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Refracting Sound Waves

AN interesting paper with the above title by W. E. Kock and F. K. Harvey of the Bell Telephone Laboratories was read before the Acoustical Society of America and published in their journal in September 1949. It has also been published as a monograph by the Bell Telephone System. One usually associates refraction with a continuous medium, and diffraction with such things as gratings, but refraction can occur in a medium containing an assemblage of obstacles such as spheres, discs or strips. To refract electromagnetic waves these obstacles must be conducting, but to refract sound waves they must be rigid; their size and the distance between them must be small compared with the wavelength under consideration.

In this editorial review of the above monograph we confine our attention to sound waves. The refraction can be explained in two ways: (1) by re-radiation from the individual obstacles and (2) by the alteration of the properties of the medium by the immersion of the obstacles. According to the first point of view each obstacle becomes a re-radiating dipole. If they were light and free to move to and fro they would not affect the progress of the wave, but if rigidly mounted, their effect is equivalent to that produced by spheres moving to and fro in the direction of the sound waves, and producing waves which are superimposed upon the original wave. The result is a wave moving more slowly than the original wave. From the second point of view, the obstacles, if perfectly rigid, have an infinite effective density and the combination of air and obstacles may be regarded as a medium with a mean density greater than that of air.

When a paddle is moved through a fluid, the effective inertia of the paddle is increased due to the fluid movement. Conversely, if the paddle is stationary and the fluid moving, the effective mass or inertia of the fluid is increased. The increase of inertia of a sphere moving through a fluid is known to be half the mass of the displaced fluid; hence a fluid moving through an array of N spheres per unit volume (Fig. 1) has its apparent density increased from ρ_0 to $\rho_0 + 0{\cdot}5N\rho_0V$ where V is the volume of one sphere. If the effective density is ρ, and a the radius of the spheres,

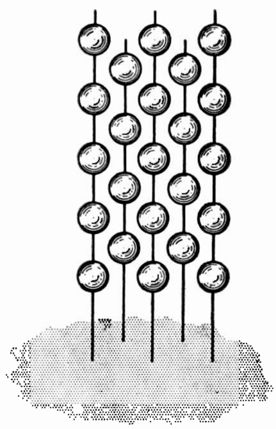


Fig. 1

$$\rho/\rho_0 = 1 + 0{\cdot}5N(4\pi/3)a^3.$$

Since the velocity of sound v is inversely proportional to the square root of the density

$$(v_0/v)^2 = n^2 = 1 + (2\pi/3)Na^3$$

where n is the index of refraction.

If discs of radius c are used, as shown in Fig. 2,

$$n^2 = 1 + \frac{8}{3}Nc^3$$

If strips are used, as shown in Figs. 3 and 4,

$$n^2 = 1 + \pi b^2 N'$$

where b is half the breadth of the strip, and N' the number per unit area looking end on.

The above statement about the increase of inertia of a sphere moving through a fluid assumed that no other object was moving or situated in its neighbourhood. The above formulae are, therefore, not strictly correct unless the separation between the obstacles is large compared with their size ; they are applicable for values of n up to about 1·2.

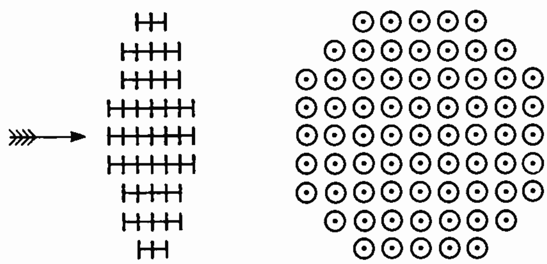


Fig. 2

If the wavelength is decreased to about twice the size of the obstacles, resonance effects occur, and n becomes very dependent on the frequency, causing the phenomenon of dispersion.

Determination of Lens Profile

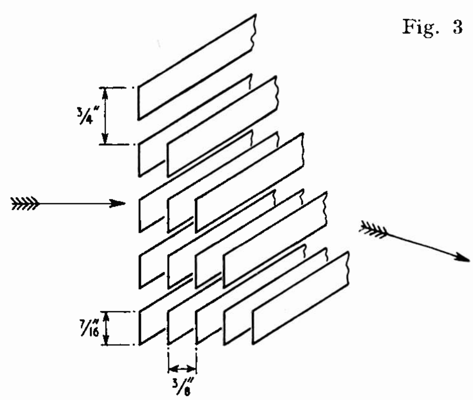
Fig. 5 shows a plano-convex lens of focal length f and index of refraction n. If the waves radiating from the focal point F are to leave the lens as a plane wave, the phase length or time of travel of all rays from F to the plane face of the lens must be equal, that is,

$$\frac{f}{v_0} + \frac{x}{v} = \frac{\sqrt{(f+x)^2 + y^2}}{v_0}$$

or, putting $v_0/v = n$,

$$(n^2 - 1)x^2 + 2fx(n-1) - y^2 = 0$$

Fig. 3



Although this is the equation of a hyperbola, it is pointed out that it need not be followed exactly, since spherical surfaces exhibit appreciable focusing effect.

To be effective the lens must have a diameter large compared with the wavelength. On account of diffraction the focal area will be surrounded by alternate rings of maximum and minimum energy. The central focal area, which receives about 80% of the energy falling on the plane face, has a diameter of about $2{\cdot}4F\lambda/d$, where d is the diameter of the lens and F the distance between the focus and the plane face of the lens.

Gain of an Acoustic Radiator

By the law of reciprocity, equivalent directional characteristics are exhibited, whether the lens is used as a radiator or receiver, and in the tests described, the combination is sometimes used as a transmitter and sometimes as a receiver of sound waves. The gain of a radiator is defined as the ratio of the maximum intensity (power flow

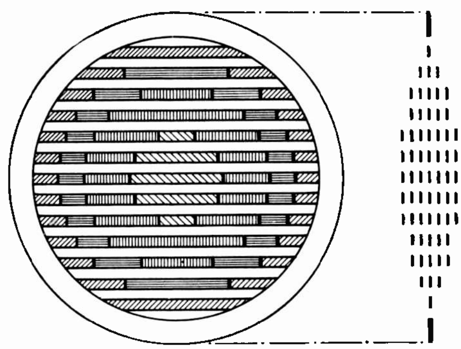


Fig. 4

per unit area) to what the intensity would be if the source radiated the same total power uniformly in all directions. The authors state that a radiator of given aperture area A gives maximum gain when the energy distribution and phase are uniform over the aperture and that the gain G is then equal to $4\pi A/\lambda^2$. It is stated that this is accurate if the aperture diameter exceeds one or two wavelengths, but no indication is given of the method of arriving at this simple result.

Experimental Results

One of the first devices to be tested was the disc lens of 6 in diameter shown in Fig. 2. The discs were 0·5 in diameter and 0·015 in thick and were stacked $\frac{3}{8}$ in apart on 0·085-in rods spaced $\frac{3}{4}$ in apart ; the rods were secured to a wire framework not shown in the diagram. Tests were made with a source of sound 10 ft away, the focus being explored by a microphone fitted with a small horn. At a frequency of 13·4 kc/s (λ = 1·01 in) the focal length was 13 in, corresponding to an index of refraction of 1·14. The value calculated from the elementary obstacle without any correction was 1·10. The lens could be tilted about a diameter with little effect on the focus.

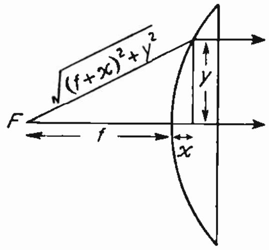


Fig. 5

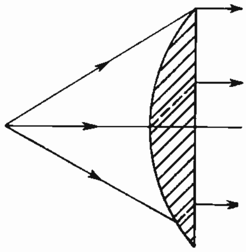


Fig. 6

A prism was made up of $\frac{7}{16}$-in strips as shown in Fig. 3. As in optics, the angle of deflection was found to vary with the wavelength, increasing from 8° for $\lambda = 2{\cdot}72$ in to 20° for $\lambda = 1{\cdot}36$ in. At this latter wavelength resonance occurs and the curve becomes discontinuous. It is pointed

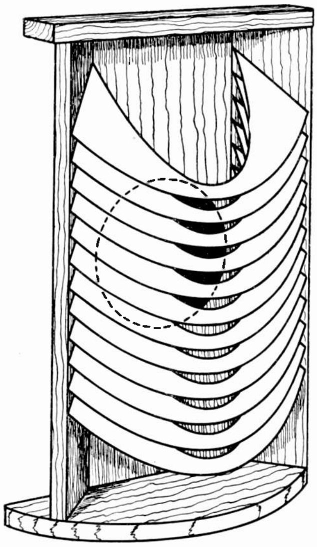


Fig. 7

out that this frequency discrimination enables the prism to be used as a convenient spectrum analyser. At the shorter wavelengths the refractive index agreed very well with the value calculated from the strip dimensions.

Fig. 4 shows a double convex lens 10 in diameter of similar strip construction. At 9 kc/s it has a focal length of about 9 in, but, as with the prism, cuts off at about 10 kc/s ($\lambda = 1{\cdot}36$ in). Lenses have also been constructed of perforated metal sheet, and a photograph of such a lens is given in the monograph.

Slant-Plate Lens

In this type of lens the sound wave is not slowed up by obstacles but by being forced to follow a longer path. In Fig. 6 the plates are of aluminium 0·5 in apart at an angle of 48·3° ($n = 1{\cdot}5$). The length of path from the focus to the plane face of the lens is the same foi the three rays shown, but it is obvious that the result is very unsymmetrical, since the energy between the centre and the upper ray is concentrated in the upper third of the plane face.

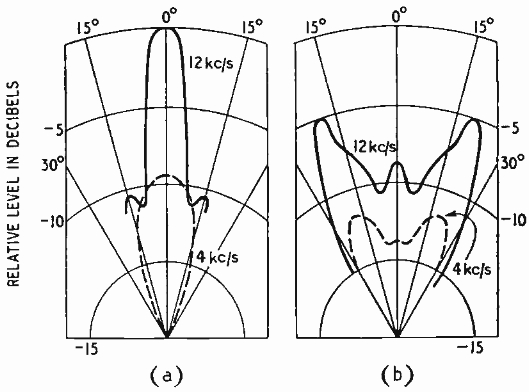


Fig. 8

Another type, which depends on difference of path-length, but without dissymmetry in the vertical plane, employs horizontal corrugated or serpentine plates. This is referred to but no mention is made of any experiments with this type of refractor.

Fig. 7 shows a cylindrical divergent lens of the slant-plate type which can be placed in front of a horn or cone-type loudspeaker. The plates are 0·5 in apart. Fig. 8(a) shows the measured distribution in the horizontal plane without the lens at two frequencies, and Fig. 8(b) shows the effect of the lens. It is stated that all observers preferred the broader pattern obtained with the lens.

All these matters are discussed much more fully in the monograph which also contains photographs of the actual apparatus.

G. W. O. H.

TELEVISION CAMERA TUBES

Sensitivity and Other Properties

By L. H. Bedford, O.B.E., M.A., B.Sc.

SUMMARY.—The paper* is primarily concerned with the question of camera tube sensitivity. From the point of view of implications to the user, a single 'figure of merit' is found which expresses the whole sensitivity performance including questions of depth of focus. This figure of merit is a coefficient in an expression relating depth of focus and scene illumination, and a curve through the figure of merit point expresses this relation. These curves are given for a number of important types of camera tubes.

From a second point of view factors determining tube sensitivity are discussed. In this connection it has been convenient to introduce a hypothetical tube, the 'Quanticon,' all of whose performance parameters are up to the theoretical maximum; e.g., the photo-cathode has 'quantum' efficiency, and the storage efficiency is unity. Then properties of the various practical tubes are deduced from this by the application of four efficiency factors and three correction factors.

Nine other tube parameters, many of which relate directly or indirectly to sensitivity, are discussed. For these a quantitative treatment is largely inapplicable and the treatment is less exhaustive.

Introduction

THE performance of any particular type of television camera tube may be assessed under the following main headings: Sensitivity, Colour response, Resolution, Extent of spurious signals (shading, etc.), Limiting of signal/noise ratio, Contrast reproduction, Image persistence, Geometrical accuracy, Stability, Life.

Many of these properties are not completely separable one from another and, in particular, aspects of the sensitivity question appear indirectly under most of the other heads. For this reason, and because of the more quantitative treatment to which this feature is subject, sensitivity has been made the predominant subject of the present discussion.

1. Sensitivity

The first question which naturally arises under this heading is "In what way should the sensitivity of television camera tubes be expressed?" The writer suggests the following criterion, which has certainly been foreshadowed but not explicitly stated in the literature :—

Suppose that a camera is submitted for test in the form of a 'black box' of unknown contents. The only variables accessible to the operator are :—

(a) The scene illumination.
(b) The lens aperture (not necessarily calibrated).
(c) The focusing position of the lens.
(d) A collection of electrical controls which may be freely manipulated to obtain an optimum picture.

Consider now the effect of varying the lens aperture. If the scene illumination is varied inversely as an area of the lens opening, that is, as $1/N^2$ where the aperture is expressed as f/N, we do not need to look into the contents of the 'black box' to say that the camera tube must be unaware of any change in the light input. All that has happened is that with decrease in aperture the depth of field is increased ; that is to say, a greater volume of space is rendered in sharp focus.

Thus with a given camera the operator can always increase the depth of focus at the expense of more scene illumination and vice versa. The form of the relation between these two quantities follows from simple optical considerations. It involves a numerical coefficient which is the 'black box' expression of the camera performance.

The following is an accurate expression for depth of fields :—

$$u_1 = \frac{u}{1 + m\alpha}$$

$$u_2 = \frac{u}{1 - m\alpha} \qquad \text{subject to } m\alpha < 1$$

$$D = u_2 - u_1 = u\,\frac{2m\alpha}{1 - m^2\alpha^2}$$

Here m is the magnification ratio (object height/image height)

u is the object distance for sharp focus
u_1 is the inner object distance for a given circle of confusion
u_2 is the outer object distance for a given circle of confusion
D is the depth of field ($= u_2 - u_1$)
α is the ratio of diameter of circle of confusion to diameter of lens aperture.

Suppose that we take the diameter of the circle of confusion as $1/s$ times the image height h_1; writing N for the aperture number and h_0 for the object height, the expression reduces to

$$D = 2\frac{N}{s}\left(\frac{h_0^2}{h_1} + h_0\right) \Big/ \left\{1 - \left(\frac{N}{s}\frac{h}{f}\right)\right\}^2 \quad \ldots \quad (1)$$

---

* This paper was presented at the Milan International Television Congress of 1949.

Note that if s is made sufficiently large the expression reduces to the numerator. However, for television purposes it is rational to take s as equal to the number of (active) scanning lines in the picture height, thus defining a 'television depth of field'. The only part of the expression which is affected by the geometry of the camera tube is the term involving h_1. This is also in general the dominant term. For comparative purposes, therefore, we take an approximate depth of field :—

$$D' = 2\frac{N}{s}\frac{h_0^2}{h_1} \quad .. \quad .. \quad .. \quad .. \quad (2)$$

Now assuming a scene illumination of E lux and a maximum scene reflectivity of ρ, the total light flux Φ on the photo cathode for an 'all white' test scene is given by

$$\Phi = E\rho A_1/4N^2 \text{ (lumen)} \quad .. \quad .. \quad (3)$$

A_1 being the area of the photo-cathode image (sq metre).

Or, $\Phi^{\frac{1}{2}} = (E\rho A_1)^{\frac{1}{2}}/2N \quad .. \quad .. \quad .. \quad (3a)$

Multiplying (2) and (3a) to eliminate N, we have

$$\Phi^{\frac{1}{2}} D' = \frac{1}{s}\frac{h_0^2}{h_1}(E\rho A_1)^{\frac{1}{2}} = \frac{h_0^2}{s}(E\rho r)^{\frac{1}{2}}$$

r being the aspect ratio.

$$\text{Thus } \frac{D'}{h_0^2} = (E\rho r)^{\frac{1}{2}}\,\Phi^{-\frac{1}{2}}\,s^{-1} \quad .. \quad (4)$$

Equation (4) is a relation between (approximate) depth of field and illumination. Of the various factors in this relation the only one determined by tube characteristics is $\Phi^{-\frac{1}{2}}$; this is, therefore, appropriately taken as the figure of merit.

