the envelope lying between A and $A + dA$ is

$$p(A)dA = \frac{A}{< \Delta I^2 >} \exp.\left(\frac{-A^2}{2 < \Delta I^2 >}\right) dA \qquad (7)$$

where $< \Delta I^2 >$ is the mean-square value of the noise current in the bandwidth Δf and is defined by

$$< \Delta I^2 > = \lim_{T \to \infty} \frac{1}{T} \int_0^T i^2(t) dt$$

$i(t)$ is the instantaneous value of the noise current, also in the bandwidth Δf. The present noise records have been analysed on the basis of this distribution.

In practice, the noise was recorded for sufficient time to enable about 250 complete waves to be obtained. For our conditions this meant that the probable error of determination of the true r.m.s. value of the noise current was not greater than 10%. This figure is derived as follows. If the 250 waves were all independent then there would be this number of data from which to determine the r.m.s. value of the wave. In fact there is correlation between adjacent waves arising from the resonant property of the selective circuit. For Qs of about eight the number of independent data is reduced to about 100. Using the statistical result that the standard deviation of the error of determination of the standard deviation of a distribution is approximately equal to the reciprocal of the square root of the number of data, we find this to be 1/10th or 10%.

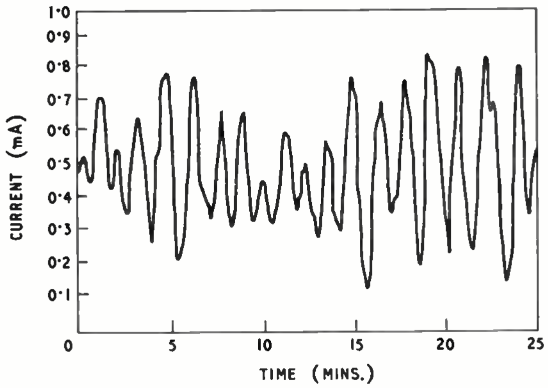


Fig. 5. *Section of a typical noise record at* 0·01 *c/s; noise bandwidth* 0·002 *c/s.*

A convenient plot, which was used to determine the r.m.s. value from the data, was the logarithm of the ratio of the number of readings N for which $(2A)^2$ exceeded the abscissa $\{(2A)^2\}$ to the total number of readings N_0. This leads to a straight line of slope $-1/8 < \Delta I^2 >$ as may be seen from equation (8).

$$N = N_0 \int_A^{\infty} P(A) dA$$
$$= N_0 \exp. - \{(2A)^2/8 < \Delta I^2 >\} \quad \ldots \quad (8)$$

A plot of this type is shown in Fig. 6.

When the mean square value $< \Delta I^2 >$ of the output noise-current wave had been obtained, it remained to determine from this the equivalent noise-current generator in shunt with the terminals of the specimen, by dividing by the overall current gain, which included the attenuation between the terminals of the specimen and the terminals of the d.c. amplifier (see next section). From a knowledge of the noise bandwidth of the system, $\Delta f = \pi f_0/2Q$, one could convert $< \Delta I^2 >$ to the spectral density of mean-square current, $< \Delta I^2 >/\Delta f$ for plotting purposes.

6. Impedance of the Specimen

To calculate the attenuation constant for the noise current between the terminals of the specimen and those of the d.c. amplifier, it is necessary to know the small-signal impedance of the specimen at its working point. Direct measurement of this, using conventional a.c. techniques, would have been extremely tedious even if a sine-wave generator for frequencies below 0·1 c/s, had been available.

The impedance at these frequencies may be inferred, however, from a knowledge of the thermal time constant τ of the noise-generating region of the device, the small signal a.c. resistance R_∞ measured at frequencies $\gg 1/\tau$, and R_0 the slope resistance of the static direct-current/voltage characteristic. It is implicit in this statement that any dispersive effects in the impedance in the frequency range considered here are to be attributed to direct thermal effects. Although long relaxation times, such that their reciprocals lie within this frequency range, are postulated to explain the spectral distribution of the noise intensity at low frequencies, it is not considered that the physical processes with which they are associated have a macroscopic effect on the impedance of the specimen.

Depending on whether the thermal time constant is greater or less than the reciprocal of the measuring frequency, either the small-signal slope resistance of the isothermal characteristic or of the static characteristic respectively is required. If the reciprocal of the thermal time constant lies in our frequency range then the locus of the small-signal current-voltage relationship about the working point becomes elliptical.

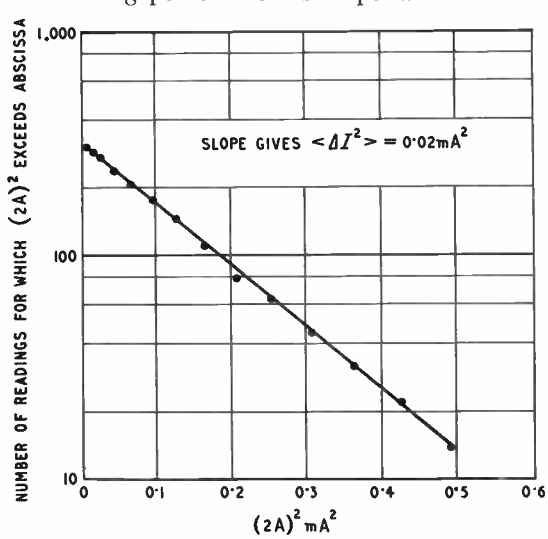


Fig. 6. *Plot of distribution of peak-to-peak amplitudes* (2A) *of waves from which the mean square value* $< \Delta I^2 >$ *of the wave-train is deduced.*

The thermal time constant referred to is that of the noise-generating region. In germanium devices, in which the resistance and noise arise mainly from potential barriers so that power dissipation is extremely localized, the effective thermal time constant is very short, $< 10^{-6}$ sec (say). We are then concerned with the slope resistance of the static characteristic at our very low frequencies and this is taken to be the same as the a.c. resistance measured at a few cycles per second. For small power loadings, so that self-heating is negligible, the isothermal and static characteristics are coincident.

On the other hand, when the specimen under test is a filament, so that its resistance originates in the bulk, as will be the case if the end-connections are made substantially non-rectifying, then the time constant is much longer. The isothermal and static characteristics of a filament are not coincident for the relatively large power dissipations which sometimes ensue when large direct current is passed.

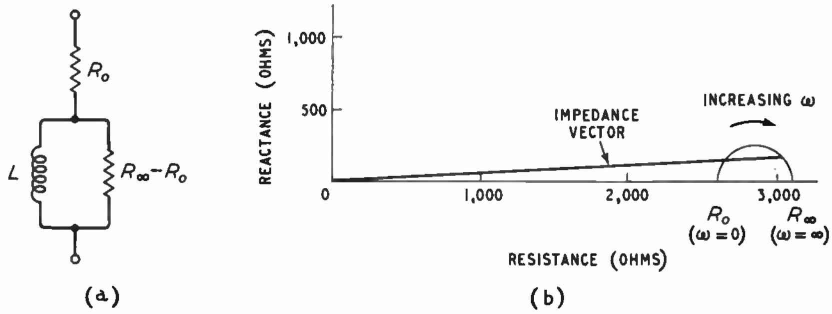


Fig. 7. *Equivalent circuit (a) and locus of impedance vector (b) for a filament for which* $R_\infty > |R_0| : L = 1040\,H$.

The general theory of the impedance of temperature-sensitive circuit elements (Burgess 1955) may be adapted to show that if the quantities R_∞, R_0 and τ of a specimen are known, then the impedance at any frequency is given by

$$Z(\omega) = R_\infty - (R_\infty - R_0)/\{1 + j\omega\tau(R_\infty + R_0)/2R_\infty\} \quad \ldots \quad \ldots \quad (9)$$

for the special case in which the isothermal current-voltage characteristics are linear. R_∞ and R_0 are readily measured. The following technique has been used to determine τ. The filament forms one arm of a d.c. bridge circuit, the other arms of which are wire-wound resistances having small temperature coefficients of resistance. The bridge is balanced so that the current flowing through the filament is not large enough to cause measurable self-heating. By increasing the voltage applied to the bridge for a short time, the temperature of the filament may be raised by about 1°C (say) while the temperature of the ambient, which is usually oil, is substantially unaffected. If the bridge voltage is then reduced to its original value, the resistance of the filament will change at a rate determined solely by its thermal time constant which may be deduced from the rate of change of the out-of-balance waveform of the bridge, which is conveniently recorded photographically.

The actual mechanism of heat loss is a mixture of conduction through the leads and conduction and convection through the surrounding oil, so that the process cannot exactly be described by a single time constant. A good fit in terms of a single time constant is nevertheless obtained in practice.

In Fig. 7 are shown the equivalent circuit which may be derived from equation (9) and the locus of the impedance vector for a filament in which sufficient power was dissipated to raise its temperature, and for which $R_\infty = 3100\,\Omega$, $R_0 = 2600\,\Omega$, $\tau = 2{\cdot}3$ sec, and $L = \tau\,(R_\infty^2 - R_0^2)/2R_\infty = 1040$ H.

7. Sources of Error

It was necessary to ensure that the noise measured was directly attributable to the fundamental noise generation process in the specimen. Other causes of fluctuating output from the system were therefore carefully investigated. Undesirable fluctuations which may have been sufficiently great in magnitude to cause error could have originated in (a) the dry batteries supplying current to the bridge circuit of which the specimen was a member, (b) the amplifiers, (c) the thermostatic enclosure, as temperature variations.

Noise generated in the batteries would have produced a noise output at the bridge terminals if the a.c. and d.c. impedances of the specimen were different (as was usually the case.) The battery used to feed the bridge was loaded so that currents flowed equal to those drawn from it during normal operation: a similar loaded battery was connected in series with it, in opposition, and the combined output voltage adjusted to zero. The batteries were separated from each other physically, and electrically and thermally screened. When connected to the noise-measuring equipment operating at full gain no increase in output was detected. This test also showed that noise of the noise-measuring equipment was also negligible. At full gain, circuit noise was just detectable as a fluctuating output current.

Temperature fluctuations in the oil-bath were minimized by a suitable design. A quart thermos flask containing transformer oil was surrounded by a metal cylinder, with the intervening space of about ½ inch all round filled with glass wool. This cylinder acted as an electrostatic screen and also as a uniform temperature surface. An enamelled resistance wire was wound on the cylinder: power dissipated in this was the sole source of heat. The cylinder was itself enclosed in a wooden box, the intervening space again being filled with glass wool. A control thermistor sampled the temperature as close to the surface of the metal cylinder as its envelope would allow. It formed one arm of a resistance bridge fed with 50-c/s a.c. The out-of-balance voltage from the bridge, after amplification, was used to control the striking of a thyratron valve which in turn controlled the supply of electrical power to the heater winding. The parameters were such that at the location of the thermistor the temperature varied by $\pm 0{\cdot}02$°C about that value for which the control thermistor bridge was balanced.

The waves of heat passing through the cylinder into the oil were considerably attenuated and, in consequence, the internal temperature of the oil-bath fluctuated less than that of the control thermistor. An assessment of the internal fluctuations was made by replacing the specimen in the enclosure by a thermistor and attempting to measure the noise output arising from temperature-dependent resistance variation. None was detected, showing that temperature fluctuations were unimportant. An upper limit for the temperature fluctuations can be obtained as follows.

If α is the temperature coefficient of the resistance R of this thermistor when fed under practically constant voltage conditions, then a change of temperature ΔT will give rise to a change in current through the thermistor $\Delta I = I\alpha\Delta T$ and $< \Delta I^2 > = I^2\alpha^2 < \Delta T >^2 \equiv \int_0^\infty S(f)_{i,T}$. $S(f)_{i,T}$, the spectral density of the mean square current fluctuation, is then given by

$$S(f)_{iT} = 4I^2\alpha^2\{\tau/(1 + \omega^2\tau^2)\} < \Delta T^2 >$$

where τ is the thermal time constant of the thermistor (c.f. Schottky 1926). The minimum detectable spectral density of mean-square noise current at $f_0 = 0{\cdot}01$ c/s was 10^{-17} amp² sec; for the thermistor used, $I = 10^{-3}$ amp, $\tau = 1{\cdot}4$ sec, $\alpha \approx 0{\cdot}04$ deg^{-1}. Hence

$$< \Delta T^2 > \ll 2 \times 10^{-5} \text{ deg}^2$$

8. Conclusions

The paper has demonstrated that direct measurement of current noise in semiconductors in the frequency range 5×10^{-3} to 10^{-1} c/s is possible. The major source of inaccuracy at the lowest frequencies has been shown to arise from the practical consideration of length of recording time. The Q-factor of about eight chosen is a reasonable compromise at these frequencies: if a larger value is chosen, a correspondingly longer recording time must be allowed to achieve the same accuracy of measurement because of the longer persistence of strong correlation between adjacent waves of the noise record: if a smaller value is chosen then, with a frequency spectrum varying inversely as the frequency, the actual location of the noise spectral density is uncertain.

The alternative method of recording broad-band low-frequency noise on a magnetic tape has the attraction that one actual noise record contains data on all frequencies in the pass-band of the recording equipment. Sensitivity may be reduced by the noisiness of the tape.

The actual noise measurements made with the equipment described here are published elsewhere, since they are best regarded in their context; that is, as details of the more complete noise spectra extending from 5×10^{-3} c/s to several Mc/s.

Acknowledgments

The author wishes to acknowledge the assistance of Messrs. H. C. Bevan and R. E. Taylor with the experimental work.

The work described above was carried out as part of the programme of the Radio Research Board. This paper is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

REFERENCES

[1] R. E. Burgess, "The A.C. Admittance of Temperature Sensitive Circuit Elements", *Proc. Phys., Soc. B.*, 1955, Vol. 68, p. 766.
[2] F. J. Hyde, "Excess Noise Spectra in Germanium", *Proc. Phys. Soc. B.*, 1956, Vol. 69, p. 242.
[3] S. O. Rice, "Mathematical Analysis of Random Noise", *Bell Syst. Tech. J.*, 1945, Vol. 24, p. 46.
[4] B. V. Rollin and I. M. Templeton, "Noise in Semiconductors at Low Frequencies", *Proc. Phys. Soc. B.*, 1953, Vol. 66, p. 259.
[5] B. V. Rollin and I. M. Templeton, "Noise in Germanium Filaments at Very Low Frequencies", *Proc. Phys. Soc. B.*, 1954, Vol. 67, p. 271.
[6] E. E. Schneider, "A New Type of Electrical Resonance", *Phil. Mag.*, 1945, Vol. 36, p. 371.
[7] W. Schottky, "Small Shot Effect and Flicker Effect", *Phys. Rev.*, 1926, Vol. 28, p. 74.

PROFESSOR G. W. O. HOWE

The Council of the British Institution of Radio Engineers has elected Professor G. W. O. Howe an Honorary Member of the Institution "in recognition of his contributions to the advancement of radio science, and in particular for his long series of notable articles in *Wireless Engineer*".

ELECTRONIC INSTRUMENTS EXHIBITION

An exhibition of electronic instruments will be staged by E.M.I. Electronics Ltd., at the Royal Hotel, Woburn Place, London, W.C.1, on November 28th–30th, 10 a.m. to 6 p.m. Tickets may be obtained free of charge from E.M.I. Electronics Ltd., Hayes, Middlesex, on written application.

NEW BOOKS

Analysis of Electric Circuits

By William H. Middendorf. Pp. 306 + xiv. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 48s.

This American book starts with the basic laws and definitions of electricity and then proceeds rapidly to alternating current and voltage, notation, and the algebra of complex numbers. It treats only alternating current and voltage in the steady-state. Seven chapters cover impedance, circuit parameters, calculation of power and series and parallel circuits.

A chapter on locus diagrams is then included and followed by a treatment of resonance. Circuits having more than one source of current or voltage are discussed and Part 1 ends with Chapter 16 on magnetic-field coupling in which transformers are treated.

Part 2 has only two chapters, on non-sinusoidal waves and network simplifications and theorems. Part 3 again has two chapters, in which polyphase circuits and communication circuits are discussed.

The author sticks strictly to the 'electric' of his title and makes no mention of valve circuits or of any electronic matters. It is a good point that he defines very clearly early on in the book the conventions that he adopts for the analyses and for the nomenclature. Not everyone will like his choice, but at least one always knows what he means.

The form of treatment is conventional and is carried out to a great extent by complex algebra. The polar form of representation is, however, used rather more than usual.

W.T.C.

Frequency Modulation Engineering (Second Edition)

By Christopher E. Tibbs, M.I.E.E., M.Brit.I.R.E. and G. G. Johnstone, B.Sc. Pp. 435 + xii. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 45s.

The first edition of this book appeared in 1947 and was due to the first author alone. The revision which has resulted in this second edition has been carried out mainly by the second author.

There are eleven chapters, of which the first four introduce the subject and deal with the theoretical aspects, including interference and its suppression and noise structure. Propagation, which means v.h.f. propagation, is then discussed.

Chapter 6 covers aerials and feeders, the emphasis being placed on transmitting rather than receiving types. Transmitters for f.m. are treated in Chapter 7. Limiters, discriminators and f.m. receivers are dealt with in the next two chapters, and the book concludes with chapters on measurements and the practical uses of f.m.

Each chapter includes a list of selected references. The treatment is, to a large extent, explanatory and the mathematics, which is not extensive, is of a fairly simple nature.

W.T.C.

Abacs or Nomograms

By A. Giet. Translated and revised by J. W. Head, M.A. (Cantab.) and H. D. Phippen, M.A. (Edin.), B.Sc. (Lond.). Pp. 225 + ix. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 35s.

This book explains how to construct nomograms, starting with simple graphs and going on by easy stages to the multiple parallel-index-line alignment chart. Many examples of different kinds of chart are included. The book has been translated from the original French.

Hi-Fi from Microphone to Ear

By G. Slot. Pp. 180. Philips Technical Library. Distributed in the U.K. by Cleaver-Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price 17s. 6d.

Introduction to Distributed Amplification

By Harry Stockman, S.D. Pp. 240. S.E.R. Co., 543 Lexington Street, Waltham, Mass., U.S.A. Price $2.90.

Radio Research 1955

Pp. 56. Reports of the Radio Research Board and the Director of Radio Research. Published for Department of Scientific and Industrial Research by H.M.S.O., York House, Kingsway, London, W.C.2. Price 3s. 6d.

ASLIB Year Book 1956-1957

Pp. 172 + xv. ASLIB, 4 Palace Gate, London, W.8. Price 12s. 6d.

TV Repair Questions and Answers: Vol. 5. Sound and Low Voltage Circuits

By Sidney Platt. Pp. 120. John F. Rider Publisher Inc., 480 Canal Street, New York 13, N.Y., U.S.A. Price $2.10.

Co-Operative Electrical Research

Journal of the Electrical Research Association, Vol. 1, No. 1, July 1956. Pp. 40. The Electrical Research Association, Thorncroft Manor, Dorking Road, Leatherhead, Surrey. Price 2s. 6d.

Les Antennes

By L. Thourel. Pp. 440. Dunod, 92 Rue Bonaparte, Paris 6e. Price 4,800 F.

Intended to supplement theoretical works in aerials, this book uses the minimum amount of mathematics consistent with a proper understanding of the ideas put forward. Calculations are backed up with experimental results, and the degree of practical validity of formulae indicated. Contents include chapters on medium-wave transmission; half-wave aerials for metric and decimetric waves; short-wave transmission; end-fire aerials; wideband omnidirectional v.h.f. and u.h.f. aerials; radiation from openings; horns; paraboloids; aerials with wide beam-widths in one plane and narrow beam-widths in another; slot aerials; lenses and frame aerials. An appendix deals with the Smith Chart.

The Distribution of Radio Brightness on the Solar Disk: Interstellar Hydrogen

International Scientific Radio Union (U.R.S.I.) Special Reports Nos. 4 and 5, in one cover. Pp. 72. General Secretariat of U.R.S.I., 42 rue des Minimes, Brussels. Belgium. Price 14s. 6d. (including postage).

Radio and Electronic Components Vol. 2—Variable Resistors and Potentiometers

By G. W. A. Dummer, M.B.E., M.I.E.E. Pp. 176 + xiii. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 30s.

The Robertson Guide to Screw Thread Forms

Leaflet from W. H. A. Robertson & Co. Ltd., Lynton Works, Bedford.

BRITISH STANDARDS

Methods of Testing Vulcanized Rubber

B.S. 903. Part C3: 1956. Price 2s. 6d.

Memorandum on the Design of Electrical Apparatus having Double Insulation

B.S. 2754: 1956. Price 4s.

Varnished Cotton Cloth Sheet and Tape for Electrical Purposes
B.S. 419: 1956. Price 5s.

Terminology of Internal Defects in Castings as Revealed by Radiography
B.S. 2737: 1956. Price 12s. 6d.

Basic Characteristics of Radio Service Selection and Intercommunication Systems for Civil Aircraft
B.S. R.2: 1956. Price 3s.

Thin Vulcanized Fibre Sheets (Including Leatheroid) for Electrical Purposes
B.S. 2768: 1956. Price 4s.

These publications can be obtained from the British Standards Institution, 2 Park Street, London, W.1.

NATIONAL BUREAU OF STANDARDS

Protection against Betatron-Synchrotron Radiation up to 100 Million Electron Volts
National Bureau of Standards Handbook 55. Pp. 52. Price 25 cents.

Units and Systems of Weights and Measures
By Lewis V. Judson. Pp. 29. Circular No. 570. Price 25 cents.

Electron Physics Tables
By L. Marton, C. Marton and W. G. Hall. Pp. 83. Circular No. 571. Price 50 cents.

Amplitude and Phase Curves for Ground-Wave Propagation in the Band 200 c/s to 500 kc/s
By James R. Wait and H. Herbert Howe. Pp. 17. Circular No. 574. Price 20 cents.

These publications can be obtained from National Bureau of Standards, U.S. Department of Commerce, Washington 25, D.C., U.S.A.

MEETINGS

I.E.E.