We may now proceed to derive this figure of merit for a number of important tube types. To do this we may assume that we know experimentally the minimum required illumination for an agreed standard of picture, with a given aperture number, and that we know the size of the photo-cathode image.

Consider, for example, the case of the iconoscope. In the best known British version, the Emitron,[1] the photo-cathode dimensions are 10·2 × 12·7 cm so that $A_1 = 0{\cdot}013$ sq metre.

Standard operating conditions are $E = 2{,}500$ lux with $N = 3$, and average 'peak white' reflectivity may be taken as 0·5 (see Fig. 2).

$$\text{Thus } \Phi = E\rho A_1/4N^2$$
$$= 2{,}500 \times 0{\cdot}5 \times 0{\cdot}013 \times 1/36$$
$$= 0{\cdot}45 \text{ lumen}$$

and $\Phi^{-\frac{1}{2}} = 1{\cdot}5$ lumens$^{-\frac{1}{2}}$, approx.

Table 1 shows the above data together with comparative data for other tube types, namely the image iconoscope, the orthicon and the image orthicon. While the information tabulated is intended to refer more to generic types, it has been necessary to refer to specific makes of tubes for data. In particular the orthicon is now an obsolete tube except in one very remarkable British embodiment, the CPS Emitron. The orthicon data are based on the rather limited information available on the latter. The image orthicon data, however, are based on the direct experience of the author, and are on a highly conservative basis.

It should be emphasized that in constructing Table 1 the only data required for a given tube type are : The dimensions of the photo-cathode image, the illumination considered adequate for full picture quality, and the lens aperture corresponding to this.

Although a single figure of merit, as shown in Table 1, completely describes the behaviour of the tube in respect of sensitivity, it is convenient to express the possibility of exchanging illumination and depth of field by means of curves. Such curves showing D'/h_0^2 against illumination are given in Fig. 1. The other numerical constants in equation (4) have been taken as s=605 (625-line standard), and r=1·33. With these figures, and again taking ρ=0·5, equation (4) becomes

TABLE 1

Tube Type	Photo-cathode Dimensions (cm)	Operating Conditions		Calculated Quantities	
		E	N	Φ	$\Phi^{-\frac{1}{2}}$
Iconoscope	10·2 × 12·7	2500	3·0	0·45	1·5
Image Iconoscope	2·0 × 2·5	800	2·0	0·0125	9·0
Orthicon	3·3 × 4·1	200	2·0	0·0085	10·9
Image Orthicon 5655	2·5 × 3·1	2000	5·6	0·0062	12·7
Image Orthicon 5769	2·5 × 3·1	2000	8·0	0·0030	18·2
Image Orthicon 5820	2·5 × 3·1	250	8·0	$3{\cdot}75 \times 10^{-4}$	51
Quanticon				$2{\cdot}4 \times 10^{-5}$	204
Image Dissector				200	0·07
Film (+ x)	1·52 × 2·02	1000	2·3	0·0072	11·8

$$D'/h_0^2 = 1{\cdot}35 \times 10^{-3}\,\Phi^{-\frac{1}{2}}E^{\frac{1}{2}} \qquad .. \qquad (5)$$

In recapitulation we may make the following remarks on the interpretation of the curves :—

If the scene illumination is pre-assigned, as in outdoor scenes, we read off the ordinate corresponding to the prescribed illumination and derive therefrom the greatest depth of field which can be obtained for any particular height h_0.

The curves, however, are not extended indefinitely to low light values but terminate at a marked point corresponding to the greatest practical aperture associable with the tube involved. If the illumination lies below this end point, the scene cannot be satisfactorily televised at all, even with the most restricted depth of field. Assuming, however, that the illumination is sufficient to allow a variety of tubes to function, the relative merit of various tube types is shown by the vertical distance between the curves. This distance is proportional to the relative depth of field.

In the case of studio or indoor scenes the illumination is to a much greater extent under control, and it is then possible to reverse the problem and postulate the required depth of field and then determine the illumination required. In this case the relative merit of the tubes is expressed by the horizontal distance between the curves, this distance being the illumination ratio.

To aid in the interpretation of the significance of the illumination figures, commonly encountered values of illumination and reflectivity are shown in Fig. 2. Also Table 1 shows data for standard cine film, from which it is seen that in sensitivity this compares very closely with the 5655 image orthicon.

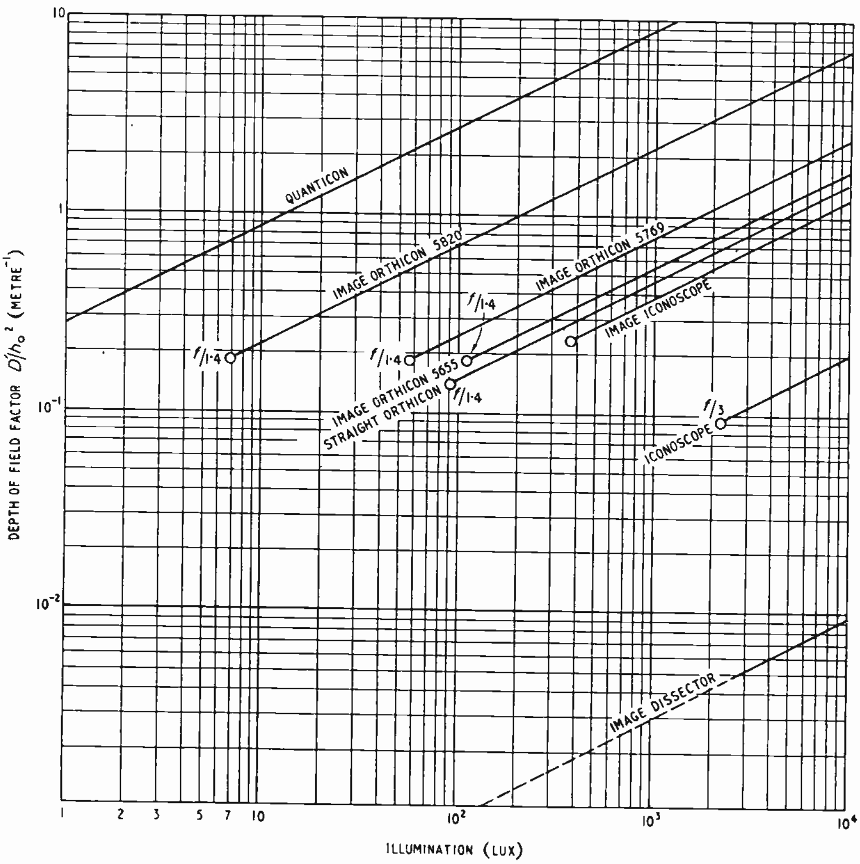


Fig. 1. *The relation between illumination and depth of field is indicated for typical camera tubes.*

Above we have considered the consequence of the light flux requirement of a television camera tube and have noted in Fig. 1 some of the enormous strides which have been made in reducing this requirement. Now we must consider what factors determine this light flux requirement and what are the theoretical possibilities for further improvement.

Fundamentally the light flux required is determined wholly by considerations of signal/noise ratio, but here we must interpret noise in a rather wide sense and include not only fluctuation and thermal noise but also other forms of unwanted signal such as shading.

In the appendix we derive a very general expression for the noise/signal ratio in a television camera tube including electron multiplication followed by valve amplification[2] :—

$$F = I^{-1}\left[2eI + m^{-2}\left\{4kTR_1^{-1} + 2eI_a g^{-2}\left(R_1^{-2} + \frac{(2\pi FC_1)^2}{3}\right)\right\}\right]^{\frac{1}{2}} \qquad .. \quad .. \quad .. \quad .. \qquad (6)$$

Here m is the electron multiplication ratio,

R_1 is the input resistance of the first amplifier valve,
C_1 is the total stray capacitance across R_1,
g is the slope of the first valve,
I_a is its noise-effective anode current,
F is the frequency band concerned,
e is the electronic charge,
k is Boltzmann's constant,
T is the temperature of R_1.

In this formula only thermal and fluctuation noise are considered, and the assumption of noiseless electron multiplication is made. We see that in these circumstances both the thermal noise of the amplifier input resistance and the shot noise of the amplifier valve can be pushed down indefinitely by resorting to a sufficient electron multiplication. The residual noise is due only to the fluctuation of the signal current itself, and the noise/signal ratio becomes

$$(2eF)^{\frac{1}{2}} I^{-\frac{1}{2}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

This formula has been applied to make two more entries in Table 1. The first is the case of a non-storage tube with electron multiplication, as typified by the image dissector.[3] For a noise/signal ratio of 1% we find that the signal current (photo-current per picture point) requires to be $1{\cdot}7 \times 10^{-8}$ A. The total photo-cathode current is thus

$$1{\cdot}7 \times 10^{-8} \times 605^2 \times 1{\cdot}33 = 8{\cdot}25 \times 10^{-3}\text{A}.$$

Assuming a photo-cathode efficiency of 40 μA per lumen we require approximately 200 lumen on the photo-cathode. The figure of merit for this tube is thus $(200)^{-\frac{1}{2}}$ or 0·07 approx.

Having examined the case of the non-storage tube it is now of interest to consider the other extreme; that is, a tube of perfect storage efficiency and having a photo-cathode of full quantum efficiency. Taking this as 710 μA per lumen ($\lambda = 550\text{m}\mu$), we find for this idealized tube

$$\Phi = 2{\cdot}4 \times 10^{-5} \text{ lumen and } \Phi^{-\frac{1}{2}} = 204, \text{ approx.}$$

This very remarkable fictitious tube may be christened the 'Quanticon'. It is a storage tube with full storage efficiency, adequate noiseless electron multiplication, and a photo-cathode having full quantum efficiency; it is 'designed' for a noise/signal ratio of 1% with a 625-line 25-frames/sec standard Its immediate usefulness in the present discussion is that it enables the performance of any prescribed tube to be described by appropriate application of efficiency factors for its various functions

Table 2 is an analysis of the various tubes on this basis; the efficiency factors are as follows :—

η_1 Relative efficiency of photo-cathode
η_2 Gain of image stage
η_3 Effective light utilization factor
η_4 Storage efficiency

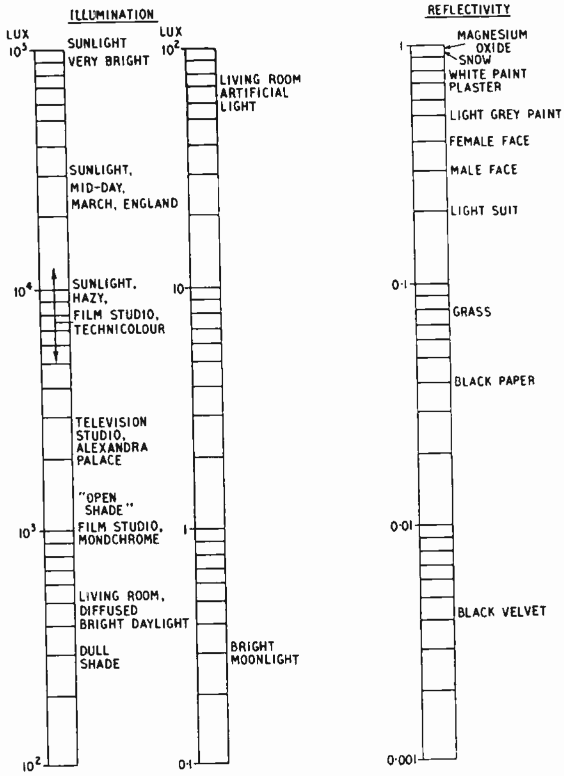


Fig. 2. *Typical values of illumination and reflectivity are indicated in this chart.*

We also require the following correction factors :—

S_1 Ratio of beam current to signal current
S_2 Noise factor due to inadequate electron multiplication
S_3 Correction factor for noise/signal ratio different from 1%.

Let us, commencing with the light flux Φ_q required by the Quanticon, determine the light flux Φ_t required by some practical tube. We do this by operating on the various parameters of the Quanticon in turn.

First, if we substitute the ideal photo-cathode by one with relative efficiency η_1 the required flux becomes Φ_q/η_1.

If we insert a stage of image gain η_2 we need $\Phi_q/\eta_1\eta_2$.

Inserting a light transmission factor η_3 for a feature such as an image orthicon mesh we reach $\Phi_q/\eta_1\eta_2\eta_3$.

Finally, if the storage efficiency is reduced from 1 to η_4 we need

$\Phi_q/\eta_1\eta_2\eta_3\eta_4$

The above are the efficiency factors; the following are correction factors :—

If we stipulate that the scanning beam current is to be S_1 times the signal current, to hold the same signal/noise ratio we must increase the light flux by S_1 times and the beam current S_1^2 times. The flux requirement is thus

$\Phi_q S_1/\eta_1\eta_2\eta_3\eta_4$.

Next, suppose that amplifier noise predominates by a factor S_2. To hold constant signal/noise ratio we must increase the flux by S_2, giving

$\Phi_q S_1 S_2/\eta_1\eta_2\eta_3\eta_4$.

Lastly, suppose that the practical tube shows a

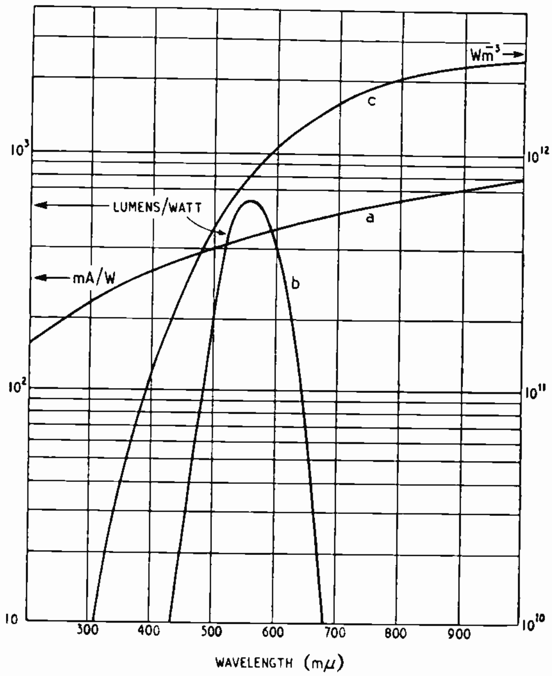


Fig. 3. *The quantum yield (a) ; the response of the human eye (b) ; and the radiation of a source at 2850° K (c) are shown.*

limiting noise/signal ratio which is S_3 times that of the Quanticon (1%). To degrade the Quanticon to this performance we must reduce light input by factor S_3^2. Hence, finally we reach :—

$$\Phi_t = \Phi_q \frac{S_1 S_2}{\eta_1\eta_2\eta_3\eta_4} \cdot \frac{1}{S_3^2}$$

and

$$\frac{\Phi_t^{-\frac{1}{2}}}{\Phi_q^{-\frac{1}{2}}} = \frac{(\eta_1\eta_2\eta_3\eta_4)^{\frac{1}{2}}}{(S_1 S_2)^{\frac{1}{2}}} S_3$$

The significance of Table 2 may be explained by considering some examples.

In the case of the iconoscope the knowns are:—

The photo-cathode sensitivity, taken as 9·6 μA/lumen, leading to $\eta_1 = 0{\cdot}0136$ and η_2 and η_3 are clearly unity. The ratio of beam current to signal current is taken as unity, since this is the assumption underlying the value of S_2 assumed ; the noise in this case is all amplifier noise, not beam noise. S_3 is taken as unity since it appears possible to obtain a 1% noise/signal ratio with the iconoscope.