14th November. "Frequency Diversity in the Reception of Selectively Fading Binary Frequency-Modulated Signals with special reference to Long-Distance Radio-telegraphy", by J. W. Allnatt, B.Sc.(Eng.), E. D. J. Jones and H. B. Law, B.Sc.Tech. "An Investigation of the Spectra of Binary Frequency-Modulated Signals with Various Build-up Waveforms", by J. W. Allnatt, B.Sc.(Eng.) and E. D. J. Jones. "An Improved Fading Machine", by H. B. Law, B.Sc.Tech., F. J. Lee, F. A. W. Levett and R. C. Looser, B.Sc.(Eng.). "The Detectability of Fading Radiotelegraph Signals in Noise", by H. B. Law, B.Sc.Tech. "The Signal/Noise Performance Rating of Receivers for Long-Distance Synchronous Radio-telegraph Systems using Frequency Modulation", by H. B. Law, B.Sc.Tech.

22nd November. "The Presentation and Demonstration of the Theory of Semi-Conductors to Students of Electrical Engineering." Discussion to be opened by P. Godfrey, B.Sc.(Eng.) at 6 o'clock.

29th November. "Differences of Opinion about Dimensions", Professor R. O. Kapp, B.Sc.(Eng.).

3rd December. "Electronics and Automation—The Use of Nucleonic Devices", by Denis Taylor, M.Sc., Ph.D.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, at 5.30 p.m., except where otherwise stated.

Brit.I.R.E.

28th November. "Colour Television", by G. N. Patchett, Ph.D., to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

22nd November. "Alternatives to the N.T.S.C. Colour System", by Dr. E. L. C. White, M.A., to be held at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2, at 7 o'clock.

Society of Instrument Technology

27th November. "Television Technique Applied to Observation and Control", by Professor J. D. McGee, O.B.E., M.Sc., Ph.D., at 7 o'clock at Manson House, Portland Place, London, W.1.

Radar Association

14th November. "Infra-Red: Its Problems and Possibilities", by Dr. F. E. Jones, M.B.E., B.Sc., Ph.D., under the chairmanship of Sir Robert Renwick, Bt., K.B.E., President of the Association, to be held at 7.30 at the Anatomy Theatre, University College, Gower Street, London, W.C.1. (Open to non-members.)

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

ALTERATION TO MSF 60 kc/s

Due to extensive maintenance work on the long-wave aerial system at Rugby, it will no longer be possible, after the end of October, to transmit MSF 60 kc/s at 1429-1530 G.M.T. In order to maintain a service to users, an alternative transmission has been arranged and for a period of about eighteen months, commencing on the 1st November 1956, MSF 60 kc/s will be radiated at 1959-2100 G.M.T. The values of the transmitted frequency will continue to be published in *Wireless Engineer.*

Values for September 1956

Date 1956 September	MSF 60 kc/s Frequency deviation from nominal*: parts in 10^9
1	+1
2	+1
3	0
4	+1
5	+1
6	+2
7	+2
8	N.M.
9	+2
10	+1
11	+2
12	+2
13	+2
14	+1
15	+1
16	+2
17	+2
18	+1
19	+1
20	+1
21	+1
22	+1
23	+1
24	+1
25	0
26	+1
27	+1
28	+2
29	+2
30	+2

N.M. = Not Measured.
*Nominal frequency is defined to be that frequency corresponding to a value of 9 192 631 830 c/s for the N.P.L. caesium resonator.

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

534.232 3266

Emission of Sound by a Rotating Dipole.—L. N. Sretenski. (*Akust. Zh.*, Jan.–March 1956, Vol. 2, No. 1, pp. 93–98.) A theoretical paper.

534.232 : 621.395.623.7 3267

The Generation of Sound Pulses for Acoustic Measurements by means of Loudspeakers.—H. Niese. (*Hochfrequenztech. u. Elektroakust.*, Nov. 1955, Vol. 64, No. 3, pp. 84–90.) The production of pulses with desired waveforms is discussed. A special loudspeaker with a spherical radiation pattern has been developed to simulate the sound from an orchestra.

534.24 : 534.861 3268

Wobbling of an Audio Note due to a Rotating Target.—M. V. J. Row & S. R. Rao. (*J. Instn Telecommun. Engrs, India*, March 1956, Vol. 2, No. 2, pp. 100–102.) Analysis is presented of the frequency rise and fall of an initially steady tone after reflection of the sound wave from a rotating target. The theory is relevant to effects which might be produced by a fan operating in a studio.

534.26 3269

Diffraction by a Cylinder of Finite Length.—W. E. Williams. (*Proc. Camb. phil. Soc.*, April 1956, Vol. 52, Part 2, pp. 322–335.) The diffraction of a plane sound wave by a hollow cylinder is considered. Laplace transforms are used, and the problem is reduced to the solution of two complex integral equations. The solution is finite for all values of the cylinder length, including those corresponding to resonance conditions.

534.31 3270

The Transient State resulting from the Excitation of a String by a Bow.—B. Bladier. (*C. R. Acad. Sci., Paris*, 4th June 1956, Vol. 242, No. 23, pp. 2704–2707.)

534.79 3271

A Re-determination of the Equal-Loudness Relations for Pure Tones.—D. W. Robinson & R. S. Dadson. (*Brit. J. appl. Phys.*, May 1956, Vol. 7, No. 5, pp. 166–181.) Report of an investigation carried out at the National Physical Laboratory. Subjective measurements were made at frequencies in the range 25 c/s – 15 kc/s and at sound pressure levels up to about 130 dB above 0·0002 dyn/cm². A new determination was made of the normal threshold of hearing in free field; the results are highly consistent with the equal-loudness contours. Discrepancies between results obtained previously by various workers are to some extent explained.

534.844 3272

Note on the Statistical Treatment of the Reverberation Process.—W. Kraak. (*Hochfrequenztech. u. Elektroakust.*, Nov. 1955, Vol. 64, No. 3, pp. 90–93.) The validity of formulae derived by Eyring (*J. acoust. Soc. Amer.*, Jan. 1930, Vol. 1, pp. 217–241) for a nonuniform distribution of absorptive material is confirmed.

534.86 : 621.375.4.029.3 3273

Transistor Preamps.—Starke. (See 3323.)

534.862.6 3274

Calculation of the Audibility of Nonlinear Distortion originating in an Electroacoustic System.—A. V. Rimski-Korsakov. (*Akust. Zh.*, Jan.–March 1956, Vol. 2, No. 1, pp. 51–61.) The probability is calculated of the products of nonlinear distortion in a sound-reproducing channel exceeding the masking level due to the fundamental signal and the threshold of audibility in the auditorium. In the particular case of a signal with a flat frequency spectrum distorted by a square-law nonlinearity, the threshold of perceptibility of the distortion corresponds to a harmonic coefficient of between 2% and 3%.

621.395.614 : 546.431.824-31 3275

Nondirectional Ceramic Sound Receivers.—A. A. Anan'eva. (*Akust. Zh.*, Jan.–March 1956, Vol. 2, No. 1, pp. 10–27.) The characteristics of cylindrical and spherical $BaTiO_3$ microphones were investigated experimentally at frequencies up to several hundred kc/s. Experimental results are presented graphically, in tabular form and in 78 oscillograms of the polar characteristics.

AERIALS AND TRANSMISSION LINES

621.372.2 **3276**

Propagation of Waves along an Infinitely Long Helix.—N. N. Smirnov. (*C. R. Acad. Sci. U.R.S.S.*, 11th May 1956, Vol. 108, No. 2, pp. 243–246. In Russian.) The dispersion equation is discussed theoretically.

621.372.22 : 621.372.51 **3277**

Impedance Transformers.—J. Willis & N. K. Sinha. (*Wireless Engr*, Sept. 1956, Vol. 33, No. 9, pp. 204–208.) Experimental work is reported on nonuniform-transmission-line devices previously discussed theoretically (1614 of June). A compensated coaxial-line-resistor termination designed to give negligible reflection over a wide band is described. Observed and calculated reflection patterns for two types of tapered line are compared. Attenuation effects are negligible in practical cases.

621.372.43 **3278**

The Optimum Tapered Transmission-Line Matching Section.—R. W. Klopfenstein: E. F. Bolinder: R. E. Collin. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1055–1056.) Comments on 1953 of July and author's reply.

621.372.8 **3279**

Production of Slow Electromagnetic Waves by means of Cylindrical Current Sheets.—F. Bertein & W. Chahid. (*C. R. Acad. Sci., Paris*, 18th June 1956, Vol. 242, No. 25, pp. 2918–2920.) Brief discussion of possible modes with waves slowed by complex helix structures; the mathematical analysis assumes a continuous conducting surface.

621.372.8 **3280**

Propagation of Electromagnetic Waves between Two Circular Cylindrical Surfaces in the Presence of Longitudinal, Periodically Spaced Diaphragms.—E. G. Solov'ev. (*Radiotekhnika, Moscow*, Jan. 1956, Vol. 11, No. 1, pp. 57–60.) Analysis is given for an E wave travelling circumferentially between a pair of coaxial cylindrical sheets with diaphragms spaced along the coaxial mid-surface. Comparison of the results with those obtained earlier (978 of April) indicates that for wavelengths very much longer than the diaphragm space period, the phase velocity is reduced by the diaphragm system and a large number of space harmonics are produced; the higher their number the lower their phase velocity. This suggests use of systems of this type for delay lines.

621.396.676 : 621.396.933 **3281**

TACAN Radio Bearing and Distance System for Aerial Navigation.—(See 3386.)

621.396.677 : 621.396.97 **3282**

Vertical Radiation and Tropical Broadcasting.—Dickinson. (See 3536.)

621.396.677.8 : 621.396.65.029.63 **3283**

A Decimetre-Wavelength Radio-Link Network providing High-Quality Program Channels using Pulse Phase Modulation: Part 2—Aerial Installations.—E. Schüttlöffel. (*Telefunken Ztg*, March 1956, Vol. 29, No. 111, pp. 12–20. English summary, p. 63.) Parabolic reflector aerials with dipole exciters are used, with auxiliary deviating reflectors at one point. Part 1: 3534 below.

AUTOMATIC COMPUTERS

016 : 681.142 **3284**

Bibliography of Literature on Mathematical Simulation (Analogue Computers) (1947–1954).—(*Avtomatika i Telemekhanika*, March & April 1956, Vol. 17, Nos. 3 & 4, pp. 279–288 & 268–383.) About 500 items are listed, including books, conference reports, and papers. About 70 references are to Russian literature.

681.142 **3285**

Electronic Differential Analyser of the G.M. Krzhizhanovski Energetics Institute of the U.S.S.R. Academy of Sciences.—I. S. Bruk & N. N. Lenov. (*Avtomatika i Telemekhanika*, March 1956, Vol. 17, No. 3, pp. 217–227.) The analyser comprises 38 operational amplifiers, four multipliers and four function transformers with a harmonics generator. The basic circuits are described. Differential equations up to the 19th order have been solved; equations up to the 25th order could be handled.

681.142 **3286**

Magnetic Shift-Register Correlator.—R. C. Kelner & M. H. Glauberman. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 172–175.) " Printed decimal digits 0 to 9 are easily recognized by a magnetic-shift register using digital-to-analog converters at each stage. Recognition is obtained using a waveform-fitting function instrumented with the shift-register for correlation."

681.142 **3287**

Triangular-Wave Analog Multiplier.—R. A. Meyers & H. B. Davis. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 182–185.)

681.142 **3288**

High-Density Williams Storage.—S. Y. Wong. (*Trans. Inst. Radio Engrs*, Dec. 1955, Vol. EC-4, No. 4, pp. 156–158. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 580.)

681.142 : 621.383.2 **3289**

Bit Storage via Electro-optical Feedback.—A. Milch. (*Trans. Inst. Radio Engrs*, Dec. 1955, Vol. EC-4, No. 4, pp. 136–144.) The use of a device including a photoemissive cathode and a luminescent anode as a computer component is discussed.

CIRCUITS AND CIRCUIT ELEMENTS

621.3-71 **3290**

Review of Industrial Applications of Heat Transfer to Electronics.—J. Kaye. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 977–991.) Techniques for controlling the temperature conditions of operation of electronic equipment are reviewed with particular reference to conditions in fast aircraft and missiles. Particular examples discussed are (*a*) an air-cooled 25-kW valve [*Trans. Inst. Radio Engrs*, April 1954, Vol. ED-1, pp. 9–26 (London)], (*b*) cold-plate techniques for cooling miniature and subminiature equipment, (*c*) valves designed for operation at surface temperatures near 500°C, and (*d*) evaporation cooling of miniature transformers by means of fluorochemicals. The importance of the subject of heat transfer to designers of electronic equipment is stressed, and training programs at the Massachusetts Institute of Technology are mentioned.

621.316.546 : 621.3.018.756 **3291**

Fast-Rise Pulse Generator with High Pulse Repetition Frequency.—C. G. Dorn. (*Rev. sci. Instrum.*, May 1956, Vol. 27, No. 5, pp. 283–284.) Description of a single-pole multi-position switch in which mercury is ejected through a rotating nozzle on to a series of contact pins, thus generating pulses having a rise time < 0·002 μs, at repetition rates > 10 kc/s, with peak pulse power of 50 W.

621.316.82 3292
On Concavity of Resistance Functions.—H. M. Melvin. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 658–659.) A short proof is given of a theorem presented by Shannon & Hagelbarger (1635 of June).

621.318.424 3293
Ferromagnetic Coupling between Crossed Coils.—U. F. Gianola & D. B. James. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 608–609.) Discussion of the operation of devices comprising e.g. a toroidal and a solenoidal coil wound on a common cylindrical saturated ferromagnetic core; gating, coincidence and signal storage applications are mentioned.

621.319.4 3294
Self-Healing in Metallized Paper Capacitors.—C. B. Charlton. (*TMC tech. J.*, March 1955, Vol. 6, No. 1, pp. 27–41.) The physical and manufacturing techniques involved in the production of truly self-healing single-layer metallized-paper capacitors are described.

621.372.4 3295
Decomposition of the Derivative of the Impedance for a Two-Terminal Network.—L. Lunelli. (*Alta Frequenza*, April 1956, Vol. 25, No. 2, pp. 152–159.) Extension of theory presented previously (3183 of 1955).

621.372.54 3296
Design Data for Ladder Networks.—E. Green. (*Marconi Rev.*, 2nd Quarter 1956, Vol. 19, No. 121, pp. 78–88.) Design data for networks with up to nine branches and attenuation curves for networks with up to eleven branches are presented in expansion of previous work (1267 of 1953 and 2563 of 1955).

621.372.54.029.6 3297
Directional Channel-Separation Filters.—S. B. Cohn & F. S. Coale. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1018–1024.) Networks are discussed which combine the properties of directional couplers with those of conventional filters; such networks are useful for channel combining and separating in microwave communication systems and in installations where a single aerial is shared by several systems. Designs using waveguides, coaxial and strip lines and lumped-constant circuits are indicated; the performance of some experimental filters is described.

621.372.542.21 3298
Low-Pass Filters for Metre Waves.—O. Guarracino. (*Alta Frequenza*, April 1956, Vol. 25, No. 2, pp. 161–168.) Filters intended for suppression of harmonics in m-λ measurements, and having cut-off frequencies of about 100–300 Mc/s, comprise three *LC* Π sections with lumped-constant components. The construction and method of adjustment are described.

621.372.543.2 3299
A Low-Pass/Band-Pass Frequency Transformation.—K. B. Irani. (*Commun. News*, April 1956, Vol. 16, No. 3, pp. 99–104.) A simple transformation is presented for converting a low-pass insertion-power ratio into a band-pass ratio; the technique facilitates the design of band-pass filters when the attenuation curves on either side of the pass band are required to be asymmetrical.

621.372.56.029.6 : 621.318.134 3300
A Unidirectional Attenuator with Delay Line and Ferrite Element for the 4-Gc/s Frequency Band.—W. Eichin. (*Nachrichtentech. Z.*, April 1956, Vol. 9, No. 4, pp. 168–172.) The attenuation afforded by various devices comprising ferrite tubes surrounding helical lines and in turn surrounded by tubular magnets was investigated experimentally; results are presented graphically. The attenuation obtained with the final design was about 1 dB in the forward direction and 20 dB in the blocking direction.

621.372.6 : 621.318.134 3301
Frequency Doubling and Mixing in Ferrites.—J. E. Pippin. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1054–1055.) Analysis is presented indicating the particular polarization and frequency conditions under which frequency doubling and mixing will occur in ferrite devices of the type discussed by Ayres et al. (2138 of July).

621.372.6.012 3302
The Derivation of the Six-Terminal-Network Curve, its Graphical Interpretation and its Application in determining the Transformation Properties of Loss-Free Six-Terminal and Eight-Terminal Networks.—H. Lueg. (*Arch. elekt. Übertragung*, April 1956, Vol. 10, No. 4, pp. 151–162.)

621.373 3303
Tuned Circuits containing Negative Resistance.—J. Gross. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 603–607.) Analysis indicates that the combination of a current-controlled negative resistance with a parallel-tuned circuit, or of a voltage-controlled negative conductance with a series-tuned circuit yields a bistable circuit rather than a self-sustaining oscillator.

621.373.42 : 621.396.61 : 621.376.32 3304
The Gain Characteristic inside the Pull-In Range particularly in F.M. Transmitters and Wobbulators.—Woschni. (See 3560.)

621.373.42.016.35 3305
Oscillator Frequency Stability.—A. S. Gladwin. (*Wireless Engr*, Sept. 1956, Vol. 33, No. 9, pp. 209–220.) The case of an oscillator connected to a mismatched load by a long feeder is considered. In addition to hysteresis effects, with resonant loads a type of instability occurs which takes the form of a periodic modulation of the oscillation frequency (see also 54 of January). Stability criteria appropriate to both effects are derived for various circuit arrangements. Results of experiments with a triode oscillator operating at 10 Mc/s are reasonably consistent with the theory. In general, the hysteresis type of instability predominates.

621.373.421.11 3306
Novel Circuit for a Stable Variable-Frequency Oscillator.—D. Makow. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1031–1036.) A circuit designed to reduce the effect of resonator frequency drift uses a multiloop feedback arrangement with three oscillators maintained at frequencies such that one is the sum of the other two, the sum frequency being controlled by a quartz crystal while the other two are controlled by variable *LC* resonators. The circuit and frequency-drift/temperature characteristics of an experimental oscillator are shown.

621.373.431.2 : 621.396.96 3307
'Hard-Tube' Pulsers for Radar.—H. A. Reise. (*Bell Lab. Rec.*, April 1956, Vol. 34, No. 4, pp. 153–156.) Developments in design of high-vacuum valves make possible the construction of blocking-oscillator pulse

modulators comparable in size and efficiency with line-type thyratron modulators, with advantages in stability resulting from the pulse shape.

621.373.5 : 621.314.7 **3308**

Current-Derived Resistance-Capacitance Oscillators using Junction Transistors.—D. E. Hooper & A. E. Jackets. (*Electronic Engng*, August 1956, Vol. 28, No. 342, pp. 333–337.) Two circuits using 180°-phase-shift networks, suitable for use at very low frequencies, and one with a 0°-phase-shift network, giving a maximum frequency of 30 kc/s, are described.

621.374 **3309**

Pulse Scaler Circuit with High Resolving Power.—U. Pellegrini. (*Alta Frequenza*, April 1956, Vol. 25, No. 2, pp. 130–139.) A circuit with a resolving time of 5×10^{-8}s is based on a step-by-step capacitor charge and a rapid discharge process. The scaling factor can be varied from 2 to 10 without loss of stability. As a frequency divider, the circuit is limited to the range 200 kc/s – 20 Mc/s. Input pulses must be at least 2 V peak-to-peak.

621.374.3/.4 **3310**

High-Frequency Electronic Counter.—A. V. Lord & S. J. Lent. (*Wireless Engr*, Sept. 1956, Vol. 33, No. 9, pp. 220–226.) A circuit suitable for the frequency divider following the 2–4-Mc/s subcarrier generator in a colour-television receiver is based on a triggered binary cascade with feedback. The high counting rate is achieved by incorporating a gating arrangement.

621.374.3 : 621.375.2 **3311**

An Input Amplifier for a Pulse-Height Analyser.—A. Folkierski. (*J. sci. Instrum.*, May 1956, Vol. 33, No. 5, pp. 187–191.) The analyser described can be gated by pulses coincident with the pulses to be measured, the error introduced being $< 1\%$ of the maximum output pulse height. Variation of the input amplification enables the scale to be expanded for detailed examination of part of a spectrum.

621.374.32 : 621.318.57 **3312**

A Nine's-Complement Decade Counter with Recorder.—J. A. Phillips. (*Electronic Engng*, August 1956, Vol. 28, No. 342, pp. 344–349.) "A brief outline of decimal counting using weighted binary digits is given with special reference to systems giving complements of nine. A binary decade electronic counter arranged so as to allow the reading of nine's complements, which may be used to represent negative numbers is then described. In the circuit arrangement used in this counter the maximum counting rate remains the same as that of a simple binary counter. Recording of the number counted is made on 'Teledeltos' paper, the record and counter reset being carried out simultaneously."

621.374.33 **3313**

Gate selects Pulses for Spectrum Analysis.—A. Ross & L. Simon. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 179–181.) A circuit permitting isolation of pulses from 0·2 to 150 μs wide, at repetition rates up to 10 000 per sec, is described.

621.375.2 **3314**

Nonlinear Distortion and Stability of Reflex Circuits.—Yu. A. Chernov. (*Radiotekhnika, Moscow*, Jan. 1956, Vol. 11, No. 1, pp. 17–31.) Two single-valve and three two-valve h.f.-crystal-detector-l.f. reflex amplifier circuits are discussed. The coefficient of nonlinear distortion, k_f, is calculated for the various circuits and the results are plotted (fig. 5) as a function of the parameter αA, the relative change of slope of the I_A/V_g curve from the value at the working point, due to the applied l.f. signal; k_f can theoretically be made zero by using a pair of identical valves in the circuit shown in fig. 4. The stability criteria are also discussed.

621.375.2.024 **3315**

D.C. Decade Amplifier.—W. G. Royce & W. D. Mathews. (*Tele-Tech & Electronic Ind.*, April 1956, Vol. 15, No. 4, pp. 90–91 . . 157.) The circuit incorporates *RC* and direct-coupled stages and a chopper stabilizing amplifier, giving a bandwidth of 0–100 kc/s, with a gain of 0–60 dB in 20-dB steps. The equivalent input d.c. drift is $\not> 10\ \mu$V; output is up to $\pm$ 35 V and $\pm$ 20 mA.

621.375.2.024 : 621.376.332 **3316**

Isolating Direct-Current Amplifiers.—A. Chevallier & B. Prokocimer. (*Rev. gén. Élect.*, April 1956, Vol. 65, No. 4, pp. 199–203.) A circuit providing an output direct current or voltage proportional to an input direct voltage, and having no common point between input and output, uses a fixed-frequency crystal-controlled oscillator in conjunction with a discriminator whose phase is varied by means of an electromechanical modulator which converts the input signal into a capacitance variation. Several applications are mentioned.

621.375.221.029.5 **3317**

Wide-Band Linear R.F. Amplifier.—B. F. Davies. (*Wireless World*, Aug. & Sept. 1956, Vol. 62, Nos. 8 & 9, pp. 374–378 & 446–449.) The amplifier described is designed for use with a common aerial to provide a distribution system for a ship. Frequency coverage is 150 kc/s–25 Mc/s with suppression in the 400–535-kc/s and 1·6–3·8-Mc/s bands; nominal gain is 15 dB. Performance figures are given; the level of intermodulation and cross-modulation products is low.

621.375.226 **3318**

Synthesis of Amplifiers with Triple-Tuned Coupled Circuits.—A. Smolinski. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 1, pp. 35–64. English summary, pp. 63–64.)

621.375.23.024 : 621.317.725 **3319**

Unity-Gain Voltmeter Amplifier.—Hyder. (See 3485.)

621.375.3 : 621.318.435 **3320**

Behaviour of Saturable Reactors in Magnetic Amplifiers.—P. N. Das. (*Indian J. Phys.*, March 1956, Vol. 39, No. 3, pp. 129–142.) A detailed analysis is presented of the behaviour of a magnetic amplifier in which the core material is assumed to have a square *B/H* characteristic. Systems with single cores, two series-connected cores and two parallel-connected cores are considered, with d.c. sources of (*a*) infinite and (*b*) low impedance. Results are presented graphically; supporting experimental evidence is mentioned briefly.

621.375.4 : 621.314.7 **3321**

Measurement Considerations in High-Frequency Power Gain of Junction Transistors.—Pritchard. (See 3566.)

621.375.4 : 621.396.96 **3322**

Transistor Amplifier for Radar Video.—R. Leslie. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 142–145.) The design of a video amplifier using Si transistors, suitable for airborne radar systems, is discussed. High-frequency compensation is obtained by *RC* degenerative feedback in a grounded-emitter circuit with temperature stabilization of emitter-current bias.

621.375.4.029.3 : 534.86 **3323**

Transistor Preamps.—H. F. Starke. (*Audio*, April 1956, Vol. 40, No. 4, pp. 31–32..73.) Discussion of practical design considerations for pre-amplifiers for use (*a*) with gramophones with a boosted low-frequency response and a flat-response main amplifier, and (*b*) with microphones, the pre-amplifier in this case having a flat response.

621.375.4.029.3 : 621.314.7 **3324**

A 200-mW Amplifier employing Transistors.—(*Mullard tech. Commun.*, April 1956, Vol. 2, No. 18, pp. 210–216.) The a.f. amplifier described comprises an input stage, a driver and a class-B stage, with overall feedback; the maximum output is 215 mW, measured at 400 c/s, with 10% total harmonic distortion, mainly third harmonic. The sensitivity at the 2·5-kΩ input terminal is about 6 mV. Minimum total distortion is 1·7%, at an output of about 15 mW.

621.376.332 **3325**

Design of a Simple Linear Frequency Discriminator.—K. G. Fancourt & J. K. Skwirzynski. (*Marconi Rev.*, 2nd Quarter 1956, Vol. 9, No. 121, pp. 61–77.) The discriminator described consists essentially of two tuned circuits with the parameters chosen to minimize second and third harmonics. Design information is presented in graphs.

GENERAL PHYSICS

534.01 : 519.2 **3326**

Statistical Properties of a Moving Waveform.—M. S. Longuet-Higgins. (*Proc. Camb. phil. Soc.*, April 1956, Vol. 52, Part 2, pp. 234–245.)

537/538].081 **3327**

The Giorgi System of Units and the Rationalization of the Equations of Electricity.—A. Iliovici. (*Rev. gén. Élect.*, April 1956, Vol. 65, No. 4, pp. 245–251.)

537.2 : 621.3.011.1 **3328**

New Theorems on the Electrostatic Field.—B. Konorski. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 1, pp. 65–157. German summary, pp. 155–157.) The ' law of least capacitance ' is discussed; the concept of the ' intermediate electrode ' is introduced to facilitate the formulation. A system of two cylinders with parallel axes is considered, and an examination is made of the variation of the total capacitance of the system on displacing the imaginary intermediate electrode constituted by an infinitely thin metal sheet shaped to coincide with one of the equipotential surfaces. The analysis is extended to systems of spheres and other geometrical forms. Formulae giving attractive and repulsive forces for numerous particular cases are tabulated.

537.29 : 537.56 : 621.385.833 **3329**

Field Ionization of Gases at a Metal Surface and the Resolution of the Field Ion Microscope.—E. W. Müller & K. Bahadur. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 624–631.)

537.29 : 539.233 : 621.385.833 **3330**

Field Desorption.—E. W. Müller. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 618–624.) Report of a study of the action of strong electric fields in removing adsorbed films of Ba, Th, etc., from a W surface, using a field-emission microscope and maintaining the metal surface positive.

537.311.1 **3331**

Electronic Conduction in Solids with Spherically Symmetric Band Structure.—R. Barrie. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 553–561.) Elastic scattering of electrons by ionized impurities, and inelastic scattering by the non-acoustical modes of the lattice vibrations in a homopolar crystal, are discussed for electrons whose energy is a nonquadratic function of the wave number vector.

537.311.1 **3332**

Acceleration of Electrons by an External Force Field.—E. N. Adams & P. N. Argyres. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 605–606.) " The usual proof that an electron in an energy band reacts to an external force as though it had an effective mass is shown to be invalid. It is shown, however, that for static externally applied fields, modified (field-dependent) energy bands can be found for which the acceleration theorem is rigorously correct."

537.311.62 : 537.312.62 **3333**

The Penetration Depth in Impure Superconducting Tin.—R. G. Chambers. (*Proc. Camb. phil. Soc.*, April 1956, Vol. 52, Part 2, pp. 363–375.) " A new method is described for measuring the surface impedance of metals at low temperatures and at radio-frequencies. Using this method, the surface impedance of normal tin and the penetration depth λ in superconducting tin have been studied at about 9 Mc/s frequency as a function of impurity content. The measured surface impedances agree well with the values expected, and the penetration depths increase with impurity content, in confirmation of Pippard's observations [*Proc. roy. Soc. A*, 24th Feb. 1953, Vol. 216, No. 1127, pp. 547–568] at 9 400 Mc/s."

537.311.62 : 538.569.4 **3334**

Cyclotron Resonance under Anomalous Skin-Effect Conditions.—R. G. Chambers. (*Phil. Mag.*, May 1956, Vol. 1, No. 5, pp. 459–465.) Results to be expected from attempts to observe cyclotron resonance in metals are discussed.

537.5 **3335**

Mobility and Space Charge of Ions in Nonuniform Field.—Yu. M. Kagan & V. I. Perel'. (*C. R. Acad. Sci. U.R.S.S.*, 11th May 1956, Vol. 108, No. 2, pp. 222–225. In Russian.) The equations developed lead to a generalization of the Child-Langmuir 3/2-power law to cover the case of arbitrary pressures.

537.5 **3336**

The Carrier Density in a Plasma and its Determination by means of the Pulse Probe.—D. Kamke & H. J. Rose. (*Z. Phys.*, 9th April 1956, Vol. 145, No. 1, pp. 83–115.) The pulse method discussed does not depend on particular assumptions regarding the transition layer between the unipolar (Langmuir) layer and the undisturbed plasma. Theory, apparatus and experimental results are described. Over 40 references.

537.52 **3337**

Statistical Study of Electron Avalanches in Gaseous Discharge.—S. Kojima & K. Kato. (*J. phys. Soc. Japan*, March 1956, Vol. 11, No. 3, pp. 322–326.) For low pressures the pulse size distribution at potentials below the breakdown value agreed with that given by the Townsend theory, assuming the absence of space charge. At atmospheric pressure the discharge was modified, probably by space charge, and pulse size tended to become uniform.

537.525 **3338**

Starting of an Electrical Gas Discharge in a Uniform Alternating Field.—W. Fucks, L. Graf, G. Mues & H. G. Müller. (*Z. Phys.*, 9th April 1956, Vol. 145, No. 1, pp. 1–19.) In the sub-critical range, i.e. when the half-period of the alternating field is greater than the duration of an ionization step, the number of ionization steps in a half-period varies with frequency and with field strength. Over this range, the breakdown-voltage/frequency characteristic is positive, but beyond a certain value of frequency it becomes negative, later undergoing a further inflection, so that at a frequency of 2×10^8 c/s it is again positive. Comprehensive experimental results illustrating these phases and the influences of pressure and electrode separation on them are presented.

537.525.92 : 537.56 **3339**

'Contact' Phenomena in Plasma.—L. A. Sena & N. S. Taube. (*Zh. eksp. teor. Fiz.*, Feb. 1956, Vol. 30, No. 2, pp. 287–290.) Discontinuities of potential between parts of a plasma which differ in electron concentration and temperature are considered theoretically by the classical contact-potential theory of metals. The validity of this treatment is confirmed experimentally.

537.533 : 537.312.62 **3340**

Investigation of Electron Emission from Superconductors.—F. Bedard, H. Meissner & G. E. Owen. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 667–670.)

537.533 : 537.534.8 **3341**

Secondary Electron Emission from Metals under the Action of Ions and Neutral Particles.—V. G. Tel'kovski. (*C. R. Acad. Sci. U.R.S.S.*, 21st May 1956, Vol. 108, No. 3, pp. 444–446. In Russian.) Experimental results obtained by bombardment of clean metals with ions of H, He, N, Ne, Ar and Mo and neutral atoms of the inert gases show that the coefficient of secondary emission increases linearly at particle velocities up to 2×10^8 cm/s; for proton bombardment a maximum occurs at a velocity of $2 \cdot 5 \times 10^8$ cm/s.

537.533.7 **3342**

Investigation of Characteristic Energy Losses by the Retarding-Field Method.—G. Haberstroh. (*Z. Phys.*, 9th April 1956, Vol. 145, No. 1, pp. 20–43.) The energy distribution of electrons and the angular distribution of their paths after passage through thin foils of Al, Ag, Ge and Al_2O_3 are studied.

537.533.8 **3343**

Dependence of Secondary Electron Emission upon Angle of Incidence of 1·3-MeV Primaries.—R. A. Shatas, J. F. Marshall & M. A. Pomerantz. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 682–686.)

537.533.8 : 537.226 **3344**

Secondary Electron Emission from Dielectrics.—A. R. Shul'man. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2150–2156.) Experiments are described in which, in order to avoid changes in the structure of the target due to electron bombardment, the primary beam was switched on for only 10–30 μs, so that there was one incident electron for about 10^5 atoms of the emitter surface, and the destruction of the target could therefore be neglected. The results obtained are different from those usually quoted; a new interpretation of the phenomenon is given.

537.56 : 538.56 **3345**

Model for Collision Processes in Gases: Small-Amplitude Oscillations of Charged Two-Component Systems.—E. P. Gross & M. Krook. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 593–604.) Continuation of work reported previously [2633 of 1954 (Bhatnagar et al.)].

537.562 : 538.561 : 523.16 **3346**

Large-Amplitude Plasma Streaming and Charge Segregation.—R. W. Larenz. (*Z. Naturf.*, Sept./Oct. 1955, Vol. 10a, Nos. 9/10, pp. 766–776.) See 1015 of 1955; see also *ibid.*, pp. 761–765.

538.311 : 538.65 **3347**

The Magnetostatic Force on Two Circular Cylindrical Conductors carrying Uniform Steady Currents.—E. E. Jones. (*J. Franklin Inst.*, April 1956, Vol. 261, No. 4, pp. 397–408.) The magnetic field due to two parallel conductors in a nonuniform magnetic field is determined for the case when the conductor material is magnetic. General expressions are deduced for the magnetostatic force and are investigated for particular examples.

538.5 : 621.313 **3348**

Fluid Self-Excited Dynamo.—L. Davis, Jr. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 939–940.) "The possibility that a simply connected perfectly conducting fluid body could generate an increasing external magnetic field by acting as a self-excited dynamo is demonstrated by exhibiting a cycle of motions that doubles the external field each cycle. The essential feature of the motion is that interior points become surface points."

538.56 : 544.68 : 535.33 **3349**

Analysis of Traces of Impurities in Rare Gases by Ultra-high-Frequency Excitation of Optical Radiation.—M. Servigne, P. Guérin de Montgareuil & D. Dominé. (*C. R. Acad. Sci., Paris*, 11th June 1956, Vol. 242, No. 24, pp. 2827–2830.) Technique is discussed in which a cell, filled at low pressure with the gas to be analysed, is arranged in the field of a continuous microwave oscillation generated by a magnetron.

538.561 : 537.533 **3350**

Čerenkov Radiation from Extended Electron Beams near a Medium of Complex Index of Refraction.—H. Lashinsky. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 631–635.) Extension of the theory presented by Danos (1628 of 1955). If ferrites are used in place of simple dielectric media, the radiated power can, under suitable conditions, be increased.

538.566 : 537.562 **3351**

Variation with Electron Energy of the Collision Cross-Section of Helium for Slow Electrons.—J. M. Anderson & L. Goldstein. (*Phys., Rev.* 15th May 1956, Vol. 102, No. 4, pp. 933–938.) Continuation of previous work on the interaction of microwaves in gas-discharge plasmas (1383 of May and back references). Momentum transfer between He atoms and electrons with energies between 0·04 and 0·4 eV is investigated, the electron density being not less than about 10^{10}/cm³. Experimental results appear to indicate a slight variation of momentum transfer with electron energy.

538.6 **3352**

Motion of a Sphere through a Conducting Fluid in the Presence of a Strong Magnetic Field.—K. Stewartson. (*Proc. Camb. phil. Soc.*, April 1956, Vol. 52, Part 2, pp. 301–316.)

537.5 **3353**

Basic Processes of Gaseous Electronics. [Book Review]—L. B. Loeb. Publishers: University of California Press, Berkeley and Los Angeles; Cambridge University Press, London, 1955, 1012 pp., 100s. (*Brit. Commun. Electronics*, April 1956, Vol. 3, No. 4, p. 214.) A comprehensive review.

538.566 : 535.4 3354

Scattering and Diffraction of Radio Waves. [Book Review]—J. R. Mentzer. Publishers: Pergamon Press, London and New York, 142 pp., 30s. (*J. Instn elect. Engrs*, May 1955, Vol. 2, No. 17, p. 301.) One of a series of monographs on *Electronics and Waves;* mathematical methods are indicated for solving problems encountered in the study of radar performance and aerial systems.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523 : 538.3 : 550.38 3355

Hydromagnetic Dynamo Theory.—W. M. Elsasser. (*Rev. mod. Phys.*, April 1956, Vol. 28, No. 2, pp. 135–163.) The equations of magnetohydrodynamics are used to study the mechanism whereby cosmic magnetic fields such as those of the earth, of sunspots and the sun, and of magnetic stars are generated and maintained.

523.16 3356

The Nature of Radiation from Radiogalaxy NGC 4486.—I. S. Shklovski. (*Astronom. Zh.*, May/June 1955, Vol. 32, No. 3, pp. 215–225. English summary.) The continuous optical radiation from the 'jet' in the core of the galaxy is explained quantitatively by the presence of relativistic electrons with energies of 10^{11}–10^{12} eV moving in a magnetic field of approximately 10^{-4} G; relativistic electrons with energies of 10^{8}–10^{9} eV diffusing into the galaxy are probably the source of r.f. emission.

523.16 : 523.42 3357

Impulsive Radio Signals from the Planet Venus.—J. D. Kraus. (*Nature, Lond.*, 7th July 1956, Vol. 178, No. 4523, p. 33.) Report of reception at the Ohio State University of radiation at a wavelength of 11 m. The observations were made using an interferometer array of horizontal $\lambda/2$ elements with reflectors. The peak power in a burst is estimated to be about 40 W per c/s of bandwidth; this is about 0·003 of the value estimated for a burst from Jupiter. On the basis of power considerations, the mechanism involved could be of lightning-discharge type. A record obtained on 30th May 1956 is reproduced and discussed *ibid.*, 14th July 1956, Vol. 178, No. 4524, pp. 103–104.

523.16 : 523.42 3358

Class II Radio Signals from Venus at a Wavelength of 11 Metres.—J. D. Kraus. (*Nature, Lond.*, 21st July 1956, Vol. 178, No. 4525, pp. 159–160.) Reception of radiation with a different waveform from that discussed previously (3357 above) is reported; this radiation, designated class II, is of a more sustained nature, lasting for a second or longer and varying at an a.f. rate, e.g. 125 c/s. A record of a series of pulses observed on 4th June 1956 is shown. The radiation appears to have a bandwidth of at least 2 Mc/s. On studying tape recordings, signals resembling echoes were noted; these may be due to reflection from the moon.

523.16 : 537.562 : 538.561 3359

Large-Amplitude Plasma Streaming and Charge Segregation.—Larenz. (See 3346.)

523.16 : 551.510.535 : 621.396.11 3360

On the Propagation of Radio Waves through the Upper Ionosphere.—Ellis. (See 3514.)

523.16 + 523.5 + 551.594.5] : 551.510.535 : 621.396.11.029.6 3361

Review of Ionospheric Effects at V.H.F. and U.H.F.—Little, Rayton & Roof. (See 3519.)

523.5 : 537.56 3362

Inadequacy of Recombination as the Source of Light from Enduring Meteor Trains.—G. S. Hawkins & A. F. Cook. (*Nature, Lond.*, 21st July 1956, Vol. 178, No. 4525, pp. 161–162.) Critical discussion of the suggestion made by Öpik (3592 of 1955) that the column of light produced by a meteor is due to recombination of the meteoric ions and free electrons.

523.72 : 523.78 3363

Observations of Solar Radio Radiation during the Eclipse of June 30th, 1954: Part 1.—O. Czyżewski, J. de Mezer & A. Strzalkowski. (*Acta geophys. polon.*, 1955, Vol. 3, No. 4, pp. 155–160. In English.) Observations made at Cracow, using apparatus operating at about 1 m λ with a parabolic aerial of diameter 5 m, are reported. Records for July 12th and 13th are shown for comparison with those for the eclipse day.

550.385 : 523.7 3364

A Note on the Annual Variation of Geomagnetic Activity and M-Regions.—J. N. Tandon. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 211–213.) " Results of an investigation are given associating recurrent 27-day geomagnetic activity with M-regions of the sun, around years of sunspot minima. The association of M-sequences with various solar features of the disk and corona is also indicated." For a longer account of related work, see *Indian J. Phys.*, April 1956, Vol. 30, No. 4, pp. 153–168.

551.51 3365

Charge Transfer in the Upper Atmosphere.—S. N. Ghosh. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 193–200.) Collision processes involving charged solar particles entering the upper atmosphere are discussed. Charge-transfer reactions involving solar H^+ and Ca^+ ions are likely to excite spectrum lines of these elements and of the atmospheric gases; in the case of H^+, at auroral levels. The ratio of the density of O^+ to O_2^+ ions and the effective recombination coefficient for the F layer are derived.

551.510.3 3366

On a Pitot-Tube Method of Upper-Atmosphere Measurements.—Vi-Cheng Liu. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 171–178.) A method is presented for deducing atmospheric density, pressure and temperature at heights up to 80 km.

551.510.3 : 535.325 3367

Thermodynamic Method for Measurement of the Refractive Index of the Atmosphere. Description of the Radiosonde MD1.—P. Misme. (*Ann. Télécommun.*, April 1956, Vol. 11, No. 4, pp. 81–84.) Apparatus is described which is capable of determining the distribution of temperature, pressure and humidity variations with a fineness sufficient for radio-propagation calculations.

551.510.5 : 551.593.9 3368

The Altitude of the (OI) 5577A Line in the Night Airglow measured from a Rocket.—O. E. Berg, M. Koomen, L. Meredith & R. Scolnik. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 302–303.) Measurements using rocket-borne photometers show that the layer from which the λ 5577 line originates lies between 70 and 105 km, with peak luminosity between 90 and 95 km.

551.510.5 : 551.593.9 3369

Distribution of the Night Airglow (OI) 5577A and Na D [-line] Layers measured from a Rocket.—M. Koomen, R. Scolnik & R. Tousey. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 304–306.) An experiment similar to that described by Berg et al. (3368 above) confirms the results for the λ 5577 line and shows that the sodium D lines are excited in a layer of altitude between 70 and 95 km.

551.510.52 **3370**

Determination of the Alpha-Ray Emission of Materials constituting the Earth's Surface.—V. F. Hess, V. J. Kisselbach & H. A. Miranda, Jr. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 265–271.) It is concluded, from measurements, that α-ray emission is not an important factor in the ionization balance of the lower atmosphere.

551.510.535 + 523 **3371**

Influence of Magnetic Field on Convective Instability in the Atmospheres of Stars and in the Ionosphere of the Earth.—B. N. Gershman & V. L. Ginzburg. (*Astronom. Zh.*, May/June 1955, Vol. 32, No. 3, pp. 201–208.) The case of a medium with anisotropic electrical and thermal conductivities is considered. In a plasma which does not contain a large number of neutral particles the calculated influence of the magnetic field on convection is essentially different from that predicted by the magnetohydrodynamic approximation; in the ionosphere the influence of the magnetic field is small owing to the presence of a large number of molecules. See also 2290 of 1955.

551.510.535 **3372**

Electron Resonance in Ionospheric Waves.—C. O. Hines. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 56–70.) Certain features of large-scale travelling disturbances in the F layer are explained as electron-resonance effects, whereby small initial disturbances are amplified. Estimates of ionospheric parameters based on this interpretation are in good agreement with values to be expected.

551.510.535 **3373**

Two Types of Development of the E_2 Layer at Ahmedabad.—R. G. Rastogi. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 71–72 and plates.) The sequence of phenomena leading to the separation of E_2 and E_1 layers after high-level sunrise is summarized and illustrated by photographic records. The existence of a layer which is photo-ionized by solar radiation at a height of about 150 km is indicated.