Finally from Table 1, we know $\Phi_t^{-\frac{1}{2}}/\Phi_q^{-\frac{1}{2}} = 7{\cdot}3 \times 10^{-3}$, and by equating this to $(\eta_1\eta_2\eta_3\eta_4)^{\frac{1}{2}} S_3/(S_1 S_2)^{\frac{1}{2}}$, the remaining unknown, η_4, the storage efficiency, follows as 0·038.

This is a remarkably good agreement with the accepted value of 'approximately 5%'. A similar procedure applied to the image orthicon yields storage efficiencies of 0·1 to 0·2, in which connection see Section 5.

As a final remark on the subject of Table 2 we may point out that while the last column shows figures of merit computed on an arbitrary standard of number of lines and permissible circle of confusion, the penultimate column can be regarded as showing absolute figures of merit. These figures of

TABLE 2

Tube Type	Relative efficiency of photo-cathode η_1	Gain of Image Stage η_2	Effective light utilization factor η_3	Storage Efficiency η_4	Ratio of beam current to signal current S_1	Noise factor for inadequate electron multiplication S_2	Ratio of tube noise to quanticon noise S_3	$\frac{(\eta_1\eta_2\eta_3\eta_4)^{\frac{1}{2}}S_3}{(S_1 S_2)^{\frac{1}{2}}}$	$\Phi^{\frac{1}{2}}$
Quanticon ..	1	1	1	1	1	1	1	1	204
Image Orthicon 5820 ..	0·056	(4)	0·7	0·10*	(2)	1	2·8	$2{\cdot}5 \times 10^{-1}$	51
Image Orthicon 5769 ..	0·007	(4)	0·7	0·10*	(2)	1	2·8	$8{\cdot}9 \times 10^{-2}$	18·2
Image Orthicon 5655 ..	0·007	(4)	0·7	0·20*	(2)	1	1·4	$6{\cdot}2 \times 10^{-2}$	12·7
Orthicon ..	0·030*	1	1	1	(2)	(8)	(1)	$5{\cdot}3 \times 10^{-2}$	10·9
Image Iconoscope	0·047	4	1	0·077*	(1)	(8)	(1)	$4{\cdot}4 \times 10^{-2}$	9·0
Iconoscope ..	0·0136	1	1	0·038*	(1)	(8) (See ref. 1)	1	$7{\cdot}3 \times 10^{-3}$	1·5

Note—Factors marked with an asterisk are calculated after assuming the rest. Figures subject to considerable uncertainty are shown in brackets.

merit are non-dimensional and are independent of any assumption on standard; they are absolute in the sense of being 'relative to the Quanticon'.

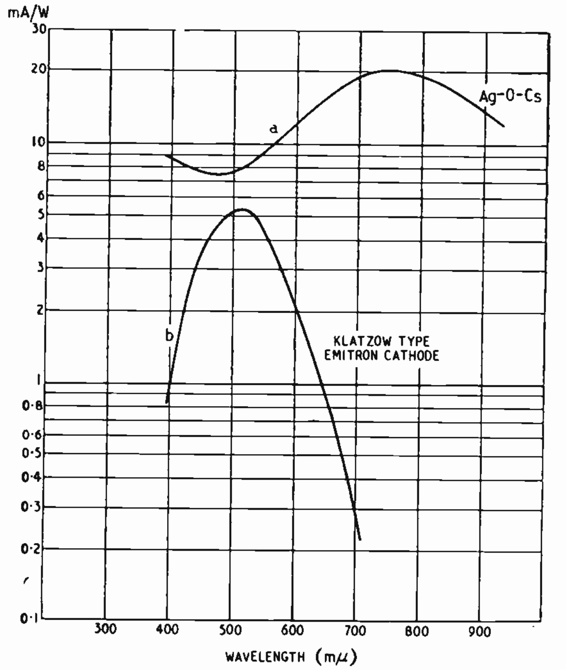


Fig. 4. *Colour response of caesium on oxygen on silver photo cathodes; (a) normal and (b) modified.*

2. Colour Response

A number of colour response curves is shown in Figs. 3-6. Fig. 3 illustrates by three curves:—(a) the quantum yield, (b) the visibility or response of the human eye, and (c) the radiation from a source at the standard colour temperature of 2850°K. Figs. 4, 5 and 6 refer to actual photo-cathodes. The presentation of all these curves is somewhat unusual. In the first place the ordinates are all on absolute scales and, secondly, they are logarithmically plotted. The advantage of this presentation will become clear.

Ideally, the desired shape of photo-cathode response curve would be identical with that of the human eye, and indeed by the use of suitable colour filters any response can theoretically be matched to this. However, this entails a loss of sensitivity which can be very considerable. Therefore, in the past, when sensitivity has been at a premium, colour correction has been applied only with moderation, or not at all. But with the very high sensitivities now available with tubes of the image orthicon class it would seem reasonable to resort to more accurate colour compensation. The required filter characteristic for this purpose is obtained by shifting curve (b) of Fig. 3 vertically into tangency with the photo-cathode response curve, as shown in Fig. 6. The ordinates between the two curves define the required filter attenuation.

The efficiency of the corrected photo-cathode in amps per lumen is derived as follows:—

Let $V(\lambda)$ = the absolute visibility factor, in lumens per watt

λ_0 = the wavelength for $V(\lambda)$ to be a maximum

W'_0 = the mechanical equivalent of light at wavelength λ_0 (= 0·0016 watt per lumen)

$P(\lambda)$ = the sensitivity of the photo-cathode. (amps per watt)

λ_1 = the wavelength at tangency of $P(\lambda)$ with the shifted $V(\lambda)$ curve

$A(\lambda)$ = the attenuation value of the colour correcting filter $[A(\lambda) = 1]$

Suppose that total radiation on the photo-cathode is

$$\int_0^\infty E(\lambda)d\lambda \text{ watts}$$

The photo current

$$I = \int_0^\infty E(\lambda)A(\lambda)P(\lambda)d\lambda$$

The total light flux Φ in lumens $= \int_0^\infty E(\lambda)V(\lambda)d\lambda$

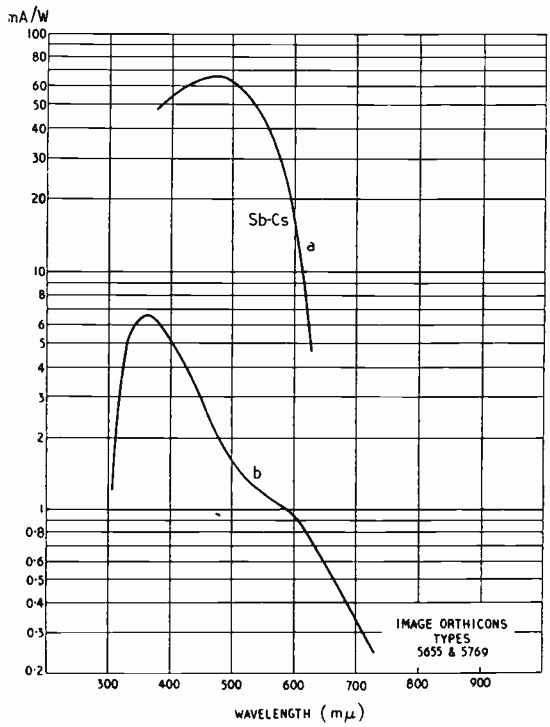


Fig. 5. *Colour response of antimony-caesium photo-cathodes; (a) as a bulk cathode and (b) as a semi-transparent cathode.*

Hence $\frac{I}{\Phi} = \frac{\int_0^{\infty} E(\lambda)A(\lambda)P(\lambda)d\lambda}{\int_0^{\infty} E(\lambda)V(\lambda)d\lambda}$

But for perfect colour correction

$$P(\lambda)A(\lambda) = P(\lambda_1)\frac{V(\lambda)}{V(\lambda_1)}$$

In this case

$$\frac{I}{\Phi} = \frac{P(\lambda_1)}{V(\lambda_1)}$$

Thus the efficiency of the corrected photo-cathode in amps per lumen is the efficiency in amps per watt at the point of contact, divided by the visibility factor (lumens per watt) at the point of contact.

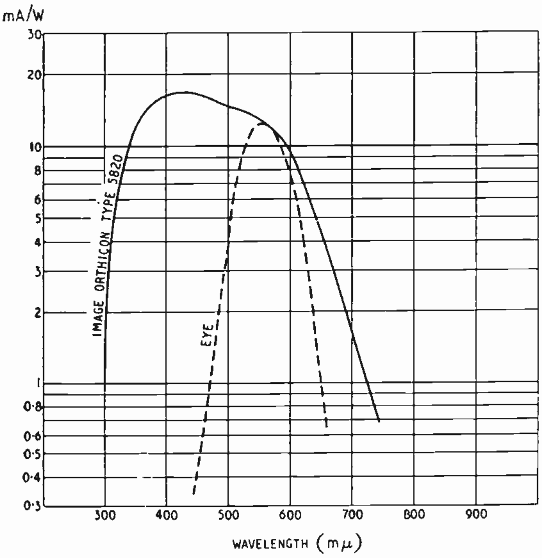


Fig. 6. *Colour response of type 5820 image orthicon photo-cathode with (dotted) the colour response of the human eye.*

A fully-corrected photo-cathode, as defined above, has the property that it will render a correct monochrome version of a coloured subject whatever the spectral distribution of the illumination may be ; that is to say, the rendering will always correctly represent what is actually seen in the studio. If colour correction is not applied, then the spectral distribution of the illumination source becomes important, and can to some extent be 'fitted' to a given photo-cathode response. In this event the tube will render a correct monochrome version of what *would be seen* in the studio with normal illumination.

In the absence of colour correction, the expression of photo-cathode sensitivity in amps per lumen is ambiguous.

Note that only in reckoning the performance of the Quanticon has full colour correction been assumed.

Fig. 4 shows response curves for :—

(a) Normal caesium-on-oxygen-on-silver photo-cathode and

(b) The modified caesium-on-oxygen-on-silver cathode used in the later Emitron mosaics (Ref. 1).

The latter photo-cathode is that developed by L. Klatzow, and shows not only a remarkable improvement in colour response over the previous cathode but also remarkably high relative efficiency taking into account the fact that the cathode is still an effective mosaic.

Fig. 5 shows corresponding data for antimony-caesium. Curve (a) is the accepted curve for the bulk cathode,[4] curve (b) the curve for the semi-transparent version of this cathode as used in the 5655 image orthicon.[5] Fig. 6 shows response curve for the newly-announced cathode for image orthicon 5820[5] which shows a very significant advance on the 5655 cathode.

Table 3 shows the relative efficiencies of these photo-cathodes as follows :—

η_5=efficiency in mA per watt at wavelength λ_1

η_6=efficiency in μA per lumen assuming full colour correction.

η_7=efficiency in μA per lumen without colour correction and assuming normal tungsten lighting.

3. Resolution

Resolution is usually expressed in terms of a test pattern of white and black bars of equal width. The result of such tests may be expressed as :—

(a) Number of bars (black *and* white) per picture height which are just resolvable ; i.e., just distinguishable from uniform grey, or

(b) The black-to-white signal amplitude is plotted against the number of bars per picture height.

In either case when resolution is being examined conditions must be adjusted so that the amplifier cut-off does not obscure the measurement of what is purely a tube characteristic Likewise lens resolution should be well above limit of tube

TABLE 3

Cathode	λ_1 (mμ)	η_5 (mA/W)	η_6 (μA/L)	η_7 (μA/L)
Emitron (Klatzow)	590	2·5	5·3	—
5655 and 5769 ..	565	1·1	1·8	5·0
5820	570	12·0	20	40

resolution, although this is not always entirely easy to achieve.

The interpretation of resolution in either forms (a) and (b) is by no means simple and a large amount of work has been, and is being, devoted to this subject.[6] Table 4 shows the generally accepted resolution values for various tubes according to method (a).

TABLE 4

Tube Type	Limiting Resolution	Reference
Image Orthicon 3″ ..	600	Author's measurement
Image Orthicon 4-½″..	900 (inferred)	
Iconoscope	Centre 1200 Corners 600	McGee, Ref. 1
Orthicon	Centre 600 Corners 400	Rose and Iams, Ref. 11

When an image orthicon is tested according to method (b) a somewhat anomalous type of curve results. This is due to the 'throw-off' effect mentioned in Section 6. The author suggests that the publication of method (b) tests on the full range of tube types would be of value.

4. Extent of Spurious Signals

For the enormous increase of sensitivity obtained by recourse to the storage principle, one has to pay this price ; that all tubes of the storage class are subject to spurious signals of one kind or another. In particular all tubes of the iconoscope family (i.e., tubes with high electron-velocity scanning beam) are subject to spurious signals known as 'shading.' The mechanism of these spurious signals has been extensively discussed[7] and there does not appear to have been any useful suggestion as to means of avoiding this shading other than by going to a tube of low-velocity scanning beam, that is to say, by changing over to the orthicon family.

The extent of shading trouble (i.e., the shading/signal ratio) increases as the light input is reduced and, in general, it is the shading signal ratio becoming unmanageable which sets the low limit of light input rather than fluctuation-noise/signal ratio.

Orthicon tubes, in which the classifying feature is that the electron velocity in the scanning beam is substantially zero at the target, are fundamentally free from the above shading effect, which is associated with secondary emission at the target. They are, however, subject to minor shading effects due to other causes ; e.g., inequality of effective landing due to the electron helical motion acquired from the scanning fields. One of the problems of tube design is, in fact, to arrange the scanning, focus and retardation fields so that uniform landing is obtained. The remaining shading is then only of a residual character expressing the departure of the design from perfection. A distinguishing feature of this orthicon shading is that it is not only relatively small but, unlike the iconoscope shading, is independent of picture content. This means that shading controls can be set up and left, and are not subject to continuous adjustment with picture content.

In the image orthicon, or any orthicon comprising electron multiplication stages, there is a further possible shading contribution from the multiplier. This is a signal of an entirely different sort which, in general, does not admit of compensation by shading controls and has therefore to be kept to an extremely low value It arises from non-uniformity of the secondary-emission ratio of the first dynode surface.

The simple theory of the image orthicon[8] suggests that the unabsorbed scanning beam should be returned in focus to its point of origin at the first dynode, namely the dynode aperture. In practice, a small amount of scanning is imparted to the return beam and the first dynode surface is scanned with a raster approximately 5 mm square. If the beam is in focus at this plane then a greatly enlarged picture of the dynode surface shows up, and this includes the dynode hole, which shows as a white spot. To avoid the appearance of a sharp picture of the dynode surface it is necessary to arrange for the return scanning beam to be slightly defocused at the dynode. Fortunately this can be done with little or no sacrifice of focus at the target.

Other forms of spurious signal which are common to all types of tube and are not subject to correction by shading controls are non-uniformity of photo-cathode sensitivity and of target secondary-emission coefficient. The holding of these factors to sufficiently close limits is one of the major problems of manufacturing technique in all cases.

5. Limiting Signal/Noise Ratio

All tubes of the storage class are fundamentally subject to a limiting signal/noise ratio, which is of particular importance in the case of the orthicon group. By this effect it is meant that as the input illumination is increased the signal/noise ratio does not increase with it indefinitely, but saturates to a certain limiting value. This effect comes about in the following way. The excursion voltage for individual picture points on the target must not be so high as to cause lateral displacement of the scanning beam. In the case of the orthicon, where the scanning-beam velocity at the target is substantially zero, this picture-point voltage excursion is strictly limited. In the case of the image orthicon it will be of the order of 1-2 V.

To examine the effect of this limitation, let

V_s = the picture-point voltage excursion.
A = the area of photo cathode.
n = the number of picture points.
a = linear dimension of picture elements ($=\sqrt{A/n}$)
C_t = the capacitance of the whole target.
C_e = the capacitance per picture element.
T = the frame time.

If the high-light illumination is just sufficient to produce excursion V_s, the charge stored per element in one frame time is C_eV_s.

On the scanning side the charge has to be neutralized by the effective beam current I_s operating for picture-point time ; viz., T/n.

thus $I_sT/n = C_eV_s = C_tV_s/n$

whence $I_s = C_tV_s/T$

The actual current I_b will exceed I_s by some factor S_1. The r.m.s. noise current associated with beam current I_b is $(2eI_bF)^{\frac{1}{2}}$, where F is the frequency bandwidth ; hence signal/noise ratio is $(2eI_bF)^{-\frac{1}{2}}\ I_0$,

$$= (2eF)^{-\frac{1}{2}}S_1^{-\frac{1}{2}}I_s^{\frac{1}{2}}$$
$$= (2eF)^{-\frac{1}{2}}S_1^{-\frac{1}{2}}T^{-\frac{1}{2}}C_t^{\frac{1}{2}}V_s^{\frac{1}{2}}$$

In the case of the image orthicon, the limiting voltage excursion is set physically in terms of the steady voltage applied to the target mesh. If the light value is increased beyond that necessary to charge the high-light picture point to V_s in the frame time, it might be thought that an abrupt saturation of white in the picture would result. In fact, this is not the case because another mechanism comes into play, that of electron re-distribution ; the more positive parts of the target continue to release secondary electrons and there is nowhere for these to go except to the more negative parts of the target. This phenomenon allows contrast to be maintained beyond the knee of the normal orthicon characteristic.[6] What happens in effect is that the image orthicon adjusts its storage time to suit increased light input. This is, in fact, a most valuable property, probably *the* most valuable property of the tube, as it provides not only a species of a.g.c. action, but also allows the storage time to be reduced so that smearing effects are suppressed.

In the straight orthicon this phenomenon is not present. The signal/noise ratio is still limited to the same expression as above because there still exists a voltage excursion V_s which cannot be exceeded without local geometrical distortion of the picture. But there is no electrode in the tube to define this voltage physically. It is therefore possible with increase of light input to reach the condition of geometrical distortion.

However, there is another phenomenon which is very much worse than this, that of target instability. In the event of the light input becoming so high that the scanning beam is unable to discharge the high-light picture points completely during the picture-point time, these picture points move progressively positive in voltage and very soon reach a voltage where the secondary-emission coefficient exceeds unity. In this case the high-light picture point becomes stabilized at final anode potential. This phenomenon is usually described as the target 'becoming unstuck.'

There is another distinction between the straight orthicon and the image orthicon in respect of limiting signal/noise ratio, which is that the straight orthicon is not able to exploit electron multiplication ; its effective signal/noise ratio is very much higher than that corresponding to equation (7). In fact, however, it is able to make a better comparison than might be expected because its construction allows a much higher value of target capacitance C_t, in this case the capacitance of the target to the signal plate. (See also the Appendix re peaked-channel noise.)

C_t is also an important variable in image orthicon design. The earlier image orthicons showed a relatively low limiting signal/noise ratio owing to C_t being made low by (so-called) wide target-mesh spacing. In the studio type 5655, this space has been reduced to the limit and C_t increased by a factor of some four times.

6. Contrast Reproduction

Fig. 7 is a collection of signal versus light curves for a number of camera tubes.[5,9,10] They show that :—

(a) The iconoscope family has a gamma which decreases from 1 at low illumination to a reduced value at high illumination. This is a distinct advantage in view of the fact that a normal cathode-ray tube picture reproducer has a gamma in excess of 1. In practice it is unusual to apply gamma correction at the transmitter when an iconoscope camera is employed.

(b) The straight orthicon is essentially a unity gamma device. To give a good picture with cathode-ray tube reproduction gamma-reducing networks are necessary. This is also quite practical since the gamma of the tube is not subject to variations under light conditions or as between tubes. It has, however, a significant repercussion on the signal/noise ratio.

(c) The image orthicon characteristic shows that again at low light levels the tube is a unity gamma device. However, it is in practice never used in this condition, because in these circumstances it would be subject to excessive 'smearing' (see Section 7). The term 'gamma' is hardly applicable to the image orthicon used in the practical condition where electron re-distribution is taking place. However, the extent to which this effect is present determines the general contrast reproduction of the tube. Fortunately, satisfactory contrast performance and adequately reduced storage time occur together.

7. Image Persistence

The types of image persistence considered are four in number, of which three are peculiar to image orthicons.

The first type is the natural storage effect which is characteristic of all members of the orthicon family. In the straight orthicon the time is that of one frame and this is sufficient to cause marked blurring on rapidly moving objects. This effect is described as 'trailing' or 'smearing'. There appears to be no mechanism for reducing this storage time in the straight orthicon other than artifices equivalent to the use of intermittent illumination.

In the image orthicon we have already noted the peculiar mechanism by which this tube reduces its effective storage time as the illumination is increased above a certain level. This remarkable property of the tube makes it possible to reduce trailing to a satisfactorily low level and this, moreover, without excessive illumination; the image orthicon curves of Fig. 1 are reckoned for this mode of operation.

The second form of image persistence is that introduced by the resistivity of the image orthicon target. An analysis of the tube mechanism shows that time constant C_tR_t introduces a form of image persistence and this must be made considerably smaller than the frame time if trailing is to be avoided. The resistivity of the target is chosen with these considerations in mind and is adjusted by means of target temperature. The resistivity is approximately halved for every 10° of temperature rise.

The third form of image persistence, usually called 'picture sticking,' occurs only when the target temperature is too low. In these circumstances two correlated phenomena are observed, 'fading' and 'sticking'. By 'fading' is meant that when the scene is exposed on the photo-cathode the signal commences at full value and then fades to a lower value (which would be zero in the case of a completely non-conducting target). When the optical picture is removed a negative picture is produced which in turn fades to zero. This effect is believed to be caused by a species of dielectric hysteresis in the glass target. This form of sticking has no practical limitation except in dictating the minimum operating temperature for the target.

The fourth type of image retention, usually called 'memory,' is a long-term picture retention

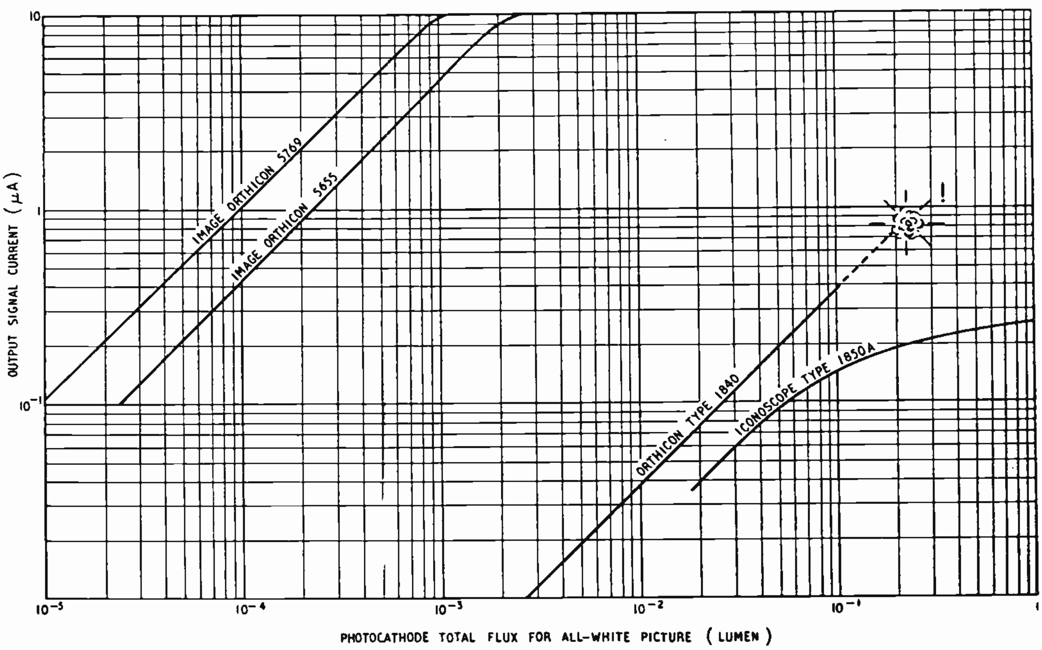


Fig. 7. *Relation between illumination and signal current for typical tubes. The slope of the curves represents the gamma.*

which is attributed to actual chemical or physical change in the glass target as a result of its conduction of the signal current by electrolysis. It occurs only if a bright picture is left on the tube for a considerable time and, moreover, does not normally occur with a new target. Commencement of 'memory' is one of the major factors determining the useful life of an image orthicon.

8. Geometrical Accuracy

In tubes of the iconoscope family, other than the transparent target iconoscope (which has not appeared commercially), scanning is oblique to the target. This necessitates keystone and frame-linearity corrections. Although these may be reckoned a great inconvenience to the designer the necessary solution appears quite practical and residual errors are not unduly objectionable.

In the image iconoscope, in addition to the above disadvantage, we find distortion of the imaging electron lens. This is eventually corrected by application of compensating distortion to the scanning fields. In addition to these difficulties there is another which relates to geometry, namely, interference between the deflection and image-lens fields. Lens field in the deflection region introduces geometrical distortion ; deflection field in the lens region introduces loss of resolution. All these facts render the setting up of an image iconoscope a matter of considerable difficulty, and residual distortion can be noticeable.

In the orthicon family the axis of the electron gun is normal to the target, so questions of keystone correction, etc., do not arise. In this case, however, in the interests of meeting severe beam-landing conditions, the scanning is of unusual character and small residual errors of geometry may be present.

The above remarks apply also to the image orthicon where again we find the possibility of interference between scanning and imaging fields. By careful arrangement of screening, however, this effect has been rendered evanescent.

9. Stability

By stability we mean absence of any tendency for the tube conditions to make an unstable transfer to another operating mode. All the tubes of the iconoscope class can be described as completely stable. All tubes of the orthicon class with one exception can be described as unstable. The exception is the image orthicon which is completely stable.

The mechanism by which the straight orthicon becomes unstable has been described in Section 5 and has been adequately discussed in the literature.

In summary, the condition for unstable transition to occur is for a high light to exceed that value which, if applied to the whole photo-cathode, would provide a photo current in excess of the scanning-beam current.

10. Life

Insufficient life data have been published to allow useful comparative tabulation. A few general remarks may be made.

It has been stated that the straight iconoscope loses photo-cathode sensitivity owing to bombardment of the mosaic by the high-velocity scanning

TABLE 5

Tube Types	Sensitivity Fig. of merit	Colour Response	Resolution	Spurious Signal	Limiting Sig/Noise	Contrast Reproduction	Image Persistence	Geometrical Accuracy	Stability
Iconoscope ..	1·5	Fig. 4	1200/600	Bad	>100	Good	Nil	Good	Complete
Image Iconoscope ..	9·0	—	—	Fair	>100	Good	Nil	Fair	Complete
Orthicon ..	10·9	—	—	Good	—	Fair	Frame time	Good	Bad
3″ Image Orthicon 5655 ..	12·7	Fig. 5	600	Good	70	Good	Variable and satisfactory	Good	Complete
3″ Image Orthicon 5769 ..	18·2	Fig. 5	600	Good	35	Fair	Variable and satisfactory	Good	Complete
3″ Image Orthicon 5820 ..	51	Fig. 6	600	Good	35	Fair	Variable and satisfactory	Good	Complete

beam. The author finds it difficult to visualize a mechanism by which pure electron bombardment, without thermal effects, can cause this deterioration, and questions whether the effect may not be associated with negative-ion bombardment. In that event, since electrostatic focusing and magnetic deflection is used, the desensitization should show as a small raster at the centre of the mosaic.

In the image iconoscope the photo-cathode is not subject to any electron bombardment and would therefore be expected to show a materially longer life if either of the above two effects are important.

In the image orthicon the principal factor determining life is undoubtedly deterioration of the glass target, due almost certainly to its electrolytic conduction. In this connection we find one quantitative agreement and one quantitative disagreement. First, since the conduction currents are higher in tubes of the close-spaced variety, one would expect to observe reduced life. This is substantiated in practice. However, all target lives are very much longer than would be expected from calculations based on the supposition that the glass conduction is wholly electrolytic.

Summary

Table 5 shows tube characteristics in comparative form. It is in general agreement with a similar comparison by McGee, but is shown in rather different form and has been made quantitative as far as possible. It makes no pretence to provide a definitive answer to the question "What is the best television camera tube"? Indeed, all the tubes fall so far short of perfection that such a question is almost without meaning.

It is worthy to note that we find in camera tubes the same situation that seems to be encountered throughout nature, that a type which is outstanding in one parameter shows compensating deficiencies in others; in particular, in examining columns (3) and (6) of the table, we observe an analogy with the case of photographic film, that high sensitivity (or speed) is only obtainable at the expense of reduced signal/noise ratio (increased graininess).

On the more encouraging side of the situation, the paper has recorded advances over a relatively short period of 25 years which can only be described as staggering, and there is every reason to suppose that a commensurate rate of progress will be maintained.

Acknowledgments

The author is indebted to Messrs. Marconi's Wireless Telegraph Company, Ltd., for permission to publish this paper, in which use is made of experience of their laboratories in work on image orthicon equipment. In particular, the author wishes to acknowledge the assistance of his colleague G. E. Partington.

In presenting data on the Emitron, the author is indebted to a great extent to J. D. McGee's "Electronic Generation of Television Signals" (Ref. 1 below) and would like to make specific acknowledgment to this outstandingly valuable paper.

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APPENDIX

Noise/signal ratio for multiplier-type camera tube followed by valve amplification

Suppose that the tube provides a high-light signal current I which is subject to m-fold electron multiplication, assumed noiseless. By this is meant that the mean-square fluctuation of the multiplied signal current mI is $2eIFm^2$; where

e is the electronic charge, and
F is the frequency band, in which case,
$2eIF$ is the mean-square fluctuation current associated with current I.

Now assume that the multiplied signal current is applied to load resistance R_1, which also forms the input resistance to the valve amplifier.

Let

C_1 be the total effective stray capacitance across R_1
T_1 be the time constant C_1R_1
g be the slope of the first valve
I_a its noise-effective anode current
R_2 the anode load (including shunting effect of the valve anode resistance, if finite).

R_2 will, of course, be subject to the effect of stray capacitance, and possibly other frequency-conscious elements such as peaking coils. However, it is assumed that the over-all compensation will be such as exactly to neutralize these effects, and since R_2 is treated alike by signal and by noise it is legitimate to consider it as a pure resistance.

The signal appearing on the anode of the first amplifier valve is thus

$$mIR_1 \times \frac{1}{1 + j\omega T_1} \times gR_2$$

In order that this shall emerge as a signal free of frequency distortion the subsequent compensation must include a network effecting the operation $(1 + j\omega T_1)$.

The amplitude characteristics of the whole amplifier subsequent to R_2 can thus be written $A\sqrt{1 + \omega^2 T_1^2}$ where A is constant over the frequency band 0 to F (and may be supposed ideally to approach 0 thereafter).

Thus the emerging signal is mIR_1AgR_2.