551.510.535 **3374**

World-Wide Spread F.—G. Reber. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 157–164.) Records from widely distributed ionosphere stations for the period of the last complete sunspot cycle show that the spread-F equator is roughly parallel to the geomagnetic equator, swinging ± 25° of latitude over the cycle.

551.510.535 : 523.72 **3375**

The Solar X-Ray Spectrum and the Density of the Upper Atmosphere.—E. T. Byram, T. A. Chubb & H. Friedman. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 251–263.) Data derived from rocket experiments give a measure of the flux density of solar X rays incident on the E layer. From the rate of X-ray absorption at heights between 128 and 110 km the atmospheric density is computed to be about one-third of the current Rocket Panel average values.

551.510.535 + 550.385] : 523.75 **3376**

Ionospheric Effects produced by Solar Flare Radiation.—V. Agy. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, p. 917.) Comment on 423 of February (Sedra & Hazzaa).

551.510.535 : 523.78 **3377**

The Effective Recombination Coefficients in the E and F_1 Layers during the Solar Eclipse of 25 February 1952.—C. M. Minnis. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 36–44.) The contribution to the E-layer ionization of each of two isolated sources of radiation assumed to exist near the east and west limbs of the sun is derived and expressed as a linear function of $1/\alpha'$, where α' is the effective recombination coefficient during the eclipse. On equating the corresponding functions for Khartoum and Ibadan it is found that for both places $\alpha'_E = 1{\cdot}2 \times 10^{-8}\ cm^3 s^{-1}$ as against the value $1{\cdot}5 \times 10^{-8}\ cm^3 s^{-1}$ obtained for Khartoum on assuming that the intensity of ionizing radiation fell to zero at second contact (2298 of 1955). For the F_1 layer it is concluded that $\alpha'_{F_1} = 0{\cdot}65 \times 10^{-8}\ cm^3 s^{-1}$.

551.510.535 : 523.78 **3378**

Interpretation of Ionospheric Measurements made during Solar Eclipses.—C. M. Minnis. (*Nature, Lond.*, 7th July 1956, Vol. 178, No. 4523, pp. 33–34.) By combining observational data obtained at Khartoum and Ibadan during the eclipse of 1952, a determination is made of the recombination coefficient in the E layer; the most probable value is 1·2. This result is at variance with the conclusions reached by Hunaerts & Nicolet (1412 of May), and implies absence of radiation from the corona. See also 3377 above.

551.510.535 : 523.78 **3379**

Ionospheric Observations during the Solar Eclipse of 30th June 1954.—B. Landmark, F. Lied, T. Orhaug & S. Skribeland. (*Geofys. Publ.*, 1956, Vol. 19, No. 8, pp. 1–39.) Records of *h'f* were obtained in Norway at Tromøya (100% obscuration), Kjeller (96%) and Tromsø (66%). Strong E_s ionization prevented the accurate observation of f_0E, but f_0F_1 was reliable and, assuming complete cut-off of the ionizing radiation at totality, gave $\alpha_E = 1{\cdot}7 \times 10^{-8}\ cm^3 s^{-1}$ at Tromøya. The F_1-layer data are consistent with a solar model in which 14% and 5% of the radiation was emitted from areas near the west and east limbs respectively; 10% originated in an undefined area which may cover the greater part of the sun's disk. The changes in f_0F_2 indicate a marked solar control of the F_2 layer and, assuming a recombination law, give $\alpha_{F_2} \simeq 3 \times 10^{-9}\ cm^3 s^{-1}$. Measurements of D-region absorption are consistent with the solar model deduced from the F_1-layer data, and give $\alpha_D/N_0 = 13 \times 10^{-4}\ s^{-1}$. A theoretical treatment is given of the eclipse changes in the D region.

551.510.535 : 550.385 **3380**

Systematic Investigations of the Influence of Geomagnetic Activity on the Nocturnal Critical Frequencies of the F_2 Layer.—G. Lange-Hesse. (*Arch. elekt. Übertragung*, April 1956, Vol. 10, No. 4, pp. 139–144.) Results of a statistical analysis of data covering a period of 6½ years are presented graphically. The probability that a geomagnetic activity index C_k, of magnitude $1{\cdot}2 \leqslant C_k \leqslant 2{\cdot}0$ determined over a 24-hour period 1800–1800, is followed by an ionospheric storm is 80% in the summer of a sunspot-maximum year and 60% in winter; the corresponding figures for a 0600–0600 C_k index in a sunspot-minimum year are 75% and 55% respectively. See also 2942 of 1954.

551.510.535 : 621.396.11 **3381**

Ionospheric Absorption at Dakar.—Delobeau & Suchy. (See 3513.)

551.510.535 : 621.396.11 **3382**

Calculation of Charge Density Distribution of Multilayers from Transit-Time Data.—J. Shmoys & S. N. Karp. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 183–191.) A method is discussed for calculating the electron-density distribution in the ionosphere from data obtained using a rocket-borne variable-frequency transmitter, or pulse reflections from higher layers. It is not possible to obtain a solution free from ambiguity.

551.594.5 **3383**

Characteristics of Auroras caused by Angular Dispersed Protons.—A. Omholt. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 18–27.)

551.594.5 : 551.510.535 **3384**

Secondary Processes due to Absorption of the Lyman Lines emitted from Aurorae.—A. Omholt. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 28–35.) Discussion indicates that the α line of the hydrogen Lyman series emitted from aurorae may be effective in ionizing NO in the lower atmosphere, but not to the extent required for polar blackouts. Absorption of the Lyman β line by oxygen atoms is not significant in ordinary aurorae.

551.594.6 **3385**

On the Waveform of a Radio Atmospheric at Short Ranges.—J. R. Wait. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, p. 1052.) Calculated values for the waveform at various distances up to 200 km from the discharge are shown graphically; the ionospherically reflected wave is not taken into account, and the discharge producing the atmospheric is represented by an idealized function.

LOCATION AND AIDS TO NAVIGATION

621.396.933 : 621.396.676 **3386**

TACAN Radio Bearing and Distance System for Aerial Navigation.—(*Elect. Commun.*, March 1956, Vol. 33, No. 1, pp. 2–100.) A symposium comprising the following papers:—

Development of Tacan at Federal Telecommunication Laboratories.—P. C. Sandretto (pp. 4–10).

Principles of Tacan.—R. I. Colin & S. H. Dodington (pp. 11–25).

Tacan Ground Beacon AN/URN-3.—H. B. Scarborough (pp. 26–34).

Antenna for the AN/URN-3 Tacan Beacon.—A. M. Casabona (pp. 35–59).

Airborne Tacan Equipment AN/ARN-21.—S. H. Dodington (pp. 60–64).

British Tacan Equipment (pp. 65–66).

Experimental Determination of Tacan Bearing and Distance Accuracy.—E. DeFaymoreau (pp. 67–73).

Coordinated-System Concept of Air Navigation.—P. C. Sandretto (pp. 74–79).

Quartz-Crystal Control at 1 000 Mc/s.—S. H. Dodington (pp. 80–84).

Error Reduction in Tacan Bearing-Indication Facility.—M. Masonson (pp. 85–100).

For a short description of Tacan, see 125 of January.

621.396.962.3 **3387**

Marconi Coherent M.T.I. Radar on 50 cm.—E. Eastwood, T. R. Blakemore & B. J. Witt. (*Marconi Rev.*, 2nd Quarter 1956, Vol. 19, No. 121, pp. 53–60.) The Type-S.232 equipment for airport terminal work is described. The pulse length is 2 or 4 μs, and the repetition rate 500–800/s.

621.396.962.38 **3388**

Some Problems of Secondary Surveillance Radar Systems.—K. E. Harris. (*J. Brit. Instn Radio Engrs*, July 1956, Vol. 16, No. 7, pp. 355–382.) Systems comprising a ground interrogator and airborne transponders, for air traffic control, are discussed. The choice of operating frequency is governed by international allocations, availability of components, and required horizontal definition. Systems are classified as dependent or independent according as they do or do not use the primary radar transmitter as interrogator. The scanning and display arrangements may also be either associated or dissociated. Side-lobe effects can be eliminated by either responsor or interrogator suppression. Other problems considered include transponder saturation and methods of count-down, the 'capture' of airborne units by one ground station to the exclusion of others, second-time-round signals, unlocked responses due to remote ground stations, and coding.

621.396.969.3 **3389**

Automatic Tracking Radar Systems.—P. Bouvier. (*Onde élect.*, April 1956, Vol. 36, No. 349, pp. 336–347.) The operating principles of the system are explained and French equipment in large-scale production is briefly described; the wavelength used is 10 cm.

621.396.969.3 **3390**

Some Limiting Cases of Radar Sea Clutter Noise.—A. H. Schooley. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1043–1047.) Analysis is presented yielding limiting values of the effective radar scattering area per unit area of the sea surface, as a function of the radar depression angle, for perfectly smooth and for rough surfaces. Some experimental data supporting the theory are also presented.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 **3391**

Absolute Determination of Pressure using the Ionization Gauge.—R. P. Henry. (*Le Vide*, March/April 1956, Vol. 11, No. 62, pp. 54–63.)

533.5 : 546.49 **3392**

Technology and Application of Mercury in Vacuum Technique.—W. Espe. (*NachrTech.*, April 1956, Vol. 6, No. 4, pp. 155–161.) A survey with 59 references.

533.56 **3393**

Diffusion Pump using Freon 12.—J. Delcher, R. Geller, G. Mongodin & F. Prévot. (*Le Vide*, March/April 1956, Vol. 11, No. 62, pp. 78–80.)

535.215 **3394**

Infrared Response of Pyrolyzed Organic Films.—J. F. Andrew. (*J. opt. Soc. Amer.*, March 1956, Vol. 46, No. 3, pp. 209–214.) Report of an experimental investigation of photoconduction in films prepared by pyrolysis of cellophane and orlon.

535.215 : 538.569 **3395**

Study of Crystallized P_2Zn_3 at Low Temperatures.— J. Lagrenaudie. (*J. Phys. Radium*, April 1956, Vol. 17, No. 4, pp. 359–362.) An experimental investigation of photoconduction and photomagnetoelectric effect in this material is reported. The existence of traps at several levels is demonstrated. The results are compared with those for Te.

535.215 : 546.811-3 3396

Relaxation of Photoconductivity of Stannic Oxide.—A. I. Andrievski & V. A. Zhuravlev. (*C. R. Acad. Sci. U.R.S.S.*, 1st May 1956, Vol. 108, No. 1, pp. 43–46. In Russian.) Relaxation times of 20–3 000 s were observed in different specimens; each specimen possessed several relaxation times, the magnitudes and numbers of which varied with the intensity of illumination. These results are discussed.

535.37 3397

Contribution to the Problem of Nonstoichiometry in Oxygen-Dominated Phosphors.—J. L. Ouweltjes & W. L. Wanmaker. (*J. electrochem. Soc.*, March 1956, Vol. 103, No. 3, pp. 160–165.)

535.376 3398

Field-Induced Color Shift in Electroluminescent Zinc Sulfide.—J. F. Waymouth & F. Bitter. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 686–689.)

537.226/.228.1 : 546.431.824-31 3399

Preparation of Barium Titanyl Oxalate Tetrahydrate for Conversion to Barium Titanate of High Purity.—W. S. Clabaugh, E. M. Swiggard & R. Gilchrist. (*J. Res. nat. Bur. Stand.*, May 1956, Vol. 56, No. 5, pp. 289–291.)

537.226/.228.1 : 546.431.824-31 3400

Anomalous Polarization in Undiluted Ceramic $BaTiO_3$.—H. L. Blood, S. Levine & N. H. Roberts. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 660–661.) Experimental results are presented and briefly discussed; observed deviations from normal ferroelectric behaviour may be related to those discussed by Känzig (e.g. 2988 of 1955).

537.226/.227 3401

Structure and Phase Transitions of Ferroelectric Sodium-Cadmium Niobates.—B. Lewis & E. A. D. White. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 646–664.) Report of a detailed experimental investigation. Sodium-cadmium niobates form single-phase solid solutions of perovskite type, the cadmium niobate entering as $CdNb_2O_6$ rather than $Cd_2Nb_2O_7$. The ferroelectric properties are associated with a doubled unit cell, whereas antiferroelectric sodium niobate has a quadrupled cell. Over a range of composition and temperature the ferroelectric and antiferroelectric structures coexist. See also 2087 of July.

537.226/.227 3402

High Permittivity of Niobates and Tantalates of Divalent Metals.—G. A. Smolenski, V. A. Isupov & A. I. Agranovskaya. (*C. R. Acad. Sci. U.R.S.S.*, 11th May 1956, Vol. 108, No. 2, pp. 232–235. In Russian.) The dielectric constant at 1 kc/s and its temperature coefficient, and the loss tangent at 1 kc/s and temperature 20°C are tabulated for niobates, metaniobates, tantalates and metatantalates of Ca, Cd, Sr, Pb and Ba. The curves presented show that $Sr_2Ta_2O_7$ is ferroelectric; the maxima of the ϵ and tan δ temperature curves for $CdNb_2O_6$ are due not to a ferroelectric phase transition but to electronic processes.

537.227 3403

Spontaneous Polarization of Guanidine Aluminum Sulfate Hexahydrate at Low Temperatures.—A. G. Chynoweth. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1021–1023.) The spontaneous polarization of this material [2415 of August (Holden et al.)] was investigated by observing the pyroelectric effect, using the method described in 1745 of June. The results indicate that the spontaneous polarization and the specific heat are smooth functions of temperature over the range from room temperature down to −180°C; there is no evidence of a phase transition or Curie point.

537.227 3404

Ferroelectricity in the Alums.—R. Pepinsky, F. Jona & G. Shirane. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1181–1182.) Measurements on a large number of alums indicate that some are ferroelectric, others antiferroelectric. The dielectric-constant/temperature curve and hysteresis loops are presented for methylammonium aluminium sulphate dodecahydrate (MASD), which is typical of the ferroelectric alums.

537.227 3405

Ferroelectric Properties of Solid Solutions of $(Pb,Ba)SnO_3$, $Pb(Ti,Sn)O_3$ and $Pb(Zr,Sn)O_3$.—G. A. Smolenski, A. I. Agranovskaya, A. M. Kalinina & T. M. Fedotova. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2134–2142.) A report is presented on an experimental investigation. The main conclusions reached are: (*a*) solid solutions of $(Ba,Pb)SnO_3$ possess ferroelectric properties; as distinct from other ferroelectrics, their central ions do not possess the electron structure of the atom of a noble gas; (*b*) the transition temperature of these solid solutions is displaced towards lower temperatures as the $BaSnO_3$ content increases; (*c*) solid solutions of $Pb(Ti,Sn)O_3$ and $Pb(Zr,Sn)O_3$ are characterized by high transition temperatures even for a high content of $PbSnO_3$; (*d*) two phase transitions are observed in solid solutions of $Pb(Zr,Sn)O_3$.

537.227 : 546.431.824-31 3406

Surface Space-Charge Layers in Barium Titanate.—A. G. Chynoweth. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 705–714.) Effects of the type discussed by Känzig (2988 of 1955) are investigated experimentally using technique described previously (1745 of June). From the waveforms of the pyroelectric current signals, it is tentatively concluded that space-charge layers up to 10^{-5} cm thick exist at the surface of single crystals, and that these space charges also produce a field through the bulk of the crystal. Corroboratory evidence is provided by an associated photovoltaic effect and asymmetry of the hysteresis loops. Various effects due to these space-charge fields are mentioned.

537.228.1 : 546.431.824-31 3407

Dielectric and Piezoelectric Properties of the Solid Solutions $(Ba,Sr)TiO_3$, $(Ba,Pb)TiO_3$, $Ba(Ti,Sn)O_3$ and $Ba(Ti,Zr)O_3$.—N. A. Roi. (*Akust. Zh.*, Jan.–March 1956, Vol. 2, No. 1, pp. 62–70.) Measurements are presented graphically of the following characteristics: (*a*) ϵ/T, (*b*) d_{33}/E_0, (*c*) coercive-force/composition, where ϵ is the permittivity, T the temperature, d_{33} the piezoelectric modulus and E_0 the polarizing field strength.

537.311.31 : 538.63 : 546.47 3408

The Interrelation of the Anisotropy of the Hall Effect and the Change of Resistance in Metals in a Magnetic Field: Part 1—Investigation of Zinc.—E. S. Borovik. (*Zh. eksp. teor. Fiz.*, Feb. 1956, Vol. 30, No. 2, pp. 262–271. English summary, *ibid.*, Supplement, p. 4.)

537.311.33 + 621.315.6 3409

Ionization Interaction between Impurities in Semiconductors and Insulators.—R. L. Longini & R. F. Greene. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 992–999.) The free energy of an imperfect crystal includes components which arise from the ionizability of these imperfections and which represent chemical interactions between them. These ionization terms, which involve the Fermi level and the parameters of the energy-band model, are used to explain systematic differences between *n*- and *p*-type semiconductors in respect of lattice-vacancy concentration, substitutional-atom diffusion coefficients and amphoteric-impurity behaviour, as well as the variation of solid/liquid impurity distribution coefficients of some semiconductors with the rate of crystal growth, and the ' charge-balance ' effect in insulators.

537.311.33 **3410**

Surface Barriers at Semiconductor Contacts.—R. Stratton. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 513–527.) Current flow across a surface of discontinuity is treated according to the diode and the diffusion theories of barrier rectifiers and the results are applied to measurements on SiC point contacts and a grain boundary in Ge, respectively. The contact resistance found is consistent with a barrier caused by donor and acceptor surface states, whose density on SiC is about $10^{13}/cm^2$ and on Ge about $5 \times 10^{11}/cm^2$.

537.311.33 **3411**

High-Frequency Conductivity in Semiconductors.—B. Donovan & N. H. March. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 528–538.) Theory is developed for nondegenerate semiconductors with spherical energy surfaces, the cases of single- and two-band models with lattice and impurity scattering being considered. Divergencies from available experimental results are discussed.

537.311.33 **3412**

The Stoichiometry of Intermetallic Semiconductors.—R. J. Hodgkinson. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 612–624.) The effects of small concentrations of point defects on the free energy of a crystal of formula AB are discussed. The maximum melting point of the compound does not occur at the composition corresponding exactly to the formula AB. The type of phase diagram arising from this fact is derived. Published experimental evidence is quoted in support of the theory. A crystal which is heat-treated in presence of its vapour will not necessarily have the same concentration of defects as one of the same composition grown from the melt at the same temperature.

537.311.33 **3413**

Negative Magnetoresistance Effect in Semiconductors.—C. Rigaux & J. M. Thuillier. (*C. R. Acad. Sci., Paris*, 4th June 1956, Vol. 242, No. 23, pp. 2710–2712.) An interpretation of the effect different from that of Mackintosh (2805 of September) or Stevens (2806 of September) is presented.

537.311.33 **3414**

Characteristic Times of Electronic Processes in Semiconductors.—E. I. Adirovich & G. M. Guro. (*C. R. Acad. Sci. U.R.S.S.*, 21st May 1956, Vol. 108, No. 3, pp. 417–420. In Russian.) Characteristic times are calculated, assuming the presence of recombination centres (traps) of one type and of fully ionized acceptors and donors. Two of the calculated characteristic times correspond to the electron and hole lifetimes calculated by Shockley & Read (420 of 1953), two others are decay times.

537.311.33 **3415**

Some Problems of the Multi-electron Theory of Semiconductors.—S. V. Vonsovski. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2022–2029.) The various stages in the development of the multi-electron theory are briefly reviewed and its advantages pointed out. The limitations of the theory are then considered, arising from (*a*) the use of the ' adiabatic ' approximation in which there is no allowance for the active dynamic participation of the system of ions, and (*b*) the exaggerated importance attached to the ordered disposition of ions. The possibilities of overcoming these limitations are indicated and a generalized multi-electron model of atomic semiconductors is discussed.

537.311.33 **3416**

Theory of Semiconductors with an Impurity Band.—A. G. Samoilovich & M. I. Klinger. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2050–2060.) The properties of an electron gas are considered for the following two cases: (*a*) a metal with a narrow conduction band, and (*b*) a semiconductor with an impurity band. The chemical potential is calculated for both cases and the electrical conductivity and thermo-e.m.f. are also determined, in the first case from the degree of filling of the narrow band, and in the second case from the temperature. The results are compared with experimental data.

537.311.33 **3417**

Properties and Structure of Ternary Semiconducting Systems: Part 2—Electrical Properties and Structure of Materials of the System comprising Thallium, Antimony and Arsenic Selenides.—N. A. Goryunova & B. T. Kolomiets. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2069–2078.) In continuation of work reported previously [1751 of June (Kolomiets & Goryunova)] an investigation was made of the variation of the properties of intermediate mixtures at the transition between the crystalline and amorphous compounds. Seven melts with gradual replacement of Sb by As were synthesized and numerous experiments carried out.

537.311.33 **3418**

Correlation between the Heat of Formation of a Semiconductor and the Electron Mobility.—V. P. Zhuze. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2079–2092.) The insufficiency of the existing theory of electron mobility is pointed out; it would be of interest to determine experimentally the dependence of mobility on some macroscopic parameter of the substance. Reference is made to a previous investigation by Blum & Regel' (*ibid.*, March 1951, Vol. 21, pp. 316–327), where fairly close correlation was established between electron mobility and the heat of formation of binary semiconducting compounds. Much new information has since been accumulated; this is summarized in a table giving data on 39 compounds. The various factors underlying the observed correlation are discussed.

537.311.33 **3419**

The Temperature Dependence of the Density and Electrical Conductivity of Liquid Solutions of the System Te-Se.—N. P. Mokrovski & A. R. Regel'. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2093–2096.)

537.311.33 : 537.226 **3420**

The Present State of some Problems of the Theory of Semiconductors and Dielectrics, and Directions of Further Development of the Theory.—S. I. Pekar. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2030–2043.) Shortened version of a paper read at a conference on semiconductors held in Leningrad in February 1955. The headings are : (*a*) phenomenological theory of semiconductors; (*b*) kinetics of electrons in the conduction band; (*c*) thermal (radiationless) electron transitions; (*d*) photo-transitions of electrons; (*e*) methods of calculating the quantum stationary states of a crystal.

537.311.33 : 538.569.4 **3421**

Quantum Theory of Cyclotron Resonance in Semiconductors: General Theory.—J. M. Luttinger. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1030–1041.)

537.311.33 : 541.57 **3422**

The Chemical Bond in Semiconductors.—E. Mooser & W. B. Pearson. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 621–645.) Discussion presented previously (2781 of September) is treated more fully.

537.311.33 : 546.23 **3423**

The Absorption Edge of Amorphous Selenium and its Change with Temperature.—C. Hilsum. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 506–512.) Experimental results showing the variation of absorption coefficient with λ over the range 0·58–0·66 μ are presented. The absorption edge shifts with temperature by 2·7 Å/deg, equivalent to a change in the energy gap of $9 \cdot 7 \times 10^{-4}$ eV/deg.

537.311.33 : 546.26-1 : 539.1 **3424**

Effect of Fast Neutron Bombardment on Physical Properties of Graphite: a Review of Early Work at the Metallurgical Laboratory.—M. Burton & T. J. Neubert. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 557–567.) Variations of the elastic modulus and the thermal and electrical resistance are related to the displacement of the carbon atoms from their normal positions in the crystal lattice. Hall-effect measurements indicate that the neutron-induced disturbances are electron traps. Abstracts of papers by various workers dealing with the particular aspects are presented on pp. 568–572, following the main paper.

537.311.33 : 546.28 **3425**

Paramagnetic Resonance in As-Doped Silicon.—A. Honig & J. Combrisson. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 917–918.) As a result of studies further to those described previously [753 of 1955 (Honig)] a new interpretation of the observed effects is advanced.

537.311.33 : 546.28 + 549.514.5] : 539.2 **3426**

Adsorption of Ammonia on Silicon.—L. Miller. (*Z. Naturf.*, Sept./Oct. 1955, Vol. 10a, Nos. 9/10, pp. 801–802.) It has been found that the adsorption of NH_3 is a useful criterion in the investigation of the surface properties of quartz and other forms of SiO_2. The presence of water on a quartz surface is known to increase the adsorption of NH_3. Methods based on these effects are used to indicate the presence of SiO_2 layers on Si. Attempts to produce an oxide-free Si surface by h.f. technique were unsuccessful.

537.311.33 : 546.289 **3427**

A Note on the Theory of Dislocation in Germanium.—T. Shindo. (*J. phys. Soc. Japan*, March 1956, Vol. 11, No. 3, pp. 331–332.) Following on the work of Read (457 of 1955), a more general expression is found for the fraction of dislocation acceptor sites occupied, which reduces to that given by Read for the case when the number of trapped electrons is small compared with the number of donor centres.

537.311.33 : 546.289 **3428**

The Electrical Properties of Dislocations in Germanium.—J. W. Allen. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 580–588.) Different experimental results can be reduced to consistency by considering the effects of impurity-atmosphere formation at the dislocations. Experiments to test this theory are suggested.

537.311.33 : 546.289 **3429**

Self-Diffusion in Germanium.—H. Letaw, Jr, W. M. Portnoy & L. Slifkin. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 636–639.) "An accurate determination of the self-diffusion coefficient in germanium has been obtained. In the temperature range 766°–928°C, it is represented by $D = 7 \cdot 8 \exp(-68\,500/RT)$ cm² sec. The probable errors in the frequency factor and activation energy are $\pm$ 3·4 cm²/sec and $\pm$ 0·96 kcal/mol, respectively."

537.311.33 : 546.289 **3430**

Scattering of Carriers from Doubly Charged Impurity Sites in Germanium.—W. W. Tyler & H. H. Woodbury. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 647–655.) Measurements are reported which indicate that Zn is a double-acceptor impurity in Ge, the acceptor levels lying 0·03 and 0·09 eV from the valence band. Hall-effect measurements show that scattering from doubly charged Zn sites is about four times that from singly charged Ga sites. Photoconductivity measurements on *n*-type Ge specimens containing Fe or Mn impurities indicate that at high levels of illumination the steady-state increase in free-electron concentration is roughly equal to the known concentrations of double-acceptor impurities. The accompanying mobility increases provide additional confirmation of the assumption that holes trapped at doubly charged impurity sites are responsible for the photosensitivity.

537.311.33 : 546.289 **3431**

Measurements of Surface Electrical Properties of Bombardment-Cleaned Germanium.—J. T. Law & C. G. B. Garrett. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, p. 656.) Measurements were made of the surface recombination velocity and surface conductivity of a *p*-type bombardment-cleaned Ge specimen (*a*) in vacuum, (*b*) after admission of oxygen, and (*c*) after subsequent heating at about 400°C. The effects of step (*b*) are annulled by step (*c*). This result is interpreted as indicating that a bombardment-cleaned surface has already at least one layer of oxygen on it before any measurements can be made.

537.311.33 : 546.289 **3432**

Trap Activation Energies in *N*-Type Germanium.—P. Ransom & F. W. G. Rose. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 625–628.) Discussion indicates that it should be possible to determine from measurements by the Morton-Haynes method [741 of 1953 (Valdes)], in darkness and with various intensities of background illumination, both the activation energy and the concentration of different traps in a single sample.

537.311.33 : 546.289 **3433**

Observations on the Growth of Excess Current in Germanium *p-n* Junctions.—A. R. F. Plummer. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 539–547.) The excess current induced by water vapour has been resolved experimentally into two components having linear and saturation relations with the applied voltage; the possibility of identifying these components with channel and surface leakage currents is discussed but not established.

537.311.33 : 546.289 **3434**

The Possibility of obtaining a *p-n* Junction in Germanium by Pulse Heating.—M. M. Bredov. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2104–2111.) The method proposed is based on the known fact that if *n*-type Ge is heated to a temperature of 800°–900° and then rapidly cooled, the sign of its conduction changes (thermal conversion). If a short pulse of heat is applied to the specimen, conversion should take place in the surface layer and a *p-n* junction should be formed at a depth corresponding to the transition between the converted layer and the unaffected bulk of the specimen. The necessary pulse heating can be obtained by irradiating the specimen with a pulsed electron beam. The theory of the method is discussed; the results have been confirmed experimentally.

537.311.33 : 546.289 : 535.215 **3435**

Photoconductivity in Manganese-Doped Germanium.—R. Newman, H. H. Woodbury & W. W. Tyler. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 613–617.) "Impurity photoconduction has been observed in *n*- and *p*-type Mn-doped germanium at low temperatures. The spectra are consistent with the published ionization energy values determined from conductivity data. High-resistivity *n*-type samples show high intrinsic photosensitivity and long response times at low temperatures. In such samples the intrinsic photocurrent could be quenched by a factor of $\sim 10^4$ with light in the 0·3 to 0·7 eV range. Intrinsic photoconductivity was found to vary more rapidly than linearly with light intensity over a limited range."

537.311.33 : [546.289 + 546.681] : 535.33/.34 **3436**

L-Spectra of Gallium and Germanium.—A. Lemasson-Lucasson. (*C. R. Acad. Sci., Paris*, 25th June 1956, Vol. 242, No. 26, pp. 3059–3061.)

537.311.33 : 546.289 : 538.63 **3437**

An Investigation of the Nernst Effect in Germanium.—T. V. Krylova & I. V. Mochan. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2119–2121.) A report is presented on an experimental investigation. One of the conclusions reached is that the mobility of holes varies as $T^{-5/2}$.

537.311.33 : 546.289 : 539.16 **3438**

Effects of Gamma Radiation on Germanium.—J. W. Cleland, J. H. Crawford, Jr, & D. K. Holmes. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 722–724.) Experiments with high-purity *n*- and *p*-type specimens are reported. The extrinsic electron concentration of *n*-type material decreased at a rate only about 10^{-3} of that for fast-neutron irradiation. Extended exposure converts *n*-type material to *p*-type. For *p*-type material the rate of removal of carriers is much lower than for *n*-type. The value deduced for the cross-section for atomic displacements is about $1{\cdot}5 \times 10^{-26}$ cm².

537.311.33 : 546.47.241 **3439**

Electrical Properties of Zinc Telluride.—B. I. Boltaks, O. A. Matveev & V. P. Savinov. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2097–2103.) An experimental investigation is reported; the main conclusions are as follows: ZnTe is a semiconductor of *p* type, with an energy gap of $0{\cdot}65 \pm 0{\cdot}03$ eV. Its electrical properties are greatly affected by atmospheric oxygen. There is a peculiar temperature dependence of the coefficient of thermo-e.m.f. for specimens with a composition close to the stoichiometric value. The mobility of holes is 30–50 cm/sec per V/cm, and varies with temperature in proportion to $T^{-3/2}$. The effective mass of a hole is about 0·2 of the mass of a free electron.

537.311.33 : 546.48.241.1 : 535.215 : 535.37 **3440**

Luminescence, Transmission and Width of the Energy Gap of CdTe Single Crystals.—C. Z. van Doorn & D. de Nobel. (*Physica*, April 1956, Vol. 22, No. 4, pp. 338–342.) Luminescence with a maximum at about 8 880 Å was obtained on illuminating a CdTe single crystal and on biasing a CdTe *p-n* junction in the forward direction. Possible mechanisms giving rise to the luminescence are indicated. The width of the energy gap determined from measurements of the spectral transmission of a single crystal is 1·51 eV at room temperature.

537.311.33 : 546.561-31 **3441**

Resistance of Metal/Semiconductor Contact at High Contact-Potential Differences.—N. A. Gozhenko & Yu. M. Altaiski. (*Zh. eksp. teor. Fiz.*, Feb. 1956, Vol. 30, No. 2, pp. 401–402.) Measurements of the contact resistance of (*a*) Cu_2O/Al and (*b*) Cu_2O/Cu, show that as the air pressure is increased from zero to about 20 mm Hg the resistance in case (*a*) first decreases and then increases, and in case (*b*) increases monotonically. The contact potential in case (*a*) is 1·18 V, in case (*b*) 0·22 V. The anomalous behaviour of the contact resistance in case (*a*) is discussed.

537.311.33 : 546.561-31 : 548.25 **3442**

The Intergrowth of Cu and Cu_2O after Oxidation and Reduction.—G. Jellinek, E. Menzel & C. Menzel-Kopp. (*Z. Naturf.*, Sept./Oct. 1955, Vol. 10a, Nos. 9/10, pp. 802–803.)

537.311.33 : 546.682.86 **3443**

Contribution to the Study of Carrier Mobility in InSb.—J. Tavernier. (*C. R. Acad. Sci., Paris*, 4th June 1956, Vol. 242, No. 23, pp. 2707–2710.) Measurements were made of the temperature variation of resistance and Hall constant for a *p*-type specimen in which the temperature of inversion of the Hall effect was not much below room temperature. Results are shown graphically. An approximate formula is derived giving the variation with applied magnetic field of the ratio of electron mobility to hole mobility; a value of 15·5 kG is hence calculated for the magnetic field strength at which the Hall effect disappears at room temperature. The observed value is 14 kG.

537.311.33 : 621.317.799 **3444**

Apparatus for Measurement of Hall Effect and Magnetoresistance in Semiconductors.—G. Della Pergola & D. Sette. (*Alta Frequenza*, April 1956, Vol. 25, No. 2, pp. 140–151.) The apparatus described permits measurements at values of magnetic induction up to about 1·3 Wb/m². Measurements on an *n*-type Ge specimen are reported.

537.311.33 : 669.046.54/.55 **3445**

Zone-Melting Processes for Compounds AB with a Measurable Vapour Pressure under Influence of the Atmosphere.—J. van den Boomgaard. (*Philips Res. Rep.*, April 1956, Vol. 11, No. 2, pp. 91–102.) Conditions under which purification by zone melting is possible are investigated. The relation between the deviation from stoichiometric composition and the position along the rod of material is derived. See also 2810 of September.

537.312.62 : 538.222 **3446**

Paramagnetic Effect in Superconducting Tin, Indium, and Thallium.—J. C. Thompson. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1004–1008.) "Measurements have been carried out on the longitudinal magnetization of pure rods in the intermediate state between normal and superconduction. The observed 'paramagnetic' flux increase is dependent on the externally sustained current, external magnetic field, and temperature only."

538.22 3447

Superexchange Interactions and Magnetic Lattices of the Rhombohedral Sesquioxides of the Transition Elements and their Solid Solutions.—Yin-Yuan Li. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1015–1020.)

538.221 3448

Magnetic Dispersion and Absorption of Iron between 0 and 7 000 Mc/s.—E. Naschke. (*J. Phys. Radium*, April 1956, Vol. 17, No. 4, pp. 330–337.) The variation of initial permeability with frequency was studied by measurements on wire specimens in which the size of the individual domains had been increased by heat treatment so as to shift the ferromagnetic dispersion due to wall movements to a frequency range lower than that associated with electron-spin rotation. The results are discussed in relation to various theories on magnetic dispersion due to wall movements.

538.221 3449

Magnetization of a Magnetic Single Crystal near the Curie Point.—D. O. Smith. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 959–963.) Experimental technique is described which enables an unambiguous indication to be obtained of spontaneous and induced magnetization of a single domain at temperatures around the Curie point. The magnetization/magnetizing-field (M/H) curves in this temperature region are highly nonlinear; replotting in the form of H/T curves shows that the magnetic energy is proportional to M^2.

538.221 : 538.24 3450

Magnetization Curves and Domain Structure.—L. F. Bates & A. Hart. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, pp. 497–505.) The theoretical work of Lee (117 of 1954) on domain structure has been supplemented by an experimental study of the changes in domain patterns in a Néel-cut crystal of Si-iron occurring when the crystal dimensions are changed. Calculated magnetization curves based on the results show better agreement with experimental curves than has been obtained previously, particularly for low field strengths. A substantial hysteresis loss occurs in strong fields with crystals of finite size.

538.221 : 621.318.12 3451

The Effect of substituting Al^{3+} Ions for Fe^{3+} Ions on the Magnetic Properties of the Compounds ($6Fe_2O_3$, BaO), ($6Fe_2O_3$, SrO), ($6Fe_2O_3$, PbO).—C. Guillaud & G. Villers. (*C. R. Acad. Sci., Paris*, 11th June 1956, Vol. 242, No. 24, pp. 2817–2820.) Experimental results indicate that the effect of the substitution is to increase the coercive force, to reduce the saturation moment, and to modify the shape of the magnetization curve. Crystals with grain dimensions $< 0{\cdot}5\,\mu$ are obtained by appropriate heat treatment.

538.221 : 621.318.124 3452

Neutron Diffraction Observation of Heat Treatment in Cobalt Ferrite.—E. Prince. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 674–676.) Results of experiments indicate that, when heat treatment is applied in a magnetic field, the magnetic moments are in general displaced from the directions which would be expected from considerations of crystal anisotropy alone.

538.221 : 621.318.134 3453

The Metallography of Ferrites.—P. Levesque & L. Gerlach. (*J. Amer. ceram. Soc.*, 1st March 1956, Vol. 39, No. 3, pp. 119–120.) A note on the preparation and etching of ferrite specimens for displaying grain size, grain orientation and porosity.

538.221 : 621.318.134 3454

Ordering and Antiferromagnetism in Ferrites.—P. W. Anderson. (*Phys. Rev.*, 15th May 1956, Vol. 102, No. 4, pp. 1008–1013.) "The octahedral sites in the spinel structure form one of the anomalous lattices in which it is possible to achieve essentially perfect short-range order while maintaining a finite entropy. In such a lattice nearest-neighbor forces alone can never lead to long-range order, while calculations indicate that even the long-range Coulomb forces are only 5% effective in creating long-range order. This is shown to have many possible consequences both for antiferromagnetism in 'normal' ferrites and for ordering in 'inverse' ferrites."

538.221 : 621.318.134 3455

Magnetic Measurements on Individual Microscopic Ferrite Particles near the Single-Domain Size.—A. H. Morrish & S. P. Yu. (*Phys. Rev.*, 1st May 1956, Vol. 102, No. 3, pp. 670–673.) Measurements made with the quartz-fibre torsion balance described previously [2155 of July (Yu & Morrish)] provide evidence confirming the existence of single-domain particles; the critical size is in agreement with that found from theory (170 of January).

538.221 : 621.318.134 3456

The Temperature-Dependent Resistivity of certain Iron-Deficient Magnesium Manganese Ferrites.—W. P. Osmond. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 665–666.) Results reported by Blackman & Sherry (1468 of May) are interpreted as indicating that the firing temperature was not high enough to ensure complete oxygen compensation for the reduced Fe_2O_3 content.

538.221 : 621.318.134 3457

The Reduction of Eddy-Current Losses in Manganese-Zinc Ferrites by Addition of Calcium.—C. Guillaud, M. Paulus & R. Vautier. (*C. R. Acad. Sci., Paris*, 4th June 1956, Vol. 242, No. 23, pp. 2712–2715.) An experimental investigation has been made of the effect of introducing a small proportion of Ca, using a radioactive isotope to facilitate study of the diffusion. The Ca apparently diffuses preferentially in the joins between the crystal grains, thus increasing the resistance of the ferrites and reducing the eddy-current losses.

538.221 : 621.318.134 : 538.652 3458

Influence of Magnetostriction on the Initial Permeability of Manganese-Zinc Ferrites.—R. Vautier. (*C. R. Acad. Sci., Paris*, 11th June 1956, Vol. 242, No. 24, pp. 2814–2817.) Theoretical considerations and experimental results indicate that it is not possible to predict the initial permeability of polycrystalline Mn-Zn ferrites from measurements of the longitudinal magnetostriction. Measurements on single crystals, parallel to the crystal axes, may be more conclusive.

538.221.023 3459

Approximate Representation of Magnetization Curves by Simple Algebraic or Transcendental Functions.—J. Fischer & H. Moser. (*Arch. Elektrotech.*, 17th April 1956, Vol. 42, No. 5, pp. 286–299.) Fifteen different functions used as approximations to the experimentally determined B/H curves are discussed, and conclusions are tabulated regarding the range of conditions over which these approximations are useful.

549.514.5 : 537.531 : 535.21-31 3460

The Effect of U.V. and X-Ray Radiation on Silicate Glasses, Fused Silica and Quartz Crystals.—A. Kats & J. M. Stevels. (*Philips Res. Rep.*, April 1956, Vol. 11, No. 2, pp. 115–156.) The results of an experimental investigation into the effect of irradiation on the structure of these SiO_2 compounds are given and discussed in terms of nomenclature introduced previously [*ibid.*, pp. 103–114 (Stevels & Kats)]. A table indicates absorption bands associated with certain of the imperfections noted.

621.318.134 : 546.3 : 669.05 **3461**

Preparation of Alkali Ferrites, Nickelites and Cobaltites by Fusion Electrolysis.—M. Dodero & C. Déportes. (*C. R. Acad. Sci., Paris*, 18th June 1956, Vol. 242, No. 25, pp. 2939–2941.)

666.1.037 **3462**

Solder Glass Sealing.—R. H. Dalton. (*J. Amer. ceram. Soc.*, 1st March 1956, Vol. 39, No. 3, pp. 109–112.) The development of low-melting-point glasses suitable for soldering ordinary glasses is described, together with some techniques used in making such seals.

MATHEMATICS

517.5 **3463**

Convenient Calculation Procedure for the Harmonic Analysis and Synthesis of Periodic Waves.—R. Chocholle. (*Rev. sci., Paris*, Jan.–March 1954, Vol. 92, No. 3325, pp. 3–14.) Simplification is effected by breaking down some operations and by grouping together identical operations.

517.9 **3464**

A Critical-Value Problem relative to a Nonlinear Differential Equation of Practical Importance.—A. Giger. (*Z. angew. Math. Phys.*, 25th March 1956, Vol. 7, No. 2, pp. 121–129.) Discussion of the equation

$$d^2\Theta/d\tau^2 + \alpha d\Theta/d\tau + \sin\Theta = \beta,$$

which arises e.g. in the analysis of the synchronization of oscillations. For every value of β within the range $0 < |\beta| < 1$ there exists a critical value α_0 of α such that for $\alpha > \alpha_0$ there is no periodic solution; the values of α_0 are calculated.

517.9 **3465**

A Solution of Tranter's Dual-Integral-Equations Problem.—J. C. Cooke. (*Quart. J. Mech. appl. Math.*, March 1956, Vol. 9, Part 1, pp. 103–110.) The solution of a pair of integral equations occurring in potential problems and previously studied by Tranter (695 of 1955) is given as an integral containing an unknown function which is determined by means of an integral equation of Fredholm's type.

517.9 **3466**

Round-Off Errors in Implicit-Finite-Difference Methods.—A. R. Mitchell. (*Quart. J. Mech. appl. Math.*, March 1956, Vol. 9, Part 1, pp. 111–121.) "Symmetrical and asymmetrical implicit finite difference replacements involving a variable parameter a and a variable mesh ratio s are considered for the heat conduction and wave equations, and expressions obtained for the round-off errors. It is found that the stable backward difference replacements, four-point for the heat conduction equation and five-point for the wave equation, give rise to minimum round-off errors."

519.21 : 621.396.621 **3467**

Notes on some Properties of Stationary Random Functions entering into Problems of Frequency Changing.—A. Blanc-Lapierre, P. Dumontet & M. Savelli. (*C. R. Acad. Sci., Paris*, 11th June 1956, Vol. 242, No. 24, pp. 2799–2800.)

MEASUREMENTS AND TEST GEAR

529.78 **3468**

Construction and Performance of New Quartz Clocks at the Physikalisch-Technische Bundesanstalt.—A. Scheibe, U. Adelsberger, G. Becker, G. Ohl & R. Süss. (*Z. angew. Phys.*, April 1956, Vol. 8, No. 4, pp. 175–183.) Frequency stability has been improved as a result of modifications in the method of supporting the quartz rod, the arrangement of electrodes, the internal thermostat, the master-oscillator circuit, and the frequency-divider circuit. In clocks P1 and P3 the frequency variation associated with aging is < 1 part in 10^9 in a month.

531.761 + 529.7 **3469**

Atomic Time and the Definition of the Second.—L. Essen. (*Nature, Lond.*, 7th July 1956, Vol. 178, No. 4523, pp. 34–35.) Difficulties inherent in the establishment of a single unit of time, as advocated by Pérard (2834 of September), are discussed. Tentative proposals are advanced, implementation of which would make the atomic standard immediately available while preserving a single unit of time closely linked with, although not defined by, that given by astronomical observations.

621.317.3.029.6 : 621.317.7.029.6 **3470**

The Technique of Microwave Measurements.—(*J. Brit. Instn Radio Engrs*, July 1956, Vol. 16, No. 7, pp. 385–400.) Report of a discussion dealing with the measurement of power, attenuation, impedance, frequency and dielectric properties.