Now consider the noise ; it consists of three terms :—

(a) fluctuation component of the signal current ; in the frequency range f to $f + \delta f$ this will be
$\delta \bar{I}_n^2 = 2eI\delta f m^2$

(b) The thermal noise of the input resistance R_1,
$\delta \bar{V}_n^2 = 4kTR_1\delta f$

(c) The shot noise of the valve current I_a ; viz,
$\delta \bar{I}_n^2 = 2eI_a\delta f$

The total noise squared-voltage *emerging* is thus :—

$$2eI\delta f m^2R_1^2g^2R_2^2A^2 + 4kTR_1\delta f g^2R_2^2A^2 + 2eI_a\delta f R_2^2A^2 (1 + \omega^2T_1^2)$$
$$= A^2R_2^2g^2\delta f \left[2eIm^2R_1^2 + 4kTR_1 + 2eI_ag^{-2}(1 + \omega^2T_1^2)\right]$$

The whole noise squared-voltage in frequency band 0–F is thus :—

$$A^2R_2^2g^2\left[2eIm^2R_1^2F + 4kTR_1F + 2eI_ag^{-2}\int_0^F \{1 + (2\pi T_1)^2f^2\}\,df\right]$$
$$= A^2R_2^2g^2F\left[2eIm^2R_1^2 + 4kTR_1 + 2eI_ag^{-2}\left\{1 + \frac{(2\pi FT_1)^2}{3}\right\}\right]$$

Hence the square of the noise/signal ratio is

$$m^{-2}I^{-2}R_1^{-2}F\left[2eIm^2R_1^2+4kTR_1+2eI_ag^{-2}\left\{1 + \frac{(2\pi FT_1)^2}{3}\right\}\right]$$

or

$$FI^{-2}\left[2eI+m^{-2}\left\{4kTR_1^{-1}+2eI_ag^{-2}\left(R_1^{-2} + \frac{(2\pi FC_1)^2}{3}\right)\right\}\right] \quad \ldots \quad (1)$$

and the noise/signal ratio itself is

$$F^{\frac{1}{2}}I^{-1}\left[2eI+m^{-2}\left\{4kTR_1^{-1}+2eI_ag^{-2}\left(R_1^{-2} + \frac{(2\pi FC_1)^2}{3}\right)\right\}\right]^{\frac{1}{2}} \quad \ldots \quad (2)$$

This formula, at the expense of being rather long, reveals a complete picture of the situation in remarkably intelligible form ; thus :—

(1) We see that all noise contributions can be crushed down into insignificance compared with the fluctuation noise of the original signal by recourse to sufficient electron multiplication. Further the formula will tell us how much electron multiplication is necessary to do this.

(2) In the event of inadequate electron multiplication being available, and in particular in the case where electron multiplication is absent ($m = 1$), we see that the thermal noise can be crushed down indefinitely by making R_1 sufficiently high. In these circumstances the noise/signal ratio becomes

$$F^{\frac{1}{2}}I^{-1}\left[2eI+m^{-2}2eI_ag^{-2}\frac{(2\pi FC)^2}{3}\right]^{\frac{1}{2}} \quad \ldots \quad (3)$$

and if the second term is predominant this approximates to

$$F^{\frac{1}{2}}I^{-1}m^{-1}(2e)^{\frac{1}{2}}I_a^{\frac{1}{2}}g^{-1}\frac{1}{\sqrt{3}}\,2\pi FC \quad \ldots \quad (4)$$

This last expression reveals the fact that the dominant contribution is now entirely shot noise, and in it we recognize the appearance of the well-known valve-noise figure of merit g^2/I_a. The numerical importance of the shot noise contribution is dependent on the admittance of the input stray capacitance at the top of the frequency band.

(3) We must also note an important distinction between the types of noise which characterize multiplier and non-multiplier camera tubes respectively. In the case of multiplier tubes the first term of equation (3) will be dominant. The noise in this case is uniform in frequency distribution. In the case of non-multiplier tubes equation (4) is relevant and this noise has a rising frequency characteristic. In fact for this case we may write

$$\delta \bar{V}_n^2 = A'\,2eI\delta f(1 + \omega^2T_1^2)$$

As ωT_1 is likely greatly to exceed unity at the top of the frequency band, the noise will all be apparent in the high frequencies, the so-called 'peaked-channel noise'. In these circumstances a considerably higher r.m.s. noise/signal ratio is permissible for unmarred viewing.

CAR IGNITION RADIATION

By C. C. Eaglesfield, M.A., A.M.I.E.E.

(*Standard Telephones and Cables, Ltd.*)

SUMMARY.—This paper extends the theory previously given by the writer[1] to cover resonances in the ignition system and the addition of resistors for suppression.

It is shown that, in practice, resonances do not appear to play an important part for the band of frequencies 40-650 Mc/s. The formulæ for suppression ratio are checked against published measurements.

1. Introduction

In a previous paper[1] the writer gave a theory of the radiation from the ignition systems of cars, in which it was deduced that the radiation from an unsuppressed system is impulsive. The treatment was extremely simple and in a few short lines of mathematics it was shown, as is known experimentally, that the effect on a receiver is independent of the frequency to which the receiver is tuned ; moreover, a formula was obtained for the effective radiated field which agreed numerically with published measurements.

It was thus shown that the radiation could be explained without assuming resonances in the ignition system, which up to that time had been considered of prime importance. However, such resonances must occur in practice, and it is of interest to consider what part they play. The present paper is an attempt to extend the previous treatment to cover resonances and also the deliberate addition of resistance as a means of suppressing the radiation.

One attempt at an extension on these lines has been given by Nethercot,[2] who calculated the current through the ignition lead considered as a uniform line, terminated by a capacitor, with and without suppressing resistors. He did not, however, calculate the radiated field, and could, therefore, give no formulæ for the effect of resonances and suppressing resistors.

The method used here is to calculate the radiated field in operational form (in general, it is more complicated than an impulse) and then to consider what effect this field will have on a receiver. To do this, it is necessary to make assumptions about the receiver and, in particular, the type of modulation to which it is sensitive. The discussion is limited to receivers sensitive to amplitude modulation. It is then shown that there is an equivalent impulse which would have the same effect, and that the amplitude of the impulse depends on the impedance of the ignition system at the receiver frequency.

The mathematics used is simple, but it is, perhaps, fair to warn the reader that, as in any application of operational methods, the simplicity is more apparent than real. The method is fairly general, but the writer has tried as far as possible to keep the mathematical work within bounds. To this end the equivalent circuits assumed for the ignition system are never more complicated than is necessary to show the effects and, as far as possible, one effect is dealt with at a time. It should not be difficult for anyone who wishes, to extend the treatment to more complicated circuits.

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In Section 2 the previous treatment is briefly recapitulated ; then, assuming a single radiator, the effect of more complicated circuits is dealt with and several particular circuits are discussed.

In Section 3 we consider the radiator as a uniform line, in which the current is different at different points on the line, but the line has small dimensions. We also consider how to take account of the dimensions of the line but without making the calculation.

In Section 4 the formulæ obtained are compared with published measurements, mainly those of Pressey and Ashwell.[3] The agreement seems satisfactory. For the frequency band considered, 40-650 Mc/s, it does not seem that resonances play an important part, so that the previous neglect of them by the writer is largely justified.

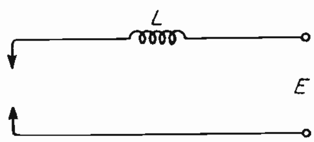

Fig. 1. *The simplest equivalent circuit for the spark system, in which L represents the inductance of the ignition lead.*

2. Some Equivalent Circuits

Before dealing with more complicated circuits than were considered before, the treatment given in the previous paper will be very briefly recapitulated. The equivalent circuit considered there was the very simple one shown in Fig. 1, consisting of a switch, an inductance L, and a source of e.m.f. E.

The current flowing is then

$$i = E/pL$$

where p is written for the differential operator d/dt.

Now if we suppose that the inductance L is a single-turn loop of small dimensions and area A, we can treat it as a magnetic dipole and calculate the field radiated by it.

Its magnetic moment is

$$m = Ai$$

and the electric field at a great distance R, in the direction of maximum radiation, is

$$\frac{\mu}{4\pi cR} \cdot \frac{d^2m}{dt^2}$$

where μ is the permeability and c the velocity of propagation.

To take account of the sudden closing of the switch, we write $E\mathbf{1}$ for E where $\mathbf{1}$ is the Heaviside step function.

The preceeding equations are now simply combined, to give for the electric field

$$\frac{\mu}{4\pi cR} \cdot \frac{AE}{L} \cdot p\mathbf{1}$$

It will be observed that we have here the product of a numerical multiplier and an impulse.

The above expression can be put into a form that is convenient for comparing with measured values of peak field, by multiplying by the receiver bandwidth

The equivalent peak field is then

$$\frac{\mu}{4\pi cR} \cdot \frac{AEB}{L} \text{ volt/metre} \quad \ldots \quad \ldots \quad (2.1)$$

where

$\mu = 4\pi \times 10^{-7}$ henry/metre
$c = 3 \times 10^8$ metre/sec
B = Receiver bandwidth in c/s
R = Distance in metres
E = Sparking voltage in volts
L = Inductance of loop in henrys
A = Area of loop in square metres.

Now before we proceed to more complicated circuits than Fig. 1 for the ignition system, we must consider in more detail the form of the impulse response of a typical receiver. For simplicity, suppose we have a straight receiver sensitive to amplitude modulation, with a number of circuits tuned near ω, the nominal angular frequency of the receiver. Just prior to the detector, the impulse response may be written, with sufficient generality, as

$$f(t) \cos \omega t \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2.2)$$

The multiplier $f(t)$, which is extracted by the detector, is the apparent impulse response at the output terminals.

The shape of $f(t)$ is in practice a pulse of width determined by the receiver bandwidth; the important thing is that we may assume that $f(t)$ changes much more slowly than ω. It will, therefore, be permissible to consider $f(t)$ as constant in certain manipulations in which ω occurs. The assumption is, in effect, that the receiver bandwidth is very small compared with the receiver frequency.

If the receiver is of the frequency-changing type, equation (2.2) applies to the situation just before the frequency-changer, and the process of frequency-changing and detection extracts $f(t)$. In practice, both detection and frequency-changing will somewhat modify $f(t)$, but this will not affect our argument.

We may now write the receiver in operational form as

$$F(p)$$

where we know from equation (2.2) that

$$pF(p)\mathbf{1} = f(t) \cos \omega t$$

We are now in a position to deal with more complicated circuits than Fig. 1, as will be seen presently.

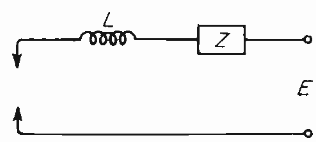

Fig. 2. *An equivalent circuit for the spark system, similar to Fig. 1, but with the addition of an arbitrary impedance Z.*

To begin with, suppose we add an additional element Z in series with L, as in Fig. 2; Z is an arbitrary function of p. The radiating area is supposed to be unaffected by this change. We now get a new expression for the electric field

$$\frac{p^2}{pL + Z(p)} \mathbf{1}$$

(In the above, the multiplier is omitted, for simplicity.)

Applying this to the receiver, we get

$$\frac{p^2}{pL + Z(p)} F(p) \mathbf{1}$$

$$= \frac{p}{pL + Z(p)} f(t) \cos \omega t \mathbf{1}$$

$$= \frac{p}{pL + Z(p)} f(t) e^{j\omega t} \mathbf{1} \text{ (Real part)}$$

To proceed further, we need to shift the time-varying terms out of the operator. $e^{j\omega t}$ may be shifted if we write $(p + j\omega)$ for p; $f(t)$ may be shifted without any change, as it is a function that varies slowly compared to ω.

We now have

$$f(t) e^{j\omega t} \frac{(p+j\omega)}{(p+j\omega)L + Z(p+j\omega)} \mathbf{1} \text{ (Real part)}$$

If we consider this expression, we conclude that it is reasonable to substitute $j\omega$ for $(p+j\omega)$. To justify this step we may allow ω to become very large.

It remains to take the real part, which is

$$\left| \frac{j\omega}{j\omega L + Z(j\omega)} \right| f(t) \cos(\omega t - \theta)$$

Apart from the unimportant phase angle, we have here the impulse response of the receiver multiplied by the factor

$$\left| \frac{j\omega}{j\omega L + Z(j\omega)} \right|$$

Clearly the same result would have been obtained if the field had been an impulse of amplitude modified by this factor ; so that we have found an equivalent impulsive field.

We may regard the addition of the impedance Z as having a suppressing action on the radiated field, in which case the ratio of the fields in the two cases may be called the suppression ratio. Its value is

$$\left| \frac{j\omega L + Z(j\omega)}{j\omega L} \right| \quad .. \quad .. \quad (2.3)$$

The suppression ratio given by (2.3) may be greater or less than unity. It is a function of the receiver frequency and depends on the impedance of the ignition system at the receiver frequency. We shall not give any more general formula for it for more general circuits, but the principles involved in obtaining it for any particular circuit should now be clear.

Suppose Z is a capacitance C. The practical interest of this is that C may represent the self-capacitance of the magneto or spark-coil.

The suppression ratio

$$= \left| \frac{j\omega L + 1/j\omega C}{j\omega L} \right|$$

$$= 1 - \left(\frac{\omega_0}{\omega}\right)^2 \quad \text{where } \omega_0^2 LC = 1 \quad .. \quad (2.4)$$

ω_0 is the resonant angular frequency of the ignition system. Equation (2.4) shows that, at receiver frequencies somewhat greater than the resonant frequency, the suppression ratio is substantially unity ; at the resonant frequency it becomes zero, and below that it becomes large.

Thus C has negligible effect above the resonant frequency, but suppresses below it ; at the resonant frequency the field is large, limited by the resistance of the ignition system, neglected so far.

It is believed that, in practice, the resonant frequency is below 40 Mc/s, so that the magneto self-capacitance is not important in the band we are considering, 40-650 Mc/s.

Now suppose Z is a resistor r.

The suppression ratio

$$= \left| \frac{j\omega L + r}{j\omega L} \right|$$

$$= \sqrt{1 + (r/\omega L)^2} \quad .. \quad .. \quad .. \quad (2.5)$$

Equation (2.5) shows that the suppression ratio falls with increasing frequency, and reaches unity at sufficiently high frequency. At low frequencies the ratio is inversely proportional to frequency.

Finally consider the circuit of Fig. 3. The practical interest of this circuit is that r_1 and r_2 may be regarded as lumped suppressor resistors placed at sparking plug and magneto respectively; the inductance L and the two capacitors C represent the ignition lead and are an approximation to a uniform line. The inductance is regarded as the radiator.

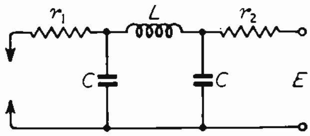

Fig. 3. *An equivalent circuit for the spark system, in which r_1 and r_2 are lumped suppressor resistances at plug and magneto respectively, and L, C, C are the inductance and capacitance of the ignition lead.*

It is a simple matter to calculate the current through the inductance and, proceeding as before, we obtain the suppression ratio due to adding the resistors r_1 and r_2.

Three cases may be distinguished. First, where $r_2 = 0$:—

Suppression ratio =

$$\sqrt{1 + \left(\frac{r_1}{\omega L}\right)^2 \left[1 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2} \quad .. \quad (2.6)$$

Second, where $r_1 = 0$:—

Suppression ratio =

$$\sqrt{\frac{1 + \left(\frac{r_2}{\omega L}\right)^2 \left[1 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2}{1 + (\omega C r_2)^2}} \quad .. \quad (2.7)$$

And third, where $r_1 = r_2 = r$:—

Suppression ratio =

$$\sqrt{1 + \left(\frac{r}{\omega L}\right)^2 \left[2 - \left(\frac{\omega}{\omega_0}\right)^2\right]^2} \quad .. \quad (2.8)$$

In each case $\omega_0^2 LC = 1$.

These equations are rather complicated, and we shall leave them until Section 4, where a numerical example will be given.

We have now shown how to deal with any equivalent circuit containing a single radiator. The extension to a small number of radiators is not difficult, by a similar method.

3. Uniform Line

So far we have had the situation that the current is the same along the length of the radiator, but we now have the current varying from point to point.

Consider Fig. 4 in which the switch is connected to the source through a uniform line, whose series impedance is inductance L and resistance r, whose capacitance is C and conductance G, and which includes a radiating area A, all per unit length.

The line may be divided into elements; for the element distant x from the switch, the current is i and the magnetic moment $A\,idx$.

The total magnetic moment of the whole line is, therefore,

$$A \int_0^l idx$$

The total voltage drop along the whole line is equal to E, so that we get

$$E = (pL + r) \int_0^l idx$$

The integral may be eliminated, so that the total magnetic moment

$$= \frac{AE}{pL+r}$$

$$= \frac{A_0 E}{pL_0+r_0} \qquad \ldots \quad \ldots \quad (3.1)$$

where A_0, L_0, r_0 are the area, inductance and resistance of the whole line; the inductance and resistance, that is, measured at very low frequency with one end of the line short-circuited.

Thus for calculating the radiation, we may replace the line by a loop, whose area, inductance and resistance are those of the whole line; the capacitance and conductance play no part.

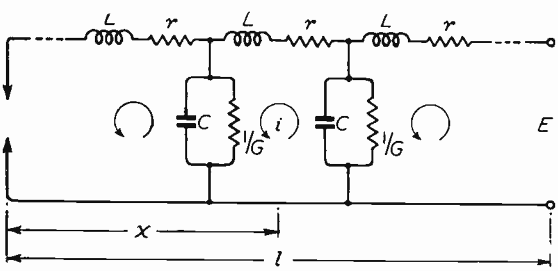

Fig. 4. *An equivalent circuit, in which the ignition lead is considered as a uniform line.*

Now to sum the magnetic moments in this simple way, we must neglect the finite dimensions of the line; however, there are cases where this is admissible, that is to say, the variations of current along the line are large even though the line is short. This is so if the propagation velocity along the line is small compared to the velocity in free space, due to a loading of the line by, for instance, considerable distributed resistance.

Thus, the simple result given above is well suited to the case of suppression by a high distributed resistance along the length of the ignition lead.

It seems likely that, even where the velocity along the line is about equal to the velocity in space, the result given is significant, since the effect of the different distances between the receiver and the various parts of the line may well be to distort the field pattern rather than to change the total amount of radiation.

If it should be desired to allow for the size of the radiator, the analysis is not, in principle, difficult. The field due to each element is written down, in terms of the magnetic moment of the element and the delay due to the time of propagation. The total field is then integrated over all the elements. We then have the total field in operational form and to investigate the effect of this on a receiver tuned to a certain frequency, we handle the operational expression in the same way as was done in Section 2, putting $p=j\omega$. By this means we get an equivalent impulsive field. Having done this for one bearing, we proceed further and obtain the radiation pattern.

While this could be done, it is doubtful whether the effort would be justified. It is evident that the first resonance would occur when a linear dimension of the ignition system (the diameter of the loop, for instance) approximated to a half-wavelength. In practice this would happen near the top of our band.

We may, therefore, conclude that it is not unreasonable to replace the uniform line by its lumped inductance; where distributed resistance is used for suppression it is perfectly justifiable to replace the line by its lumped inductance and resistance.

4. Some Numerical Cases

In this section we deal with experimental results that have been published and see how well they are explained by the equations that have been developed in the previous sections. The discussion splits into unsuppressed systems, suppression by lumped resistors and suppression by distributed resistance.

For an unsuppressed system we have equation (2.1), which states that the effective peak field is independent of the receiver frequency. One might wonder whether there would not be resonances within the band 40-650 Mc/s at the lower end due to the self-capacitance of the magneto or spark-coil and at the upper end due to the dimensions of the ignition system. However, according to George,[4] the effective field is substantially flat between 40 and 450 Mc/s ; it is also substantially flat, according to Pressey and Ashwell,[3] between 40 and 650 Mc/s. It is true that the second reference shows signs of resonances at the higher frequencies, but as they are always at the same frequencies for different ignition systems, they seem to be due to the measuring apparatus.

As pointed out previously,[1] equation (2.1) gives a magnitude of field agreeing well with George's experimental figures ; it also agrees within a few decibels with Pressey and Ashwell's figures.

It therefore seems that equation (2.1) is established as a useful formula for the unsuppressed field in this band of frequencies.

For suppression by lumped resistors, Pressey and Ashwell give results both on cars and on a basic ignition system simulating the ignition system of a car. It is more interesting to consider their results on the basic system, since certain resonant effects are obscured on the cars, due presumably to the multiple ignition leads. The measurements were made in three parts :—

Case 1. A resistor at the sparking-plug.

Case 2. A resistor at the magneto.

Case 3. A resistor at both plug and magneto.

It is reasonable to take Fig. 3 as an equivalent circuit to explain these results ; this is probably the simplest circuit that can be devised to differentiate between the three cases. Accordingly we use equations (2.6), (2.7) and (2.8).

In comparing the measurements with the equations, the inductance L is estimated from the dimensions given in the reference at 0·9 μH ; C is chosen at 2·3 pF to agree with the measured resonant frequencies ; and r_1 and r_2 are taken as 2,500 ohms. Now the resistances used in the experiment were 10,000 ohms, but it seems unlikely that they had an effective resistance, at 100 Mc/s and over, of more than 2,500 ohms, due to their distributed self-capacitance and capacitance across their terminals. The lower value of resistance was chosen to give agreement between the curves.

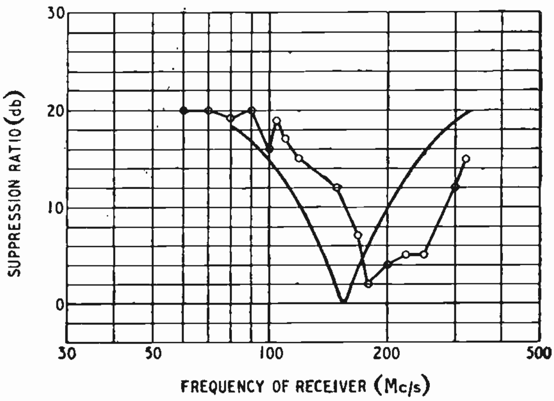

Fig. 6. *Similar to Fig. 5, but with a resistor at both plug and magneto.*

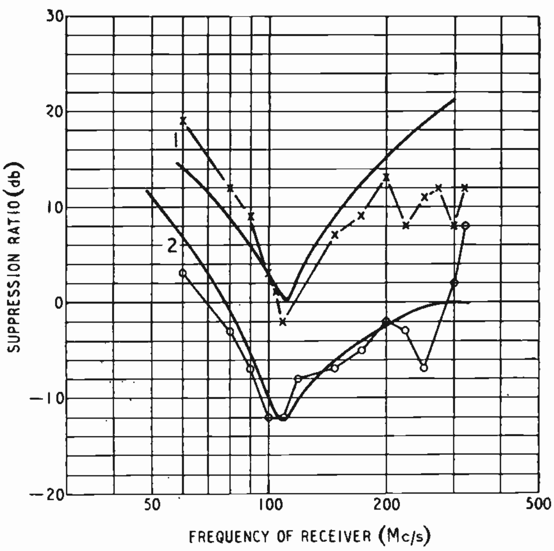

Fig. 5. *The suppression ratio with lumped resistors. The full lines are calculated curves and the broken lines are experimental results taken from Fig. 5 of reference (3) ; 1. Resistor at plug ; 2. Resistor at magneto.*

The results are exhibited in Figs. 5 and 6 : it will be observed that the general shape is the same for the calculated and measured curves. Thus the equivalent circuit of Fig. 3 seems adequate to explain the main characteristics of suppression by lumped resistors, which are :—

Case 1. (Plug resistor.) A resonance at which the suppression is zero.

Case 2. (Magneto resistor.) A region of frequency over which the suppression is negative—i.e. the field is increased.

Case 3. (Both plug and magneto resistor.) A resonance at which the suppression is zero, but at a higher frequency than for Case 1.

It may also be expected that the equations will give reliable numerical values for the suppression ratio, if the precaution is taken of measuring the effective resistance of the resistors at the frequencies concerned.

Passing now to suppression by distributed resistance, it has been shown in Section (3) that we are justified in taking as the equivalent circuit for this case a lumped inductance and resistance. The relevant equation for the suppression ratio is therefore (2·5). Pressey and Ashwell give measurements of the suppression ratio with distributed resistance, both on cars and the basic system ; we will discuss the latter, as being probably more reliable. For this case we will calculate the actual radiated field, rather than the suppression ratio, and accordingly Fig. 7 shows the peak field strength calculated for the conditions of the measurement. These are taken as

$$L = 0{\cdot}9\ \mu\text{H}\ ;\quad A = 0{\cdot}1\ \text{m}^2\ ;\quad R = 18{\cdot}5\ \text{m}\ ;$$
$$B = 2{\cdot}5\ \text{Mc/s}\ ;\quad r = 10{,}000\ \text{ohms}\ ;\quad E = 11\ \text{kV}.$$

All except the last are either stated or implied in the description ; the voltage is chosen to make the results agree.

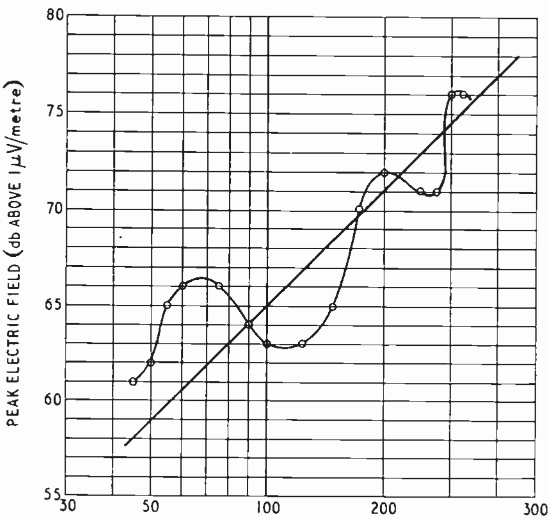

Fig. 7. *The peak electric field in free space from an ignition system suppressed by distributed resistance. The full line is calculated, and the experimental points derived from reference* (3). *Note that the level of unsuppressed radiation is calculated as* 89 *db above* 1 μ*V/metre.*

On the same figure are shown the experimental points, derived from Figs. 4 and 6 of the reference. It will be observed that the general agreement is good, with the exception of the rather remarkable undulations in the experimental curve ; the cause of these is not clear, but peaks and troughs occur at or near multiples of 70 Mc/s. To some extent this effect is seen in all the illustrations of the reference and may possibly be due to a mismatched aerial-feeder cable.

It may be objected that the figure chosen for the sparking voltage, 11 kV, is high, particularly as the plug was presumably not under compression. To some extent there seems a discrepancy here, although not a large one ; but it may be in the measurement rather than in the theory, for the following reason : the measurement was made with the ignition lead in a horizontal loop close to the ground and the receiving aerial was only 10 ft above ground level. Thus the image of the loop tends to cancel the field near ground level, the degree of cancellation depending on the reflectivity of the ground. Therefore in coverting the measured figures into free-space figures, a small uncertainty in the reflectivity would have a large effect.

On the whole, it seems a fair summary of this section to say that the agreement between the equations and published measurements is satisfactory, for unsuppressed radiation, and for radiation from systems suppressed by both lumped and distributed resistance.

5. Conclusions

The previous simple theory, which led to the conclusion that the radiated field of an ignition system is impulsive and affects all receivers in a way independent of their tuned frequency, has been extended to cover resonances in the ignition system and the introduction of suppressing devices. It has been shown that the field is still impulsive, but of an amplitude modified by the impedance of the ignition system at the receiver frequency.

In the unsuppressed case, the effect of resonances is apparently small in the band of frequencies 40-650 Mc/s.

Suppression by lumped resistors is not very satisfactory, as there are frequencies well within the band at which the suppression ratio may be zero or negative. Suppression by distributed resistance is much more satisfactory, as there are not likely to be any resonances within the band.

The agreement between the theory and published measurements is satisfactory, and the treatment may easily be extended to cover more complicated cases than have been considered here.

The formulæ for the two most important cases, unsuppressed radiation and suppression by distributed resistance, are both simple.

Acknowledgment

The writer wishes to express his acknowledgment to the Directors of Standard Telephones and Cables, Ltd., for permission to publish this paper.

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MICROWAVE AERIAL-RADIATION PATTERNS

Errors Recorded on Field Sites

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SUMMARY.—This paper describes an investigation of the magnitude of errors involved in measuring the side-lobe amplitudes in the radiation patterns of 3-centimetre fan-beam aerials. Errors due to the length of the site and to the size of the aperture of the transmitting aerial are briefly discussed while errors due to ground reflections and to the measuring equipment are treated in more detail. The standard deviation of side-lobe amplitudes in the radiation patterns of cheese aerials is found to be 1·4 db for measurements on two typical field sites. It is concluded that the presence of trees, hedges and similar objects near radiation-pattern measuring sites are the largest contributing factor to errors in the measurement of side-lobe amplitude.

Introduction

THIS paper describes an investigation of the degree of precision with which the side-lobe structure of three-centimetre fan-beam aerials may be examined on typical field sites. The side-lobe amplitudes of a cheese aerial have been compared when its radiation patterns at three frequencies were recorded on a near approximation to a 'free-space' site and when they were recorded on two typical field sites.

The analysis of the results of this investigation is immediately applicable to the problem of designing a navigational radar aerial to have side-lobe amplitudes below certain specified limits. The Ministry of Transport Performance Standards for Marine Radar[1] require the aerial side-lobe level within $\pm 10°$ from the direction of the main beam to be more than 20 db below the main beam level, and outside $\pm 10°$ to be more than 26 db below the main beam level. Manufacturers of Civil Marine Radar equipment, therefore, must design their aerials to have a side-lobe structure within these limits. This paper has been written to show the magnitudes of the errors involved in the necessary field measurements and to discuss the principal factors contributing to them.

To record the radiation pattern of a microwave aerial it is ideally necessary to have the measurement system in free space with its terminals infinitely far apart. This ensures that a plane-polarized wave is incident at the aperture of the receiving aerial under examination and that no energy is reflected or diffracted by objects external to the system. Only an approximation to this ideal arrangement can be obtained in practice; this results in the introduction of errors into the recorded radiation pattern. A typical measuring site for microwave-aerial radiation patterns consists of a large, flat field with a transmitter and a receiver mounted as high as practicable above the ground. The aerial under examination is normally connected to the receiver and is rotatable. The transmission aerial at the other end of the site is fixed in position and is arranged to illuminate the ground as little as possible. The site should be as clear of trees, hedges and buildings as possible as these can cause considerable trouble by reflecting energy from the transmitter to the receiver. A much better type of site for aerial-pattern recording is that where the terminals of the system are situated on hills or cliffs with a deep valley or ravine between. Such a site is much less liable to have ground and tree reflections and closely approaches the ideal free-space site.

The errors in radiation patterns recorded on such field sites may be divided into three principal groups:—

(a) those due to the transmitting and receiving terminals being spaced by a finite distance, which may be called *Base Line Errors*;

(b) those due to lack of uniformity in energy distribution of the incident wavefront at the aperture of the receiving aerial, which may be called *Transmitting Aerial Errors*; and

(c) those due to reflections from the ground and nearby objects necessarily inherent in any typical field measuring site, which may be called *Site Errors*.

(To the above must be added the errors due to inaccuracies in the measuring equipment and in the reading of associated meters.) These errors will now be examined separately. The first two will be treated briefly as an existing publication[2] gives full descriptions of these errors and their magnitudes. The third will be treated in some

MS accepted by the Editor, February 1950

detail as there is little information in the literature on the probable magnitude of this type of error.