621.317.328 : 621.396.823 : 621.3.013.78 **3471**

A Method of making Screen-Room Measurements.—K. E. Mortenson & C. J. Truax. (*Elect. Engng, N.Y.*, April 1956, Vol. 75, No. 4, p. 326.) Digest of paper published in *Trans. Amer. Inst. elect. Engrs*, Part I, *Communication and Electronics*, Jan. 1956, Vol. 74, pp. 746–750. A method is described for determining the 'free-space' interference field strengths of electrical equipment from measurements made in a screened room. The limitations of the method are: (*a*) the size of the equipment must be less than one third of the room size and the linear dimensions must be less than one tenth of the wavelength used, and (*b*) the frequency used should be about half the lowest resonant mode of the room.

621.317.328.029.62/.63 : 621.396.621.54 **3472**

A V.H.F./U.H.F. Field-Strength Recording Receiver using Post-Detector Selectivity.—Harvey, Newell & Spencer. (See 3528.)

621.317.33 **3473**

A Slide-Wire Cylinder for the Townsend Circuit as a Simple Adjunct in the Precision Measurement of Very High Resistances.—H. Mette. (*Z. angew. Phys.*, April 1956, Vol. 8, No. 4, pp. 191–193.)

621.317.33 : 621.375.4 : 621.314.7 **3474**

Measurement of the Input Resistance and Reactance of a Transistor Amplifier by varying the Impedance of an Oscillator.—A. P. Teplova, V. M. Tuchkevich & A. I. Uvarov. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2112–2118.) A simple method is described which involves connecting an oscillator to the transistor input and varying the impedance of the oscillator. The theory of the method is discussed and measurements at frequencies up to 10 Mc/s are reported.

621.317.335.2 : 621.318.42 **3475**

Measurement of the Self-Capacitance of an Inductor at High Frequencies.—J. P. Newsome. (*Electronic Engng*, August 1956, Vol. 28, No. 342, pp. 350–352.) The methods of measurement discussed include one based on the determination of the self-resonance frequency of the inductor by use of a Q meter; this is particularly useful for small values of self-capacitance.

621.317.337 : 621.372.41 **3476**

Measurement of the Electrical Equivalent-Circuit Constants of High-Q Resonators.—E. Frisch. (*Nachrichtentech. Z.*, April 1956, Vol. 9, No. 4, pp. 182–185.) A method of determining the equivalent *LCR* values of ferrite-rod and piezoelectric resonators is described, involving frequency and impedance measurements. Other methods are reviewed.

621.317.34.018.782.4 **3477**

Error Sources in Group-Delay Measurements on Electric Networks.—A. van Weel. (*Philips Res. Rep.*, April 1956, Vol. 11, No. 2, pp. 81–90.) "Errors in group-delay measurements can be caused by spurious phase modulation in the amplitude modulator or in the network under test, by a varying carrier-frequency level on the detector, and by overloading the network under test. These effects are discussed and counter measures are indicated."

621.317.35 : 621.372.5.012 **3478**

A Sensitive Method for the Measurement of Amplitude Linearity.—S. I. Kramer. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1059–1060.) The method outlined is based on applying a linear saw-tooth waveform to the input terminals of the device under test and passing the output through a differentiator; the differentiated waveform is observed oscillographically, departure from linearity being indicated by departure of the c.r.o. trace from the horizontal.

621.317.373 **3479**

A Simple Method of Accurate Phase Measurement of a Four-Terminal Network.—B. Chatterjee. (*J. Instn Telecommun. Engrs, India*, March 1956, Vol. 2, No. 2, pp. 93–95.) Brief description of a method in which the change of phase produced by a quadripole is measured by inserting the quadripole in the feedback loop of an oscillating circuit and noting the resulting frequency change.

621.317.4 : 539.152.1 : 538.569.4 **3480**

A Nuclear-Resonance Meter for Magnetic Flux.—V. Andresciani & D. Sette. (*Ricerca sci.*, April 1956, Vol. 26, No. 4, pp. 1101–1115.) An instrument for measurement of flux values between 0·15 and 1·2 Wb/m² is described; a transitron oscillator is used.

621.317.42 : 538.632 **3481**

Measurements on Magnetically Soft Materials by means of the Hall Generator.—F. Assmus & R. Boll. (*Elektrotech. Z., Edn A*, 11th April 1956, Vol. 77, No. 8, pp. 234–236.) Small Hall generators made of Group III–V alloys were used in several applications involving the measurement of magnetic field strengths in the range 0·1–10 oersted. The applications briefly described include measurement of the field strength in individual crystals of a silicon-iron rectangular-frame specimen, the magnetization of strips of metal, etc. The technique is particularly useful for indicating local variations.

621.317.443.029.5/.62 **3482**

Advances in the Design and Application of the Radio-Frequency Permeameter.—A. L. Rasmussen, A. W. Enfield & A. Hess. (*J. Res. nat. Bur. Stand.*, May 1956, Vol. 56, No. 5, pp. 261–267.) The instrument described previously [1857 of 1954 (Haas)] has been further developed. The frequency range covered is 0·05–50 Mc/s. In the range 0·1–35 Mc/s the accuracy of permeability determinations obtained from reference to a primary standard is within ± 2%.

621.317.444 **3483**

Development of a Vibrating-Coil Magnetometer.—D. O. Smith. (*Rev. sci. Instrum.*, May 1956, Vol. 27, No. 5, pp. 261–268.) An alternating voltage proportional to the magnetic field of a dipole created by inserting a small sample of magnetic material into a magnetizing field is derived by means of a coil vibrating along the axis of the dipole at a distance up to 2 cm from the sample. Measurements are continuous and recordable; accuracy is within 1% for a dipole moment of $8{\cdot}56 \times 10^{-4}$ A.m².

621.317.7 : 537.54 : 621.396.822.029.6 **3484**

The Gas-Discharge Tube as a Device for Noise Measurement in the Centimetre Waveband.—W. Klein & W. Friz. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 589–600. In German.) The production of white noise in the electron plasma of the self-supporting gas discharge is explained on the basis of thermodynamic theory. The available noise power for a discharge with purely electronic absorption corresponds to the full energy value of the electron temperature.

621.317.725 : 621.375.23.024 **3485**

Unity-Gain Voltmeter Amplifier.—H. R. Hyder. (*Tele-Tech & Electronic Ind.*, April 1956, Vol. 15, No. 4, pp. 84–85.) Circuit details are given of a highly stable three-stage d.c. amplifier incorporating differential first stage and cathode-follower output, suitable as a coupling unit between a high-impedance source and a low-impedance load; with a 0–1-V voltmeter connected across the output, ranges of 1 to 1 000 V are obtainable.

621.317.725 : 621.385 **3486**

Improved Slide-Back Valve Voltmeter.—O. E. Dzierzynski. (*Wireless World*, Sept. 1956, Vol. 62, No. 9, pp. 441–445.)

621.317.727 **3487**

A Switch-Dial Potential Divider.—W. K. Clothier. (*J. sci. Instrum.*, May 1956, Vol. 33, No. 5, pp. 196–198.) Variants of a general class of divider network are described in which the errors due to switch contacts are small, making them specially suitable for low-resistance applications.

621.317.729 : 621.396.823 **3488**

Equipment for recording R.F. Interference due to High-Voltage Power Transmission Lines.—J. Carteron, E. Fromy & B. Prokocimer. (*Rev. gén. Élect.*, April 1956, Vol. 65, No. 4, pp. 203–208.) Equipment for ground measurements of the field strength due to corona effects comprises (*a*) a small vertical aerial fixed directly to the metal case enclosing (*b*) an amplifier with a small number of circuits tuned to the fixed operating frequency, (*c*) a quasi-peak detector, and (*d*) a continuous electro-mechanical recorder actuated by a d.c. amplifier of the type described by Chevallier & Prokocimer (3316 above) in which stable operation is achieved by using a high degree of feedback distributed between the stages.

621.317.742 **3489**

A New Technique for the Measurement of Microwave Standing-Wave Ratios.—A. C. MacPherson & D. M. Kerns. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1024–1030.) A high-precision method using a stationary detector and sliding load is described. Generator, detector and load are connected respectively to the arms of a three-arm waveguide junction. The variation of the detector response as the phase of the load is varied yields a curve similar to a standing-wave pattern, from which the unknown load can be determined using the procedure indicated. The technique is amenable to rigorous theoretical analysis.

621.317.755 **3490**

Increasing the Accuracy of C.R.O. Measurements.—T. H. Bonn. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, p. 1062.) Techniques in which the c.r.o. is used as a null detector yield accuracies within ± 0·1%.

621.317.755 **3491**

An Automatic Cathode-Ray-Oscilloscope Beam-Brightening Device for Transient Recordings.—O. H. Davie: J. Wood. (*J. sci. Instrum.*, May 1956, Vol. 33, No. 5, p. 203.) Comment on 860 of March and author's reply. Modifications to the original device are suggested.

621.317.755 : 537.52 **3492**

The Production of a Short-Duration Pulse of High-Velocity Electrons.—D. H. Le Croissette. (*Electronic Engng*, August 1956, Vol. 28, No. 342, pp. 356–358.) A pulse of duration 0·2 μs, used for initiating ionization in a gas-filled system, is obtained by making an electron beam traverse a hole in a steel plate; the operation is synchronized with an oscillograph timebase, thus permitting the simultaneous display of the ionizing pulse and the resulting discharge build-up.

621.317.761 **3493**

The 'Frequency Microscope', a Recording Frequency-Measuring Instrument with Very High Sensitivity.—G. Ohl. (*Arch. elekt. Übertragung*, April 1956, Vol. 10, No. 4, pp. 145–150.) A precision method of using a drum-type chronograph is described. The beat produced by two signals with nearly equal frequencies is used to trace a sequence of marks on the drum, the rate of rotation of which is controlled by a quartz crystal and is adjustable in discrete steps. The heterodyne frequency can be accurately determined by the graphical method described.

621.317.761 : 621.314.7 **3494**

Transistor Frequency Meters.—L. R. Blake & A. R. Eames. (*Electronic Engng*, August 1956, Vol. 28, No. 342, pp. 322–327.) Based on the switched-capacitor method, using a transistor switch, the meter described covers the range 0·3–100 kc/s in six sub-ranges, giving an accuracy within 0·5–1%. The indication is independent of signal level or waveform.

621.317.763.029.6 **3495**

The Generation of Multiple TE_{mo} and TM_{mo} Modes between Parallel Plates and in Rectangular Waveguides by Interference, and its Application to the Measurement of Wavelength.—J. I. Caicoya. (*Rev. Telecomunicación, Madrid*, March 1956, Vol. 11, No. 43, pp. 2–30. In Spanish and English.) Detailed analysis is presented for the reflection of microwaves at plane surfaces and the generation of multiple modes by interference. The basic experimental system comprises a pair of parallel rectangular plates with variable separation, arranged symmetrically with respect to a reference plane, and a third parallel rectangular plate whose position is adjusted independently to effect the auxiliary reflection required to produce interference. Horns with variable angular position are used as signal source and detector. Wavelength is determined from the settings for zero detected energy. The instrument has a wide operating frequency band.

621.317.784.029.3 **3496**

Electronic Wattmeter with Wide Frequency Range.—T. J. Schultz. (*Rev. sci. Instrum.*, May 1956, Vol. 27, No. 5, pp. 278–279.) A dynamometer movement is employed, the input to the two coils being supplied by independent power amplifiers using voltage and current negative feedback. Frequency response is level to within ± 0·17 dB between 20 c/s and 20 kc/s.

621.317.799 : 537.311.33 **3497**

Apparatus for Measurement of Hall Effect and Magnetoresistance in Semiconductors.—Della Pergola & Sette. (See 3444.)

621.317.799 : 621.385.029.6 : 621.396.96 **3498**

Magnetron Tester detects Lost Pulses.—P. Koustas & D. D. Mawhinney. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 164–168.) Radar magnetron output pulses of incorrect frequency, or inadequate amplitude or width, are detected by a coincidence meter in which the output is sampled and analysed, and are compared with a signal derived from the magnetron modulator circuit.

621.319.4(083.74) **3499**

New Variable Capacitors with Zero Initial Capacitance.—G. Zickner. (*Z. angew. Phys.*, April 1956, Vol. 8, No. 4, pp. 187–191.) Two types of standard capacitor are described in which the capacitance between two fixed plate systems is varied by means of a rotatable screen. These capacitors have three terminals, and are hence only suitable for use in certain types of circuit, such as bridges. The time stability is equal to that of fixed standard air capacitors, and the capacitance is more precisely defined than in capacitors with only one set of plates connected to the case.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.768 : 534.86 **3500**

Calibration of Vibration Pickups at High Frequencies using a Michelson Interferometer.—S. M. Davies. (*Nature, Lond.*, 21st July 1956, Vol. 178, No. 4525, p. 161.)

621.316.825 : 621.317.39 **3501**

The Use of Semiconductors in investigating Natural Phenomena.—A. F. Chudnovski. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2122–2133.) Brief descriptions are given of the following measuring instruments based on the use of thermistors: (*a*) probe for measuring the temperature distribution in soil; (*b*) electropsychrometer for remote measurements; (*c*) 'thermospider' for measuring the average temperature of the soil surface; (*d*) thermo-anemometer; (*e*) instrument for determining the absolute air humidity; (*f*) instrument for direct measurements of small temperature differences and absolute humidity of the air; (*g*) microelectrometer for measuring the surface temperature of leaves and stalks of plants. General considerations underlying the operation of these instruments are discussed.

621.383.2 : 621.385.832 : 531.76 **3502**

Physical Bases of Electron-Optical Chronography.—E. K. Zavoiski & S. D. Fanchenko. (*C. R. Acad. Sci. U.R.S.S.*, 11th May 1956, Vol. 108, No. 2, pp. 218–221. In Russian.) Very short flashes of light can be measured by means of an electron-optical image converter in which the electron beam is deflected by a rapidly rotating electric or magnetic field. In the limiting case a circle of radius 5 cm is traced in 10^{-10} s; assuming a resolution of 300 lines/cm the shortest measurable time interval is 10^{-14} s.

621.384.611 **3503**

Cyclotron with Sectional Magnet.—E. M. Moroz. (*C. R. Acad. Sci. U.R.S.S.*, 21st May 1956, Vol. 108, No. 3, pp. 436–439. In Russian.) The principles of operation of a cyclotron using a magnet comprised of wedge-shaped sectors are discussed.

621.384.612 **3504**

Influence of Radiation on Synchrotron Oscillations of Electrons in Systems with Strong [alternating-gradient] **Focusing.**—A. N. Matveev. (*C. R. Acad. Sci. U.R.S.S.*, 21st May 1956, Vol. 108, No. 3, pp. 432–435. In Russian.)

621.387.424 **3505**

An Oxygen-Quenched Geiger-Müller Counter.—D. Srdoč. (*J. sci. Instrum.*, May 1956, Vol. 33, No. 5, pp. 185–186.)

621.398 **3506**

Determination of Visual Interpolation Errors in the Plotting of Curves from Commutated Data.—L. Katz. (*Trans. Inst. Radio Engrs*, Feb. 1955, Vol. TRC-1, No. 1, pp. 15–24.) The frequency and sampling-rate requirements of telemetering systems are discussed, in relation to the errors to be expected in interpolating between the measured points.

621.385.833 **3507**

Optique électronique I : Lentilles électroniques. [Book Review]—P. Grivet, M. Y. Bernard & A. Septier. Publishers: Bordas, Paris, 1955, 184 pp., 1450 Fr. (*Proc. phys. Soc.*, 1st May 1956, Vol. 69, No. 437B, p. 587.) A research monograph in which the theoretical exposition is supplemented by practical detail. ". . . the best short account of electron lenses that has yet appeared."

PROPAGATION OF WAVES

621.396.11 **3508**

On the Lateral Deviation of Radio Waves coming from Europe.—K. Miya & S. Kanaya. (*Rep. Ionosphere Res. Japan*, March 1956, Vol. 10, No. 1, pp. 1–8.) Measurements of reception in Japan with aerials pointing in various directions indicate that propagation often takes place along paths deviating from the great circle. The observations support the theory advanced previously (235 of January) that forward scattering at the earth's surface is involved.

621.396.11 : 523.5 **3509**

Some Properties of Oblique Radio Reflections from Meteor Ionization Trails.—O. G. Villard, Jr, A. M. Peterson, L. A. Manning & V. R. Eshleman. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 233–249.) Observations were made over a 960-km path using one transmitter on frequencies of 23·2, 46·4 and 92·8 Mc/s and a second transmitter located at various distances along and offset from the main propagation path and operating on adjacent frequencies. The percentage of the total time during which reflections were received was in accordance with theoretical expectations. Re-radiation from low-density trails was highly directional; the relatively infrequent high-density trails gave long-duration echoes which were much less directional and were subject to fading. Contours of constant correlation were highly elongated in the direction of the propagation path. See also 236 of January.

621.396.11 : 551.510.535 **3510**

Reflection of Radio Signals by the Ionosphere.—P. Poincelot. (*Ann. Télécommun.*, April 1956, Vol. 11, No. 4, pp. 70–80.) The propagation of plane waves in a stratified medium is analysed (*a*) for linear variation of ionization with height, and (*b*) for an exponential variation. Results for continuous waves are obtained first, and pulse propagation is then studied, using group-velocity theory; numerical examples are given. The influence of the longitudinal component of the earth's magnetic field is discussed. See also e.g. 3725 of 1955.

621.396.11 : 551.510.535 **3511**

Orientation of Aerial of Ionospheric Station.—Z. Ts. Rapoport. (*Zh. eksp. teor. Fiz.*, Feb. 1956, Vol. 30, No. 2, pp. 407–408.) The effect is calculated of the orientation relative to the magnetic meridian of the electric vector of the wave incident normally on the ionosphere (angle β) on the ratio of the average energy flux of the reflected ordinary wave (S_2) to that of the extraordinary wave (S_1). The curves showing (S_2/S_1) as a function of β are plotted with $|K_2|$, the polarization index of the ordinary wave, as parameter.

621.396.11 : 551.510.535 **3512**

Ionospheric Focussing and Image Zones.—B. D. Khurana. (*J. Instn Telecommun. Engrs, India*, March 1956, Vol. 2, No. 2, pp. 96–99.) "The desired target region of reception in short-wave broadcasting is covered by firing the radio waves from a suitably designed transmitting antenna, into the ionosphere, at predetermined angles. Analysis shows that in addition to the target region, some extra zones on the earth's surface also come to receive an appreciably enhanced signal strength. This so-called 'focussing' results from the curvature of the reflecting layers. The 'first order image zones' have been determined for the regional short-wave transmitters of AIR [All India Radio], and plotted on the great-circle map, as an illustration."

621.396.11 : 551.510.535 **3513**

Ionospheric Absorption at Dakar.—F. Delobeau & K. Suchy. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 45–50. In French.) Selective and nonselective absorption characteristics have been determined from measurements at Dakar. Nonselective absorption is proportional to D-layer electron density and follows the density variations with sunspot number. Variations of selective absorption are related to the observation that the collision frequency at mid-height of the E layer varies inversely as the sunspot number.

621.396.11 : 551.510.535 : 523.16 **3514**

On the Propagation of Radio Waves through the Upper Ionosphere.—G. R. Ellis. (*J. atmos. terr. Phys.*, July 1956, Vol. 9, No. 1, pp. 51–55.) "The low-frequency limit for the propagation of radio waves through the ionosphere is discussed. It is shown that reflection and absorption of extraordinary waves can occur well above the F region near the level where $f = f_H$, if the wave frequency is less than $f_H F_2$, and if the electron density near this level is not negligible. In these circumstances the low-frequency limit will be determined by $f_0 F_2$, and observations of cosmic radio emission at frequencies much below 1 Mc/s are unlikely."

621.396.11 : 621.396.91 **3515**

Time Signals for the Determination of Longitude.—W. H. Ward. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1064–1065.) In connection with determinations of longitude to be made during the International Geophysical Year, radio propagation velocities are required to be known with high accuracy. A method for determining this velocity is outlined, involving two pairs of transmitting and receiving stations and one land-line link.

621.396.11.029.45/.5 **3516**

Amplitude and Phase Curves for Ground-Wave Propagation in the Band 200 c/s to 500 kc/s.—J. R. Wait & H. H. Howe. (*Nat. Bur. Stand. Circulars*, 21st May 1956, No. 574, 17 pp.) Values of the field strength and phase at distances from 1 to 1 500 miles are computed, assuming a very short vertical radiator and ground conductivity values of 4, 0·01 and 0·001 mho/m.

621.396.11.029.6 **3517**

Marconi's Last Paper, 'On the Propagation of Microwaves over Considerable Distances'.—T. J. Carroll. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1056–1057.) An English translation is given of this paper, which was written in 1933 and describes experiments on the reception of 500-Mc/s signals at distances up to 258 km, almost nine times the optical distance.

621.396.11.029.6 **3518**

Reflection of Ultra-short Waves at Layer Inhomogeneities of the Troposphere.—V. N. Troitski. (*Radiotekhnika, Moscow*, Jan. 1956, Vol. 11, No. 1, pp. 7–16.) Reflection at oblique incidence is considered for a layer in which permittivity $\epsilon(z)$ varies with height in accordance with the formula $\epsilon(z) = \epsilon_0 - Ne^{az}(1 + e^{az})^{-1} - M.4e^{az}(1 + e^{az})^{-2}$, where ϵ_0 is the permittivity at the boundary and M, N, and a are characteristic parameters of the layer. The variation of the reflection coefficient with layer thickness is investigated. See also *ibid.*, May 1956, Vol. 11, No. 5, pp. 3–20.

621.396.11.029.6 : 551.510.535 : [523.16 + 523.5 + 551.594.5 **3519**

Review of Ionospheric Effects at V.H.F. and U.H.F.—C. G. Little, W. M. Rayton & R. B. Roof. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 992–1018.) The present state of knowledge on the following effects is summarized: radar echoes from aurora, radar echoes from meteors, the Faraday effect and radar echoes from the moon, radio noise of auroral origin, absorption of radio waves by the ionosphere, refraction of radio waves by the ionosphere, and the scintillation of radio stars. 182 references.