Base Line Errors

As the transmitting aerial radiates a spherical wave, the phase front of the wave incident at the aperture of the receiving aerial will be linear only when the distance between the aerials is infinite. For a finite separation distance the phase front will be curved and the recorded radiation pattern of the receiving aerial will be different from the pattern produced by an incident plane wave. This difference will, however, be small if the amount of phase curvature is small and it is generally accepted, and can be verified by theory, that the error in the radiation pattern is negligibly small if the phase difference in the wavefront between the centre and the edge of the receiving-aerial aperture is less than or equal to one-sixteenth of a wavelength. This imposes a lower limit on the length of the site which is given by

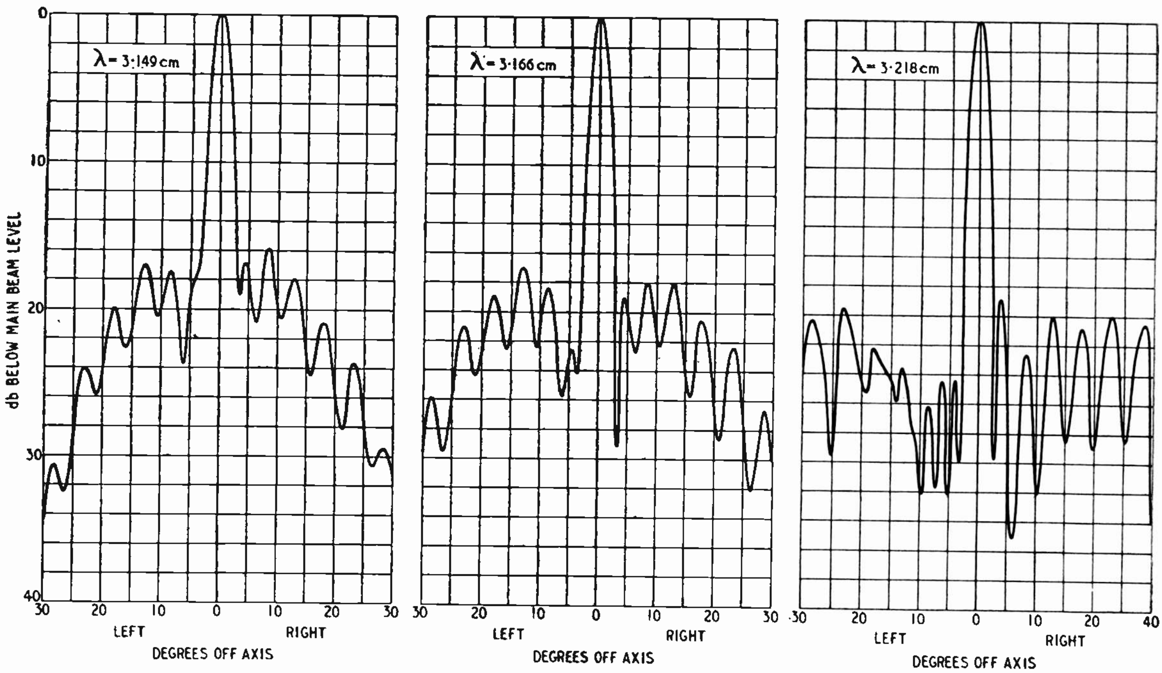
$$r \geqslant 2a^2/\lambda \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where r = length of Base Line of Site.
a = width of aperture of receiving aerial under examination.
and λ = wavelength.

Thus if (1) is satisfied Base Line Errors are negligible.

This assumes that the receiving aerial is focused to receive a plane wavefront; if this is not the case then these errors may be measurable. However, the majority of normal microwave aerials are focused systems and (1) gives good assurance of freedom from Base Line Errors.

If (1) is not satisfied the measured radiation pattern changes quite rapidly as the base line is decreased. The effect is that the minima of the pattern increase in level and become less sharp and distinct. The side-lobe level increases, the first side-lobe grows and eventually becomes a shoulder on the main lobe, after which it is absorbed within the main lobe. In a typical case, as the phase difference between the centre and edge of the receiving-aerial aperture changed from 0 to $\lambda/24$ to $\lambda/12$, the first side-lobe amplitude changed from 21 db to 20·9 db to 18 db below the main beam level.



Figs. 1, 2 and 3. *Horizontal radiation patterns of test cheese on site A at wavelengths of* 3·149, 3·166 *and* 3·218 *cm respectively.*

Transmitting Aerial Errors

It is desirable to make the beam width of the transmitting aerial as small as possible to minimize the illumination of the ground, trees and other objects on or near the site. If the transmitting-aerial beam width is made so small that the aperture of the receiving aerial is not uniformly illuminated then the recorded pattern will be in error. This imposes a maximum size for the transmitting-aerial aperture. If the variation of illumination between the centre and edge of the receiving-aerial aperture is to be less than 0·25 db,

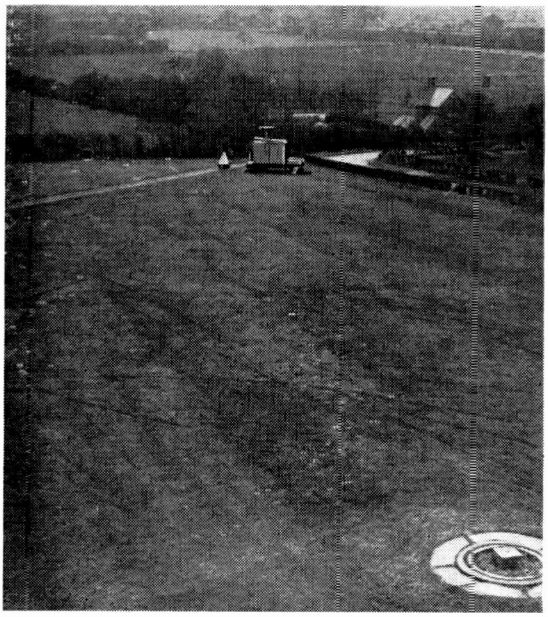


Fig. 4. *Photograph of test site B.*

it has been stated[2] that the directivity of the transmitting aerial should be such that one-eighth of its beam angle between zeros is greater than the angle subtended at the transmitter by the receiving-aerial aperture.

This angle is $\theta = a/r$ radians, using the same notation. The angle between zeros of the main beam of the transmitting aerial is given approximately by

$$\phi = 2\lambda/a_T \text{ radians}$$

where a_T is the aperture width of the transmitting aerial which is assumed to have a uniformly-illuminated rectangular aperture.

So the condition is $a/r \leqslant \lambda/4a_T$

$$\text{or } a_T \leqslant r\,\lambda/4a \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

If (1) holds as an equality then an easily remembered result is obtained; viz., $a_T \leqslant a/2$. Condition (2) gives a very uniform illumination of the receiving-aerial aperture, but the beam width of the transmitting aerial may be wide enough to illuminate objects on the site and so cause disturbing reflections. If the 0·25-db figure for variation in illumination across the receiving-aerial aperture is relaxed to 1·0 db then a formula* for a_T is

$$a_T \leqslant \lambda r/2.13a \qquad \ldots \quad \ldots \quad \ldots \quad (3)$$

Either condition (2) or (3) may be used depending on the required accuracy and the nature of the measurements being carried out.

As the directivity of the transmitting aerial is increased and the aperture illumination of the receiving aerial becomes less uniform, the side-lobes decrease and the width of the main beam increases slightly. In a typical case when the aperture illumination of the receiving aerial at the centre and edge of the aperture differed by 0, 1 and 2 db successively, the first side-lobe changed from 21 db to 21·8 db to 23·3 db below the main beam level, the aperture phase distribution being constant.

Site Errors

If the transmitting aerial illuminates the ground between the aerials or any objects such as trees, hedges or buildings near the site, energy will be scattered and the field at the aperture of the receiving aerial will be due to the direct radiation from the transmitter and the scattered radiation. This can cause two disturbing effects.

*Private communication from J. L. Jedrychowski and L. G. Reynolds.

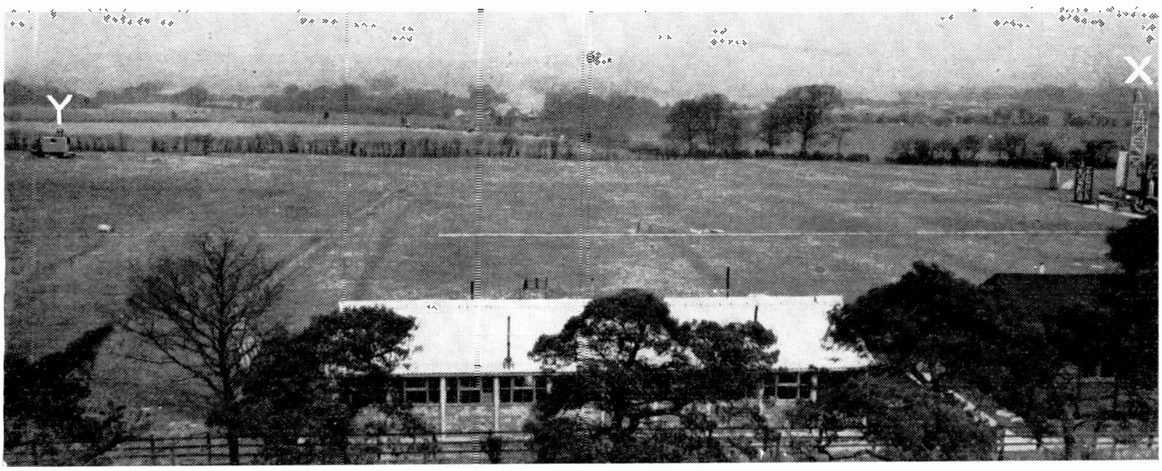
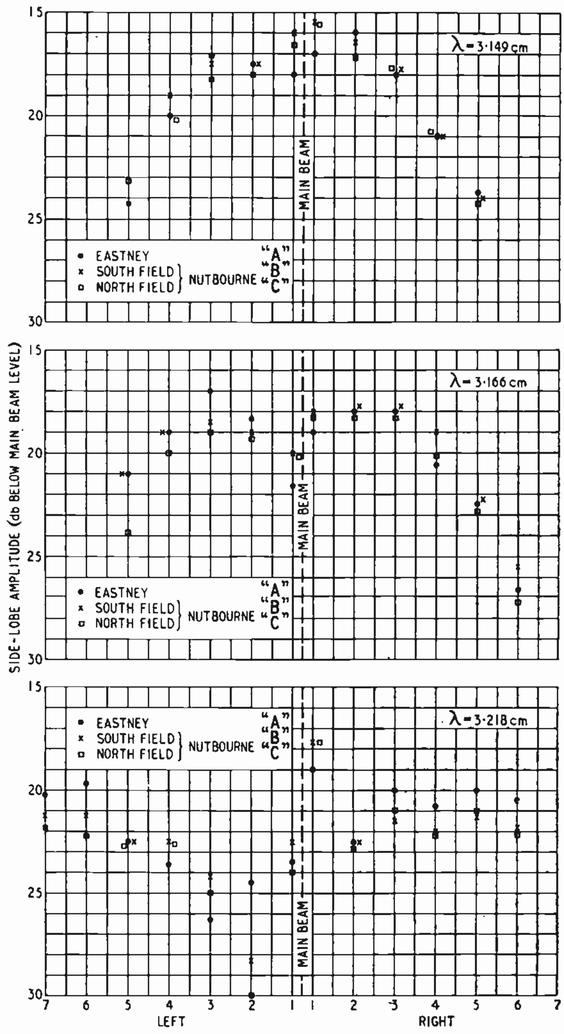


Fig. 5. *Test site C showing the transmitter tower X and the receiver cabin Y.*

If the grass, trees or hedges are being moved by the wind, a considerable fluctuation on the receiver output meter may occur which can be sufficient to make even reasonably accurate readings impossible. Also the recorded radiation patterns of a given aerial on several field sites with ground illumination may differ, particularly in side-lobe amplitudes, by measurable amounts. The first effect is not very serious and is absent on still days. It is most readily caused by long grass blowing in the wind and is usually removed when the grass is cut. In order to study the magnitudes of variations due to the second effect a series of experiments has been carried out which are described below :—

A cheese aerial of aperture 2 ft × 3 in, designed for horizontal polarization, was taken to a particularly good site where its radiation patterns at wavelengths of 3·166, 3·149 and 3·128 cm were recorded by hand plotting, observations being taken every $\frac{1}{4}°$ to 30° on each side of the main beam. These radiation patterns are shown in Figs. 1, 2 and 3 where they are plotted in decibels below the main beam level against degrees rotation.



Figs. 6, 7 and 8. *Charts of side-lobe levels of test cheese at sites A, B and C for wavelengths of* 3·149, 3·166 *and* 3·218 *cm respectively.*

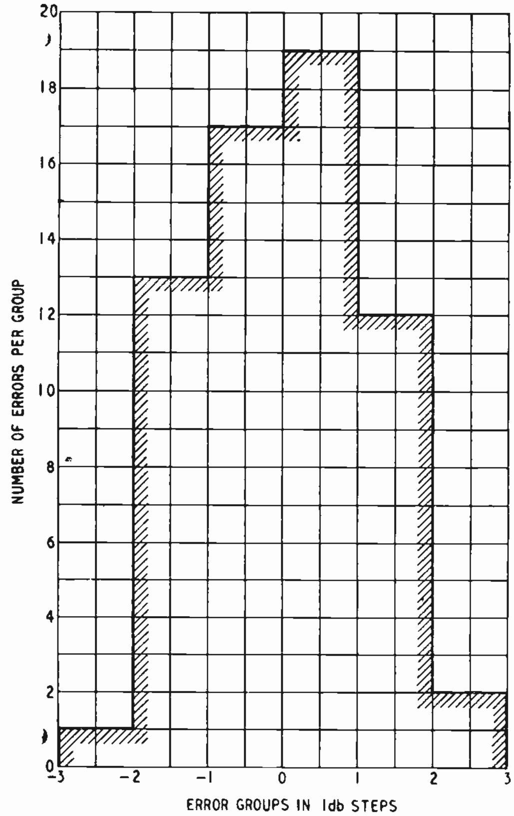


Fig. 9. *Histogram of errors in the measurement of side-lobe levels of test cheese for sites B and C against A.*

Radiation patterns were recorded at different wavelengths because site errors are of a random-interference nature and so will depend to some extent on wavelength. Observations at different wavelengths are therefore desirable for the statistical analysis to follow.

The site consisted of two 100-ft towers with no intervening objects, the buildings on the ground being 80 ft below the level of the aerials. The distance between the towers was such that equation (1) was satisfied for the receiving aerial under examination and the transmitting aerial used satisfied (3). Under these conditions, with the vertical beamwidth of the transmitting aerial approximately 5° to the 6-db points, ground illumination was quite negligible due to the large aerial height and the relatively short distance (190 ft) between the towers. Thus the site was a good approach to the ideal. This will be called Site A.

The same cheese aerial was then examined on two typical field sites (B and C) with ground illumination. Automatic recorders were used on both sites and conditions (1) and (3) were satisfied by the length of each site and by the aperture of each transmitting aerial. Fig. 4 is a photograph from the transmitting aerial of Site B mounted on a 40-ft wooden tower, looking at the receiving aerial on a rotatable cabin. There are hedges and trees near the receiving aerial which is mounted 14 ft above ground level, but the site is a good example of a flat, unobstructed field site. Fig. 5 shows Site C. The transmitting aerial is on a 40-ft wooden tower at X and the receiving aerial under examination is 14 ft above ground on a rotatable cabin at Y. The site is also a good example of a flat, open unobstructed field site, but there is a hedge and a tree near the receiving aerial.

The cheese radiation patterns on these sites at the same wavelength were very similar in shape and configuration to the patterns measured on Site A—the same number of side-lobes occurred at the same angular positions, the main beam widths were the same and in general there was good agreement except in the amplitude of the side-lobes where a considerable amount of scatter was observed. To illustrate this Figs. 6, 7 and 8 are diagrams of side-lobe amplitudes in decibels below the main beam level for the cheese at 3·166, 3·149 and 3·128 cm wavelengths measured on the three sites A, B and C. It will be noticed that the scatter about the site A results is of a random nature. The deviations from site A results represent the errors in side-lobe amplitudes measured on field sites against the free space values of Site A. The factors contributing to these errors will be considered later. A histogram* of the differences between Site A and Sites B and C measurements at all three frequencies was drawn using 1-db error groups. This showed a normal form of error distribution and the variance and the standard deviation were calculated from the observations in the usual manner.