621.396.11.029.62 **3520**

V.H.F. Diffraction by Mountains of the Alaska Range. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1049–1050.) Report of reception at Lake Minchumina of 200-Mc/s television signals from Anchorage, 200 miles away on the far side of the mountain ridge. Measurements of field-strength distribution made from an aeroplane established a fine-structure diffraction pattern. Time variations of field strength and direction of arrival can be explained by changes in meteorological conditions over the paths of signal components scattered and/or diffracted by widely separated peaks. The results give substantial support to knife-edge theory.

621.396.11.029.62 : 551.510.535 **3521**

Oblique-Incidence Measurements of the Heights at which Ionospheric Scattering of V.H.F. Radio Waves occurs.—V. C. Pineo. (*J. geophys. Res.*, June 1956, Vol. 61, No. 2, Part 1, pp. 165–169.) From the differences in propagation times for pulses propagated along tropospheric and ionospheric paths between stations 810 km apart it is tentatively concluded that the operative scattering layers are at heights of 86 km and 70 km for the night-time and midday hours respectively.

621.396.11.029.63 **3522**

Propagation Tests at a Frequency of 1 000 Mc/s over Various Paths.—F. Vecchiacchi. (*Alta Frequenza*, April 1956, Vol. 25, No. 2, pp. 100–129.) Detailed report of tests made in northern and central Italy during the period 1951–1954. All the paths tested afforded optical visibility; the two longest were 189 km and 196 km respectively. The results indicate that wide-band communication can be maintained for a high percentage of the time. Field-strength fluctuations were much greater in summer than in winter, but on almost every day in summer there was a period of a few hours during which the amplitude of the fluctuations was reduced. Winter periods relatively free from fluctuations are associated with rainy weather.

621.396.812.029.62 + 621.397.62 + 621.396.677.3 **3523**

Long-Distance Television Reception in the U.S.S.R.—W. Sorokine. (*Télévision*, March/April 1956, No. 62, pp. 85–88.) Long digest of reports of amateur band-I reception published in *Radio, Moscow*, Nov. & Dec. 1955. Details and diagrams are given of one of the receivers and aerials used.

RECEPTION

621.376.23 : 621.396.822 **3524**

Some Points in the Theory of Square-Law Detection of Background Noise.—A. Blanc-Lapierre, P. Dumontet & M. Savelli. (*C. R. Acad. Sci., Paris*, 18th June 1956, Vol. 242, No. 25, pp. 2911–2913.) The spectrum of $X^2(t) + S^2(t)$ is studied, $X(t)$ being a stationary random Laplace function and $S(t)$ its transform in certain linear filters.

621.396.62 : 621.396.812.3 **3525**

The Statistics of Combiner Diversity.—H. Staras. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1057–1058.) An analytic method for evaluating the combined statistical distribution in terms of a tabulated function is discussed; results are presented graphically for the combined signal up to ten-fold diversity.

621.396.62.029.62 : 621.376.33 **3526**

Switched-Tuned F.M. Unit.—J. M. Beukers. (*Wireless World*, Sept. 1956, Vol. 62, No. 9, pp. 427–434.) A modified form of the receiver described by Amos & Johnstone (2096 of 1955) incorporates a reactance valve controlled by the error voltage from the ratio detector and in turn controlling the oscillator so as to provide a.f.c. Constructional details are given.

621.396.621.54 **3527**

Communications Receiver Type-BX 925A.—J. H. van Wageningen. (*Commun. News*, April 1956, Vol. 16, No. 3, pp. 92–98.) A single-heterodyne receiver for telegraphy or telephony is described; it has two stages of r.f. and two stages of i.f. amplification. Special features include the combination of mechanical bandspread with high-speed tuning by motor, and the provision of a crystal-controlled calibration oscillator.

621.396.621.54 : 621.317.328.029.62/.63 **3528**

A V.H.F./U.H.F. Field-Strength Recording Receiver using Post-Detector Selectivity.—R. V. Harvey, G. F. Newell & J. G. Spencer. (*B.B.C. Engng Div. Monographs*, April 1956, No. 6, pp. 1–26.) Design and performance details for a pre-tuned receiver for bands III and IV are discussed. A separate signal-frequency unit is used for each band, followed by a common i.f. unit working at 10·7 Mc/s. The output signal/noise ratio has been increased by restricting the bandwidth of the circuits following the detector, enabling a higher sensitivity to be obtained. The receiver has been designed for unattended operation over periods up to one month with a calibration stability within ± 1 dB.

621.396.621.54 : 621.385.5 3529

The Presentation and Application of the Characteristics of the Pentagrid Converter Valve.—Wilshire. (See 3590.)

621.396.621.54.029.45/.51 : 621.375.234 3530

A Very-Low-Frequency Receiver with High Selectivity.—C. S. Fowler. (*J. Brit. Instn Radio Engrs*, July 1956, Vol. 16, No. 7, pp. 401–404.) A superheterodyne receiver for the frequency band 6–36 kc/s is described. High selectivity is obtained by using mixed positive and negative feedback to control the Q factor of the i.f. tuned circuits.

621.396.82 : 621.397.62(083.74) 3531

I.R.E. Standards on Methods of Measurement of the Conducted Interference Output of Broadcast and Television Receivers in the Range of 300 kc/s to 25 Mc/s, 1956.—(*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1040–1043.) Standard 56 I.R.E. 27.S1, supplement to 54 I.R.E. 17.S1.

621.396.823 : 621.317.729 3532

Equipment for recording R.F. Interference due to High-Voltage Power Transmission Lines.—Carteron, Fromy & Prokocimer. (See 3488.)

STATIONS AND COMMUNICATION SYSTEMS

621.396.3 : 621.396.43 : 523.5 3533

Janet [communication system].—W. T. Cocking. (*Wireless Engr*, Sept. 1956, Vol. 33, No. 9, p. 203.) Brief note on a long-range radiotelegraphy system developed by the Canadian Defence Research Board, in which the propagation path is provided by ionized meteor trails. Frequencies between 30 and 60 Mc/s are used, and transmitters with a power output of about 800 W are used with Yagi aerial systems having a gain of about 10 dB. Messages for transmission are recorded in readiness, and the actual transmission starts automatically when ionization occurs at the appropriate reflection point relative to transmitter and receiver. For another account, see *Wireless World*, Sept. 1956, Vol. 62, No. 9, pp. 404–405.

621.396.41 : 621.396.65.029.63 3534

A Decimetre-Wavelength Radio-Link Network providing High-Quality Program Channels using Pulse Phase Modulation: Part 1—Transmission Requirements, Planning and Results.—G. Bühl. (*Telefunken Ztg*, March 1956, Vol. 29, No. 111, pp. 5–12. English summary, pp. 62–63.) Description of the 500-mile Austrian network, which comprises 25 stations in six main sections. Carrier frequencies between 2·06 and 2·3 kMc/s are used; three 15-kc/s program channels and six 3·2-kc/s speech channels are accommodated. The overall signal/noise ratio is > 66 dB.

621.396.71.029.55(43) 3535

Federal German Post Office Overseas Radio Transmitting Station at Elmshorn.—E. Meinel. (*Nachrichtentech. Z.*, April 1956, Vol. 9, No. 4, pp. 151–158.) The station comprises 16 s.w. transmitters, including four 20-kW s.s.b. and two 50-kW d.s.b. telephony transmitters and ten 20-kW transmitters for telegraphy; 21 rhombic aerials and several horizontal dipole arrays are used. The equipment and services are briefly described.

621.396.97 : 621.396.677 3536

Vertical Radiation and Tropical Broadcasting.—A. H. Dickinson. (*J. Brit. Instn Radio Engrs*, July 1956, Vol. 16, No. 7, pp. 405–411.) An estimate, based on five years' operating experience, is presented of the requirements in respect of aerial design, transmitter power and operating frequencies for s.w. broadcasting stations in the tropics to serve the large areas outside the main population centres. Aerials comprising 16-element binomial arrays [2335 of 1952 (Adorian & Dickinson)] used in conjunction with 5-kW transmitters should be able to serve areas of 90 000 miles². Co-channel stations should be separated by 1 500 miles. Each station requires two or three frequencies in the 2·5-, 3·5-, 5- and 9-Mc/s bands, in order to cope with ionosphere variations, but the number of frequency changes should be kept to a minimum for the convenience of listeners.

SUBSIDIARY APPARATUS

621.311.6 3537

A Balanced, Unregulated, Dual Power Supply.—K. N. Hemmenway. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, p. 1053.) A circuit is described for simultaneously providing positive and negative voltages which remain equal in face of line-voltage variations; practical details are given for a unit supplying $\pm$ 300 V at 38·9 mA. A graph shows the performance of the unit used with a d.c. amplifier providing a balanced load.

621.311.6 : 621.314.63 : 537.311.33 : 535.215 3538

Semiconductor Solar-Energy Converters.—A. Hähnlein. (*Nachrichtentech. Z.*, April 1956, Vol. 9, No. 4, pp. 145–150.) A concise review of the physical fundamentals includes brief discussions of radiant-energy absorption in semiconductors, the effect of *p-n* junctions and the energy conversion efficiency.

621.311.61 : 621.314.1 : 621.314.7 3539

Efficient and Reliable Transistor High-Voltage Power Supply.—G. E. Driver. (*Nucleonics*, March 1956, Vol. 14, No. 3, pp. 74, 76.) The system comprises a 9-V battery, a transistor oscillator, crystal rectifier and corona-type regulator; the output is about 20 μA at 900 V.

621.314.634 3540

Life-Test Results on Selenium Rectifiers.—G. C. Chernish. (*Tele-Tech & Electronic Ind.*, April 1956, Vol. 15, No. 4, pp. 68–69 . . 169.) Tests on a representative selection of Se rectifiers for radio and television equipment show very great variations in shelf life, useful life and temperature characteristics; the need for drastic derating is suggested.

TELEVISION AND PHOTOTELEGRAPHY

621.397.242 : 621.397.743 3541

A 21-Mc/s Local Television Network.—H. J. Schmidt. (*Nachrichtentech. Z.*, April 1956, Vol. 9, No. 4, pp. 173–177.) The modulators, amplifiers and demodulators used in the coaxial-line network linking the studios, control rooms and transmitters located in various parts of Hamburg are discussed. A d.s.b. system with positive a.m. is used.

621.397.5 : 535.623 3542

Notes on a Colour-Television System with Two Amplitude-Modulated [sub-] **Carriers.**—J. Wolf. (*Elektronische Rundschau*, April 1956, Vol. 10, No. 4, pp. 101–104.) Factors relevant to the choice of colour subcarriers for a European system are discussed; it is shown that frequency interlace is not an essential prerequisite for the transmission of colour information within the luminance band. A simple method of fixing the ratio between colour subcarrier and line frequency in the two-subcarrier system described by Haantjes & Teer (1224 of April) is indicated with reference to a suitable circuit.

621.397.5(083.74) 3543

Television in the World Today.—C. J. Hirsch. (*Elect. Engng, N.Y.*, April 1956, Vol. 75, No. 4, pp. 321–325.) The various television standards in use are tabulated and briefly discussed.

621.397.6 : 621.397.7 : 535.623 3544

Pedestal Processing Amplifier for Television Studio Operation.—R. C. Kennedy. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 297–302.) "The pedestal processing amplifier is a device capable of removing the synchronizing pulses from either a colour or monochrome television signal so as to permit simultaneous presentation of pictures from separate locations. It utilizes a new type of sync separator which provides a sync signal having constant amplitude for input signal variations of ± 14 decibels."

621.397.61 3545

A Flat-Bed Facsimile Telegraph Transmitter.—W. D. Buckingham. (*Elect. Engng, N.Y.*, April 1956, Vol. 75, No. 4, pp. 356–359.) Experimental equipment is described in which the message sheet may be of any desired length, and is advanced slowly while scanning is effected by the forward sweep across the sheet of a light spot of diameter 0·01 in. The light is produced by a special type of tungsten arc lamp. A cylindrical reflector is used for concentrating the light reflected from the message sheet on the photocell.

621.397.61 : 535.623 3546

Colorimetry, Film Requirements and Masking Techniques for Color Television.—H. N. Kozanowski & S. L. Bendell. (*J. Soc. Mot. Pict. Telev. Engrs*, April 1956, Vol. 65, No. 4, pp. 201–204.) Basic requirements for transmission of colour films are discussed and improved equipment for electronic masking and hue control is described.

621.397.611.2 : 621.397.8 3547

The Possibility of a 'Normal' Resolution by Television Transmitting Tubes with Energy Storage.—Ya. A. Ryftin. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 25, No. 12, pp. 2214–2232.) 'Normal', or maximum attainable, resolution is defined and an analysis is made of the causes which lower the operational quality of storage tubes. The possibility of obtaining 'normal' resolution with this type of tube is discussed and some practical suggestions are made. A rough estimate is given of the extent to which existing storage tubes fail to provide full-quality service with 625-line scanning.

621.397.62 + 621.396.812.029.62 + 621.396.677.3 3548

Long-Distance Television Reception in the U.S.S.R.—Sorokine. (See 3523.)

621.397.62 : 535.623 3549

Color Purity in Ungated Sequential Displays.—G. S. Ley. (*Trans. Inst. Radio Engrs*, Jan. 1955, Vol. BTR-1, No. 1, pp. 36–43. Abstract, *Proc. Inst. Radio Engrs*, March 1955, Vol. 43, No. 3, p. 383.)

621.397.62 : 535.623 3550

The Practical Aspects of the Color Subcarrier Synchronization Problem.—W. J. Gruen. (*Trans. Inst. Radio Engrs*, Jan. 1955, Vol. BTR-1, No. 1, pp. 44–51. Abstract, *Proc. Inst. Radio Engrs*, March 1955, Vol. 43, No. 3, p. 383.)

621.397.62 : 621.376.33 3551

Sampling Detector for Intercarrier TV Sound.—K. Schlesinger. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 138–141.) One half of a double triode is connected as a feedback oscillator, locked through the inductance of its tank circuit to a driver stage fed by the 4·5-Mc/s f.m. sound carrier. It is coupled through a common cathode connection to the sampling triode, which is arranged to function at zero passage of the carrier voltage, thus yielding maximum f.m. detection while ignoring residual a.m.

621.397.62 : 621.396.82(083.74) 3552

I.R.E. Standards on Methods of Measurement of the Conducted Interference Output of Broadcast and Television Receivers in the Range of 300 kc/s to 25 Mc/s, 1956. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1040–1043.) Standard 56 I.R.E. 27.SI, supplement to 54 I.R.E. 17.SI.

621.397.621.2 : 535.623 : 621.385.832 3553

Effect of Magnetic Deflection on Electron-Beam Convergence [in colour-television tubes].—P. E. Kaus. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 168–189.) "The image curvatures of deflection yokes are calculated and minimized using third-order perturbation theory. It is found that the mean image curvature is too large to dispense with dynamic convergence when a point focus is needed. Proper field shaping, however, can produce a good line focus over the whole screen without dynamic convergence."

621.397.621.2 : 535.623 : 621.385.832 3554

Recent Improvements in the 21AXP22 Color Kinescope.—R. B. Janes, L. B. Headrick & J. Evans. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 143–167.) The location and formation of the phosphor dots on the face-plate of this three-gun tube [2771 of 1955 (Seelen et al.)] are effected in a special optical device called a 'lighthouse'. Modifications of this device leading to improved colour performance of the tube are described.

621.397.621.2 : 535.623 : 621.385.832 3555

Kinescope Electron Guns for producing Non-circular Spots.—Knechtli & Beam. (See 3593.)

621.397.7 : 621.397.6 3556

Standardization of Television Equipment at Radiodiffusion-Télévision Française.—L. Goussot. (*Onde élect.*, April–June 1956, Vol. 36, Nos. 349–351, pp. 352–368, 479–486 & 541–550.) Video-frequency equipment is considered to have reached a stable state of development; present practice is described. Component specifications and characteristics are detailed in an appendix.

621.397.5 : 535.623 3557

Color Television Engineering. [Book Review]—J. W. Wentworth. Publishers: McGraw-Hill, New York and London, $8 or 60s. (*Engineering, Lond.*, 13th April 1956, Vol. 181, No. 4701, p. 208.) "The outstanding value of the book is its clear presentation of fundamental colour theory and the marriage of this theory with that of television engineering."

TRANSMISSION

621.376.32 : 621.396.61 : 621.396.41 3558

Exciters multiplex F.M. Carriers.—H. G. Stratman. (*Electronics*, Aug. 1956, Vol. 29, No. 8, pp. 148–150.) The equipment consists of a f.m. exciter which provides a main carrier of frequency 100 Mc/s, using a serrasoid modulator circuit [342 of 1949 (Day)], and a similar unit generating an audio-modulated sub-carrier of frequency 32·5 kc/s to perform the multiplexing operation. The total audio distortion is < 0·2%, with a crosstalk figure of about − 55 dB.

621.396.61 : 621.375.232.4 **3559**

Linear 15-kW Amplifier with Grounded-Grid Stage.—A. Di Marco. (*Rev. telegr. Electronica, Buenos Aires*, March 1956, Vol. 44, No. 522, pp. 125–128.) A description is given of a two-stage amplifier for a transmitter. The second stage is cathode-excited, while the first stage is designed for class-AB1 operation. The gain is 50 dB. A vertical-panel construction system is used, giving good accessibility.

621.396.61 : 621.376.32 : 621.373.42 **3560**

The Gain Characteristic inside the Pull-In Range particularly in F.M. Transmitters and Wobbulators.—E. G. Woschni. (*Hochfrequenztech. u. Elektroakust.*, Nov. 1955, Vol. 64, No. 3, pp. 63–73.) Continuation of earlier work on the occurrence of pull-in ranges in f.m. transmitters and wobbulators controlled by reactance valves (*ibid.*, Dec. 1954, Vol. 63, No. 5, pp. 119–125). The dependence of the pull-in range on the residual attenuation is analysed. A formula is derived expressing the gain variation in terms of the maximum gain at the middle of the pull-in range and of the fractional detuning. Values of lock-in range and gain obtained experimentally are in some cases substantially higher than calculated values; the discrepancies are attributed to distortion introduced during the frequency-modulation process.

VALVES AND THERMIONICS

621.3-71 **3561**

Review of Industrial Applications of Heat Transfer to Electronics.—Kaye. (See 3290.)

621.314.63 : 621.314.7 **3562**

Low-Frequency Circuit Theory of the Double-Base Diode.—J. J. Suran. (*Trans. Inst. Radio Engrs*, April 1955, Vol. ED-2, No. 2, pp. 40–48.) A study is made of the operating mechanism of the single-junction semiconductor device with two ohmic contacts; large-signal operation is treated by applying small-signal theory to successive restricted regions of the characteristic, part of which exhibits negative resistance. Circuit parameters are related to the physical constants of the device.

621.314.7 **3563**

The Four-Terminal-Network Parameters of the Junction Transistor in the Three Basic Circuit Arrangements.—G. Meyer-Brötz. (*Telefunken Ztg*, March 1956, Vol. 29, No. 111, pp. 21–28. English summary, pp. 63–64.)

621.314.7 **3564**

Experimental Study of Point-Contact Transistor.—S. Iwase. (*Rep. elect. Commun. Lab., Japan*, Nov. 1955, Vol. 3, No. 11, pp. 27–33.) An account is given of the Ge surface treatment, and of experiments on the electrical forming of the transistor with different point-contact materials. Best characteristics are obtained with a collector containing 0·25%–1% of a Group-V impurity; the emitter substance should not be the same as the collector.

621.314.7 **3565**

A Junction Transistor with High Current Gain.—J. W. Granville. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 565–579.) The production and performance of a new transistor with a *p-n*-junction emitter and *n-n*+-junction collector are described and compared with the corresponding aspects of point-contact transistors. The *n-n*+ junction is made by alloying a Sn-Sb alloy to the Ge, while the *p-n* junction is made by alloying In to the Ge. High noise factors, of the order of 60 dB, were observed in experimental *p-n-n*+ transistors; possible methods of eliminating this and other drawbacks are mentioned. Use of Si instead of Ge could lead to improved performance.

621.314.7 : 621.375.4 **3566**

Measurement Considerations in High-Frequency Power Gain of Junction Transistors.—R. L. Pritchard. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1050–1051.) Reasons are given for the particular choice of methods used in the work described previously (3774 of 1955); the theory is extended to two types of neutralization used in common-emitter transistor amplifiers.

621.383.2 **3567**

The Time Lag and other Undesirable Phenomena observed in Vacuum Photo-tubes at Weak Illumination: Part 2.—M. Sugawara. (*J. phys. Soc. Japan*, March 1956, Vol. 11, No. 3, pp. 271–278.) A specially constructed cell, having a second, semitransparent cathode which can be insulated, is used to show that abnormal response characteristics in standard photocells can be explained by the adherence of photo-emissive material to the inner surfaces of the cell. Part 1: 2905 of September.

621.383.2 : 535.215.08 **3568**

Apparatus for the Study of Spectral Response of Photoelectric Surface.—H. Mitsuhashi & T. Nakayama. (*J. phys. Soc. Japan*, March 1956, Vol. 11, No. 3, pp. 308–311.) Constancy of the test source intensity is secured by a servomechanism controlled by comparison with a standard source. The photoelectric response is also recorded automatically.

621.383.2 : 621.396.822 **3569**

Flicker Noise in Vacuum Photoelectric Diodes.—R. J. J. Zijlstra & C. T. J. Alkemade. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 656–657.) Noise in photocells with Cs-Cs_2O-Ag and with Cs_3-Sb photocathodes was measured over the frequency range 1 c/s–1 kc/s. Results are presented graphically; they are consistent with the assumption that the frequency-dependent flicker noise superimposed on the shot noise is generated in a cathode layer whose resistance fluctuates with time.

621.383.2 : 681.142 **3570**

Bit Storage via Electro-optical Feedback.—Milch. (See 3289.)

621.385 : 621.3.015.3 **3571**

Theory of Transient Processes in Electronic Devices and in Circuits containing such Devices.—G. A. Grinberg. (*Zh. tekh. Fiz.*, Oct. 1955, Vol. 26, No. 12, pp. 2183–2192.) A mathematical analysis is given of the rise of the current in an electronic device on application of a pulse voltage. The case of a plane diode with a direct voltage suddenly applied is considered in detail.

621.385.002.2 **3572**

Techniques for the Manufacture and Inspection of Reliable Electronic Valves.—J. Brasier. (*Le Vide*, March/April 1956, Vol. 11, No. 62, pp. 66–77.) U.S.A. procedure for preparing specifications for reliable valves is indicated; the distinction between specifications applicable during actual manufacture and those applicable during a subsequent inspection is emphasized. French official specifications and the manufacturing steps taken to satisfy them are described and illustrated.

621.385.029.6 **3573**

Plasma-Frequency Reduction Factors in Electron Beams.—G. M. Branch & T. G. Mihran. (*Trans. Inst. Radio Engrs*, April 1955, Vol. ED-2, No. 2, pp. 3–11.) Long-beam microwave valves are discussed. The plasma-frequency reduction factor due to the presence of the drift-tube walls is calculated for a variety of beam and drift-tube cross-sections, and the results are presented in a series of graphs. One particular result is that for an annular beam the reduction factor depends primarily on the width of the annulus.

621.385.029.6 3574

Modern Reflex Klystrons.—R. Hechtel. (*Arch. elekt. Übertragung*, April 1956, Vol. 10, No. 4, pp. 133–138.) The construction and performance characteristics of an experimental klystron with an output of 4–5 W in the 3·6–4·2-kMc/s frequency band are compared with those of the U.S.A. types RK 5976 and 431A.

621.385.029.6 3575

Travelling-Wave Valves for 4-cm Waves: Research and Development at the Centre National d'Études des Télécommunications.—A. Bobenrieth & O. Cahen. (*Onde élect.*, April 1956, Vol. 36, No. 349, pp. 307–317.) The design and production of valves to the specifications of the French Post Office are described. Characteristics of an experimental model are given; saturation power is > 1 W at 7·0–7·5 kMc/s, varying only slightly with frequency, for inputs of about 0·3 mW.

621.385.029.6 3576

Recent Developments of O-Type Carcinotrons.—P. Palluel. (*Onde élect.*, April 1956, Vol. 36, No. 349, pp. 318–335.) A range of six models developed by the Compagnie Générale de T.S.F. covers the range 1–15 kMc/s; details are given of construction and performance. See also 1904 of June (Palluel & Goldberger).

621.385.029.6 3577

When is a Backward Wave not a Backward Wave?—J. E. Rowe & G. Hok. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1060–1061.) A critical discussion of some methods of analysing the large-signal operation of travelling-wave valves.

621.385.029.6 : 621.396.822 3578

Noise in Traveling-Wave Tubes.—A. G. Mungall. (*Trans. Inst. Radio Engrs*, April 1955, Vol. ED-2, No. 2, pp. 12–17.) Noise measurements on valves for operation at 3·2 cm λ are reported. The effects of anode-to-helix separation, space charge, field distribution and gas pressure are studied. A modified theory of space-charge smoothing of microwave shot noise is suggested. Possible improvement of noise figure by use of a triode gun in place of a diode is discussed.

621.385.029.6 : 621.396.822 3579

The Noise Factor of Traveling-Wave Tubes.—G. Hok. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, p. 1061.) Discussion indicates that no theoretical lower limit for the noise factor is found when a simple mathematical model with appropriate means for shaping the beam is chosen.

621.385.032.2 3580

Effect of Cathode Roughness on the Maximum Current Density in an Electron Beam.—G. W. Preston. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 627–630.) Analysis indicates that the current density in a focused beam may be greatly reduced due to roughness of the cathode surface; the minimum beam diameter attainable is unaffected by change of cathode temperature or proportional changes in the potentials of all electrodes.

621.385.032.21 : 537.5 3581

High-Frequency Oscillations in the Space Charge of some Electron Emission Systems.—K. T. Dolder & O. Klemperer. (*J. Electronics*, May 1956, Vol. 1, No. 6, pp. 601–611.) "The occurrence of multiple electron sources in electron emission systems was investigated for thermionic filamentary cathodes in the form of a straight wire, of a hairpin and of a helical spiral. The experimental results are all consistent with the view that the occurrence of multiple sources is the result of standing electron space charge oscillations close to the cathode surface. The frequencies of these oscillations are believed to be between 10^8 and 10^9 c/s."

621.385.032.212 : 621.396.822 3582

Electron-Beam Noisiness and Equivalent Thermal Temperature for High-Field Emission from a Low-Temperature Cathode.—R. W. DeGrasse & G. Wade. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1048–1049.) Analysis indicates that the noise-equivalent temperature of a field-emission cathode at 0°K is directly proportional to the strength of the field at the cathode, E, and inversely proportional to the square root of the work function ϕ. For a tungsten cathode with $\phi = 4{\cdot}5$ eV and $E = 3{\cdot}5 \times 10^9$ V/m the equivalent temperature is 2 640°K. A small change in either E or ϕ has a very large effect on the emission.

621.385.032.216 3583

Electrolytic Transport Phenomena in the Oxide Cathode.—R. H. Plumlee. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 190–230.) Experiments are described in which chemical changes were detected in BaO cathodes following emission of electrons. The evaporation of H_2, H_2O, O_2, CO and CO_2 from the cathode was found to depend on field strength, temperature, state of cathode activity, lapse of time, and previous duty period. Some correlation was also found between residual gas pressures and cathode activity. It is deduced that the cathode coating contains impurities incorporated as anions in labile equilibrium with their molecular dissociation fragments present in the vacuum at low partial pressures.

621.385.032.216 3584

Emission and Conduction Measurements on Oxide Cathodes.—A. Kestelyn-Loebenstein. (*Appl. sci. Res.*, 1956, Vol. B6, Nos. 1/2, pp. 105–116.) An experimental investigation of cathodes with Ni base is reported; the observed characteristics are fundamentally different from those for W-base cathodes (*Le Vide*, July/Sept. 1954, Vol. 9, Nos. 52/53, pp. 148–154). The shape of the characteristics is not consistent with a pore-conduction mechanism, but a second conduction mechanism whose onset depends on field strength is indicated; this is thought to have its seat in the Ni/coating interface.

621.385.032.216 3585

Capillary Cathodes produced by Compression and Sintering.—G. Mesnard & R. Uzan. (*Le Vide*, March/April 1956, Vol. 11, No. 62, pp. 44–53.) Cathodes with a porous nickel or tungsten surface, containing mixed Ba and Sr carbonates, are discussed and their performance is compared with that of cathodes in which the alkaline-earth carbonates are mixed homogeneously with nickel or tungsten powder. See also 1842 of 1955 (Uzan & Mesnard).

621.385.032.216 : 537.311.33 3586

The Electron Donor Centers in the Oxide Cathode.—R. H. Plumlee. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 231–274.) The chemistry of the oxide cathode, and of electronically active solids in general, is considered in terms of the electronic chemical potential, which is determined by the Fermi level of the material. A particular impurity group is identified as the important donor-centre type. For a brief note on this work, see *J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 659–660.

621.385.15 + 621.383.27] : 621.396.822 3587

Flicker Noise in Secondary-Emission Tubes and Multiplier Phototubes.—R. C. Schwantes, H. J. Hannam & A. van der Ziel. (*J. appl. Phys.*, June 1956, Vol. 27, No. 6, pp. 573–577.) Noise measurements on Type-EFP 60 secondary-emission valves and Type-5819 photomultipliers are reported; the existence of a flicker-noise component varying as $1/f$ at frequencies up to 10^4 c/s was established for the valves but not for the photomultipliers. The results are discussed in terms of fluctuations of the work function of the emitting surfaces.

621.385.33.026.446 3588

Technology of the 120-kW Transmitting Triode Type-RS 526.—E. Uredat. (*Telefunken Ztg*, March 1956, Vol. 29, No. 111, pp. 47–54. English summary, p. 65.) The construction of this water-cooled triode is described and compared with that of the 80-kW air-cooled triode Type-RS 726 and the 120-kW triode Type-RS 826 cooled by evaporation of water. The characteristics of the three triodes are tabulated.

621.385.5 3589

Current Partition in Electron Valves with More than One Positive Electrode, for Low Current Densities.—H. Göllnitz. (*Hochfrequenztech. u. Elektroakust.*, Jan. 1956, Vol. 64, No. 4, pp. 95–102.) Current partition in pentodes is examined by calculating the electron trajectory for the limiting case dividing electrons passing through the suppressor grid from those reflected by it, for an arbitrary angle of incidence of the electrons. The calculation is facilitated by considering only paths through the saddle points of the suppressor-grid field.

621.385.5 : 621.396.621.54 3590

The Presentation and Application of the Characteristics of the Pentagrid Converter Valve.—H. R. Wilshire. (*Proc. Instn Radio Engrs, Aust.*, April 1956, Vol. 17, No. 4, pp. 113–122.) "The conversion transconductance (g_c) of pentagrid converter valves (1R5 and 6BE6) is a function of the signal grid bias, direct screen voltage, screen grid oscillator voltage, oscillator grid current and, in some circuits, the oscillator voltage at the cathode. This paper discusses the measurement and display of the variation of g_c with these five parameters with the object of obtaining optimum performance in the converter stage of radio receivers."

621.385.832 3591

Theory of Deflection.—A. M. Strashkevich. (*Radiotekhnika, Moscow*, Feb. 1956, Vol. 11, No. 2, pp. 64–69.) The general properties of axially antisymmetric fields which can be used in the deflectron [3290 of 1952 (Schlesinger)] are considered. The condition is derived for equal sensitivity of deflection of an electron beam in two mutually perpendicular directions and an example of a system satisfying this condition is given.

621.385.832 : 535.376.07 3592

Variations of the Properties of Luminescent Screens under Electron Bombardment in Cathode-Ray Tubes.—K. H. J. Rottgardt & W. Berthold. (*Z. Naturf.*, Sept./Oct. 1955, Vol. 10a, Nos. 9/10, pp. 736–740.) The luminescence decay curves and the dependence of luminescence intensity on anode voltage are compared for Al-coated ZnS:Ag screens (*a*) before and (*b*) after bombardment by 16-kV electrons. The results indicate that the observed reduction of luminescence is associated with disturbance of the crystal lattice. See also 2485 of 1955.

621.385.832 : 621.397.621.2 : 535.623 3593

Kinescope Electron Guns for producing Non-circular Spots.—R. C. Knechtli & W. R. Beam. (*RCA Rev.*, June 1956, Vol. 17, No. 2, pp. 275–296.) Designs are described in which either the electron crossover or an interposed aperture is shaped so as to produce a spot of desired noncircular form. One example is a line-crossover gun suitable for the parallel-line-screen colour kinescope discussed by Bond et al. (848 of 1952).

621.387 : 621.318.57(083.74) 3594

I.R.E. Standards on Electron Tubes: TR and ATR Tube Definitions, 1956. (*Proc. Inst. Radio Engrs*, Aug. 1956, Vol. 44, No. 8, pp. 1037–1039.) Standard 56 I.R.E. 7. S3.

MISCELLANEOUS

061.4 : 621.37/.39 3595

Radio Show Review.—(*Wireless World*, Oct. 1956, Vol. 62, No. 10, pp. 468–480.) Report of design trends observed at the 1956 National Radio Exhibition. Greater standardization of television receivers is noted; transistors are used in portable broadcast receivers and sound-reproducing equipment. Band-III and dual-band aerials were featured. Transistors with cut-off frequencies up to 10 Mc/s were shown. For another account, see *Wireless Engr*, Oct. 1956, Vol. 33, No. 10, pp. 229–234.

061.6 : 621.396 3596

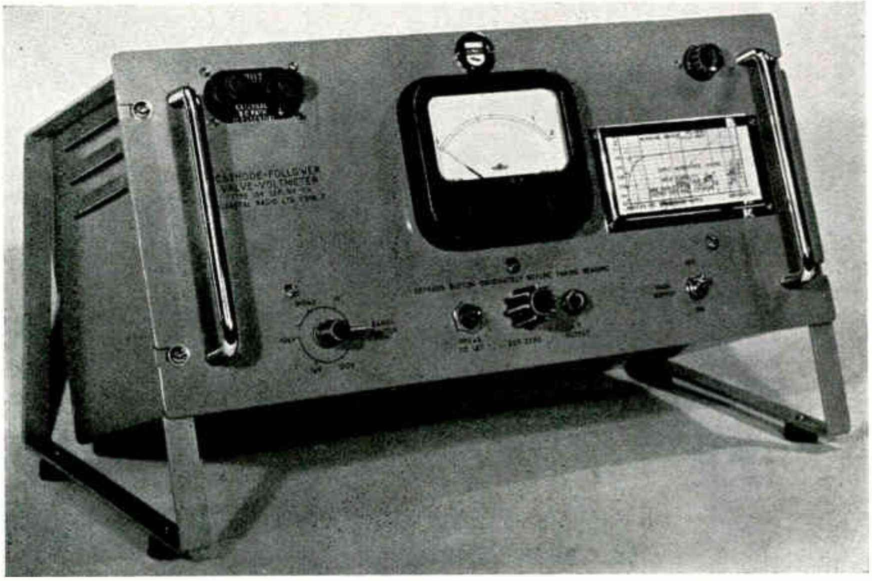
Physics at the Radar Research Establishment, Malvern.—R. A. Smith. (*Proc. roy. Soc. A*, 10th April 1956, Vol. 235, No. 1200, pp. 1–10.) An account of the organization and research programme.

621.3 : 378.9 3597

B.B.C. Engineering Training Centre.—(*Engineer, Lond.*, 1st June 1956, Vol. 201, No. 5236, pp. 609–610.) A brief description of the organization, equipment and curriculum of the Centre at Wood Norton Hall.

621.3.002.2 : 551.58 3598

Consideration of Climatic Influences in the Development and Construction of Electronic Equipment.—E. Ganz & K. Michel. (*Bull. schweiz. elektrotech. Ver.*, 12th May 1956, Vol. 47, No. 10, pp. 441–458. In French.) Factors discussed include temperature, pressure, humidity, icing, air pollution and ultraviolet radiation; both large-scale geographic and local environmental variations are considered. No simple tropicalization process is universally satisfactory; the particular conditions must be studied in each case. Climatological knowledge should be more systematically disseminated.



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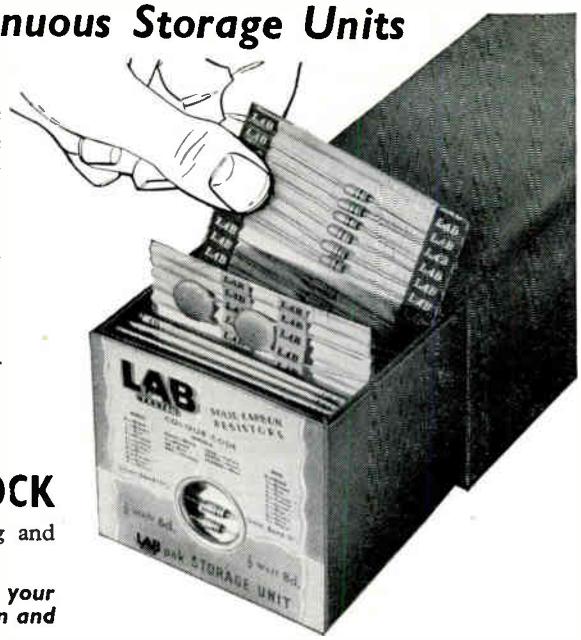

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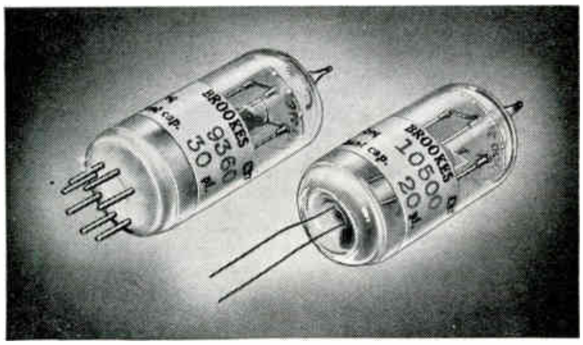

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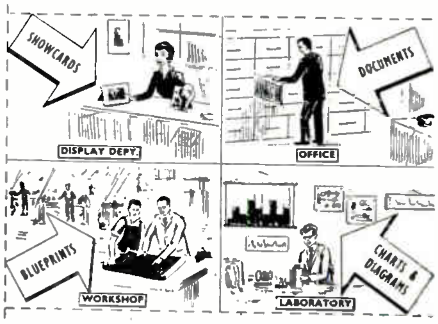

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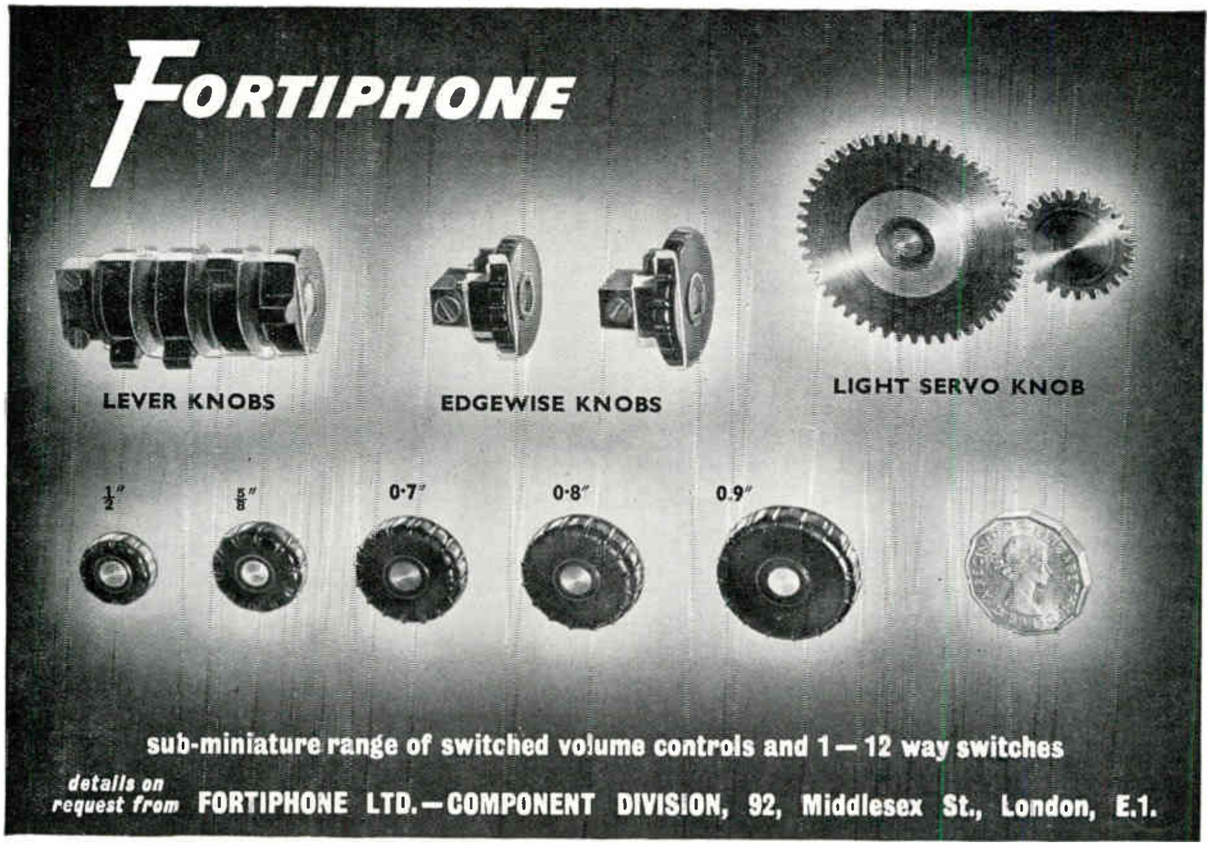

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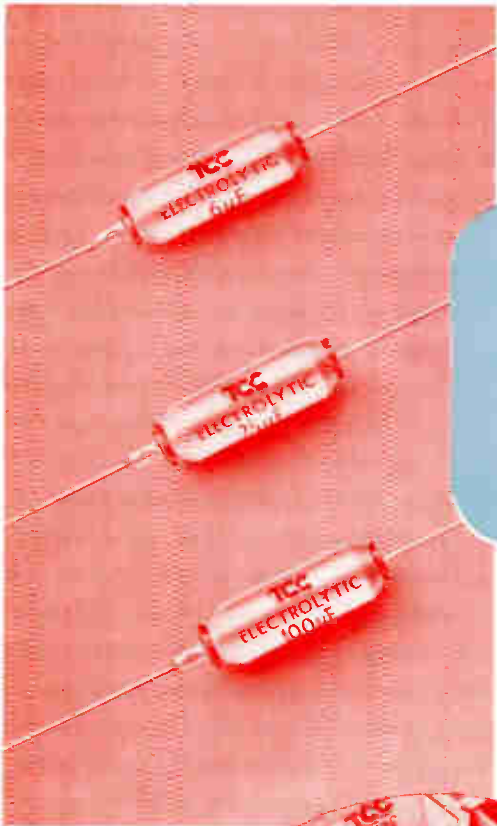

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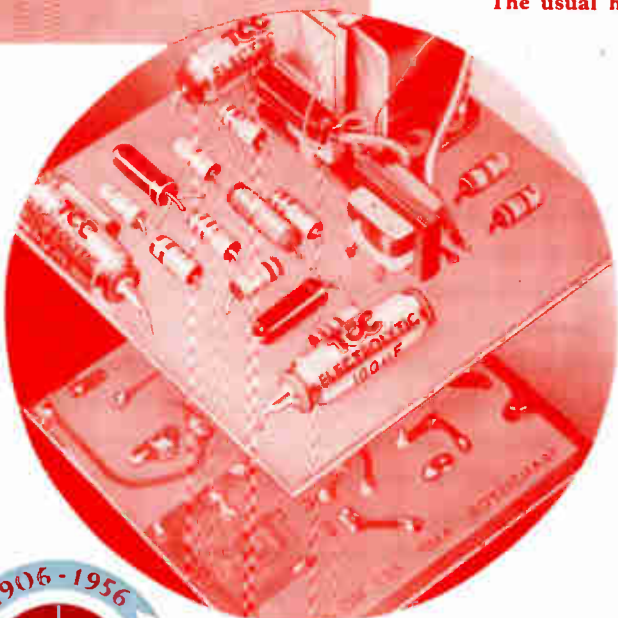

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0.001	BM6	0.610	0.135
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0.005	BM20	0.610	0.180
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0.00022	BM28	0.500	0.180
0.00025	BM29	0.500	0.180
0.0003	BM3	0.610	0.135
0.0003	BM30	0.500	0.180
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