Fig. 9 shows the histogram of errors between Sites A and B and C. The standard deviation was found to be 1·4 db and, using this percentage probabilities of certain side-lobes near the 20-db

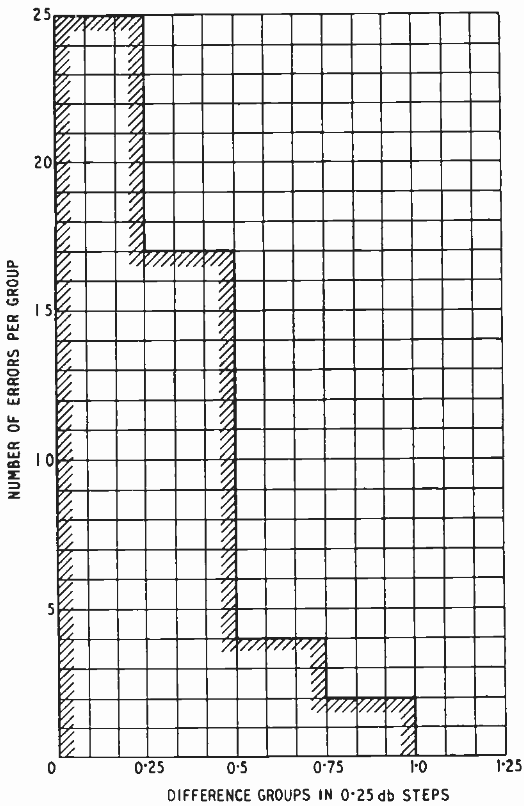


Fig. 11. *Histogram of magnitudes of errors due to automatic recording.*

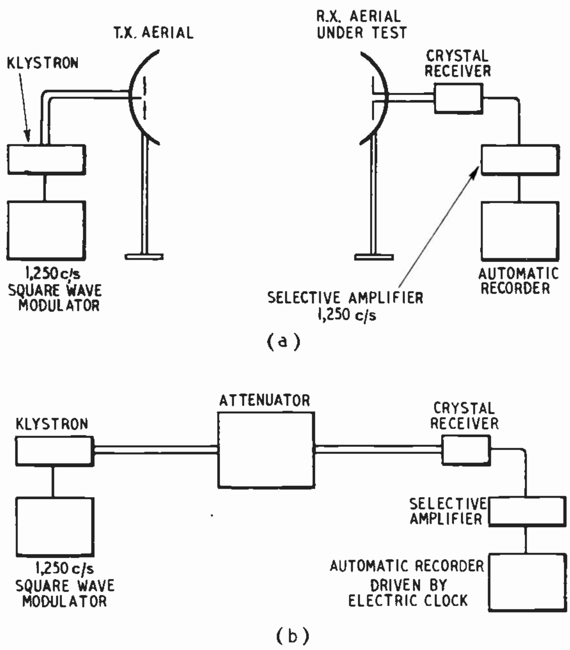


Fig. 10. *Arrangement of apparatus (a) and block diagram of receiver stability testing equipment (b).*

* *Histogram* (a diagram composed of cells). A non-continuous form of frequency distribution in which the number of observations lying within a given range is plotted as a rectangle standing on a base representing that range.
See W. R. Hinton, "Graphical Statistical Methods," *Wireless Engineer*, Dec. 1949, p. 400.

and the 26-db levels of the Ministry of Transport specification being within the specification were calculated. These results are given in Table 1*.

TABLE 1

% Probability of being within Specification	>20 db Specified	>26 db Specified
	Side-lobe amplitude in db below main beam level	Side-lobe amplitude in db below main beam level
0·6	16	22
2·0	17	23
7·0	18	24
26	19	25
50	20	26
74	21	27
93	22	28
98	23	29
99·4	24	30

* The second and third columns refer to side-lobes within $\pm 10°$ and outside $\pm 10°$ of the centre line of the main beam respectively.
Side-lobes within $\pm 10°$ are required to be more than 20 db below the main beam level and side-lobes outside $\pm 10°$ are required to be more than 26 db below the main beam level.
The % probability of a range of side-lobes being below the appropriate specification levels is given in the first column.

Factors Contributing to Side-lobe Amplitude Variations

The principal factors contributing to the side-lobe amplitude variations observed were considered to be

(a) Variations in the transmitting and receiving equipment ;
(b) Variations in the automatic-recorder tracings ; and
(c) Variations caused by different field sites.

All of these are included in the side-lobe amplitude variations already observed which represent the total errors occurring in practice.

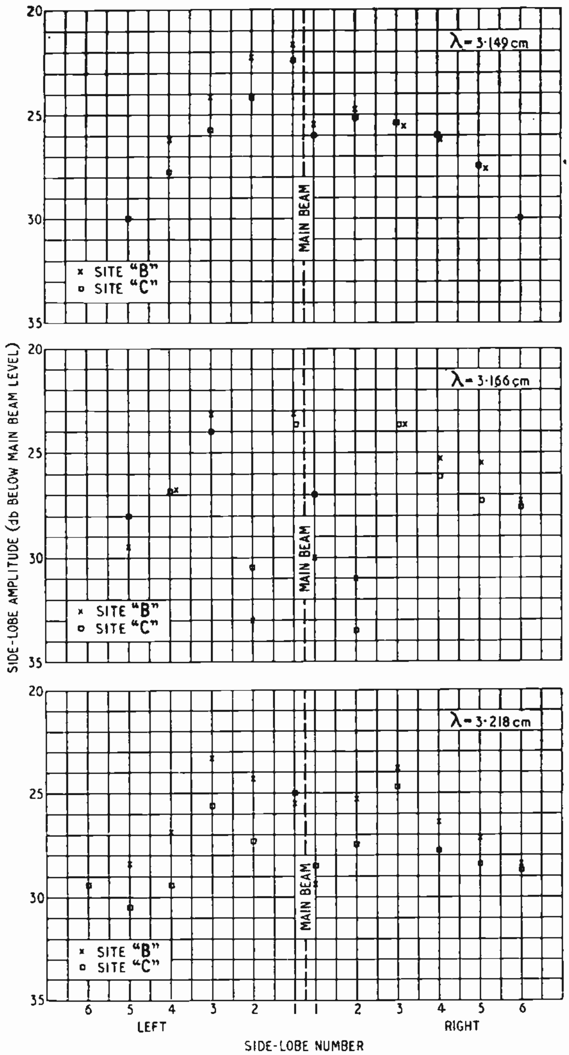
(a) Variations due to Transmitting and Receiving Equipment.

The transmitter used in the above experimental work was a reflex-klystron, square-wave modulated at a frequency of 1,250 c/s. The receiver was a tuned crystal attached to the test aerial which fed an audio-amplifier tuned to 1,250 c/s. [See Fig. 10 (a).] To test the stability of this equipment, the transmitter and receiver were set up on the bench and connected by a length of waveguide containing an attenuator. [See Fig. 10 (b).] This arrangement removed any fluctuations due to the free-space propagation element in the field measuring system. The output of the amplifier was connected to an automatic recorder driven by an electric clock and the equipment was allowed to run for several hours—the output being recorded on a paper chart. While the equipment was running the range switches on the amplifier were operated, the signal lever was altered and the frequency was changed. The total signal fluctuations resulting from all these causes were always considerably less than 0·25 db and so were effectively negligible. The experiment was repeated on a field site, the waveguide being replaced by the free-space propagation path, thus making operating conditions the same as in normal radiation-pattern measurements. Over a run of several hours with range switches being operated, frequency being changed and signal level varied, the maximum fluctuation was 0·25 db. This was a small rapid fluctuation due to the free-space propagation path and presumably caused by the wind moving the transmitting aerial.

It was therefore concluded that variations due to equipment instability were at the most 0·25 db. The calibration of the receiving equipment is obtained by calibrating the crystal and amplifier together (as a unit) against a sub-standard r.f. attenuator. This method is very simple and straightforward and for extreme accuracy may be carried out at each frequency being used. The amplifier meter readings or recorder chart marks are in this way directly related to decibels and the probable errors involved in the amplifier meter readings are small fractions of a decibel—the accuracy of the r.f. attenuator calibration. Thus the amplifier meter readings may safely be taken as a good standard.

(b) Variations in the Automatic-recorder Tracings.

Depending on the speed of recording, the side-lobe amplitudes on the pen-recorder chart may be either too small or too large due to the pen dragging on the paper at low speeds and overshooting the true level of peaky lobes at higher recording speeds. To obtain an estimate of these errors a considerable number of radiation patterns were recorded by the pen recorder and the side-lobe amplitudes noted simultaneously from the amplifier meter. Taking the visual observations as standard the errors in side-lobe amplitude levels on the recorder charts were noted and are shown plotted in histogram form in Fig. 11. Fig. 11 is a histogram of the moduli of the errors and shows that errors between 0·25 and 0·5 db occur most frequently. These errors were probably not present in the previous experiment on equipment stability as the pen movement was at a constant speed practically all the time it was running.



Figs. 12, 13 and 14. *Chart of side-lobe levels of a 2 ft dish on sites B and C for wavelengths of* 3·149, 3·166 *and* 3·218 *cm respectively.*

(c) *Variations caused by Different Field Sites.*

As the previous two error magnitudes have been shown to be small it is reasonable to conclude that the total errors of Fig. 9 are principally due to variations caused by different field sites. As the test cheese aerial had a vertical beamwidth of approximately 40° to 6-db points it could 'see' a considerable amount of the ground. To investigate the importance of this factor a second test aerial with similar horizontal directivity and a 4° vertical beam was examined on the same two field sites. This aerial could therefore see very much less of the ground than the test cheese and radiation patterns were recorded at the same three frequencies. The scatter in side-lobe amplitudes is shown in Figs. 12, 13 and 14, which show that these variations are of the same order as those obtained with the test cheese. A statistical significance test between the two groups of results on Sites B and C was made and a figure of 0·2 obtained which indicates very little significance in the fact that the ground cannot be 'seen' by one receiving aerial and can be 'seen' by the other. That is, the test showed that there was no significant difference between the random nature of one set of results and the random nature of the other. It would therefore appear that energy reflected from trees, hedges and buildings is more important in producing site errors than energy reflected from the ground.

These results indicate the importance of having a site clear of reflecting objects of any kind and the histogram of Fig. 9 shows the distribution of errors likely to be encountered with typical field sites.

Conclusion

The principal factors contributing to the total errors involved in the measurement of side-lobe amplitudes of three-centimetre fan-beam aerials have been described and their contributions investigated. The calculated standard deviation of 1·4 db is intended to provide aerial designers with the order of magnitude of site errors in side-lobe amplitude measurements carried out on typical field sites. These errors are somewhat greater than has generally been believed.

It is shown in Table 1 that to insure a high probability of measured side-lobe amplitudes being within a given specification, the measured amplitudes should be considerably lower than the specification level.

Acknowledgment

This paper is published with the approval of the Lords Commissioners of the Admiralty, but the responsibility for any statements of fact or opinions expressed rests solely with the authors.

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[1] "Marine Radar Performance Standards," H.M. Stationery Office, London.

[2] Cutler, C. C., King, A. P., and Kock, W. E., "Microwave Antenna Measurements," Bell Telephone System Monograph, B1526.

CORRESPONDENCE

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

Wide band Two-phase Networks

SIR,—In his comments on my paper[1] Mr. N. O. Johannesson has emphasized the fact that the computation of elliptic functions by Landen transformations from circular functions is a laborious process, and he suggests as an alternative a method based on the Theta functions. While I must agree that such a method is quicker I feel, at the same time, that its advantages would only be apparent when carried out by a trained mathematician. The simplicity of the Landen transformations on the other hand makes them much more suitable for reliable handling by an industrial computing department. It was for this reason that I suggested their use.

However, both methods are fundamentally unsound, for they proceed, by one means or another, to relate the required function to an associated circular function whereas, in fact, the functions occurring in practically all these network problems are much more nearly like hyperbolic functions. The logical thing to do is to reverse the Landen transformations and work from a suitable hyperbolic function. I realized this while writing the paper but at the time was uncertain as how best to calculate the hyperbolic function with which to start the transformations. This I have now discovered; the method is as follows.

1. Compute the descending sequence of complementary moduli, $k'_o, k'_1 \ldots k'_s$, related by the recurrence formulæ

$$k'_{m+1} = [k'_m/(1+k_m)]^2 \quad \ldots \quad (1a)$$

$$1 = (k'_m)^2 + (k_m)^2 \quad \ldots \quad (1b)$$

and commencing with $k'_o = \omega_a/\omega_b$. The sequence terminates with k'_s when $k'_s \leqslant 0{\cdot}001$.

2. Compute

$$K_s = \log_e (4/k'_s) \quad \ldots \quad (2)$$

and $cs_s = \text{cosech}\ [(2\sigma + 1)K_s/n2^{s+1}] \quad \ldots \quad (3)$

3. With (3) as the starting function obtain the required elliptic function $cs\ [(2\sigma+1)K/2n] = cs_o$ by the recurrence relation.

$$cs_{m-1} = \frac{1}{1+k'_m}\left(cs_m - \frac{k'_m}{cs_m}\right) \quad \ldots \quad (4)$$

The beauty of the scheme is that the tighter the design requirements (i.e., the larger the bandwidth ratio) the easier does the computing become. For bandwidths exceeding one decade only one step is required to give adequate accuracy. In the numerical example of the paper

$k'_o = 0{\cdot}05$; $k_o = 0{\cdot}998749$; $k'_1 = 0{\cdot}000625782$

$K_1 = \log_e (4/0{\cdot}000625782) = 8{\cdot}76281$

$\text{cosech}\ (K_1/16) = 1{\cdot}73771$

$\text{cosech}\ (3K_1/16) = 0{\cdot}401816$

From these hyperbolic functions one transformation using (4), followed by a division by $\sqrt{k'_o}$ gives the pole values :—

7·7648 and 1·7888,9

correct to at least five significant figures.

Among the formulæ given by Mr. Johannesson (7) and (8*a*) appear to be incorrect; should not $\sqrt{q'}$ have been written for q'? Fortunately the two errors cancel one another out.

Since the writing of the paper an additional result has been discovered which is of some engineering interest. It is that the all-pass networks required in the two-phase circuit may be made with resistors and capacitors only; this simplifies the problem of manufacture in very wideband cases. A description of these networks will be published shortly.[2]

H. J. ORCHARD.

Kingsbury, London, N.W.9.

[1] "Synthesis of Wideband Two-Phase Networks," *Wireless Engineer*, March 1950, p. 72.

[2] "The Synthesis of RC-Networks to have Prescribed Transfer Functions." To be published shortly in *Proc.Inst.Radio Engrs.*

SIR,—In the last few months three articles on wide band two-phase networks have been published (by Darlington[1], Orchard[2], Saraga[3]) in which elliptic functions are used for obtaining a Tchebycheff approximation to the ideal performance. Though the expressions for this approximation given by the three authors must be—and are in fact—equivalent, as they define the same mathematical relation, they differ very much in the form in which they are stated.

It is thought that a demonstration of this equivalence may be of interest to the readers of these articles. The equivalence will be proved by reference to certain standard formulæ obtained in the theory of elliptic functions and their transformation (see, e.g., Cayley[4]). We shall assume that the required constant phase difference is $\pi/2$. As the three authors differ in the symbols they use, it is necessary to restate their expressions for the Tchebycheff approximation using the same symbols throughout. These symbols, which are defined in the figure, have been so chosen that Cayley's symbols (in his discussion of the quadric transformation) can be used without any alteration.

With these new symbols Darlington's expressions for the Tchebycheff approximation are :—

$$x = (1/\sqrt{k_o})\ \text{dn}\ (u,k_o') \quad \ldots \quad (1a)$$

$$y = (1/\sqrt{\lambda})\ \text{dn}\ [n\ (\Lambda'/K_o')u,\lambda'] \quad \ldots \quad (1b)$$

$$n\ (K_o/K_o') = \Lambda/\Lambda' \quad \ldots \quad (1c)$$

(1c) follows from Darlington's equation (5).

Orchard's corresponding expressions are :—

$$x = (1/\sqrt{k_o})\ \text{dn}\ (u,k_o') \quad \ldots \quad (2a)$$

$$T = \sqrt{\gamma'}\ \text{cd}\ [2n(\Gamma'/K_o')u,\gamma'] \quad \ldots \quad (2b)$$

$$4n\ (K_o/K_o') = \Gamma/\Gamma' \quad \ldots \quad (2c)$$

$$T = (1-y)/(1+y) \quad \ldots \quad (2d)$$

Saraga's corresponding expressions are (see also Baumann's[5] expressions for the same mathematical relation in connection with a different network problem) :—

$$x = \sqrt{k_o}\ \text{sn}\ (v,\ k_o) \quad \ldots \quad (3a)$$

$$y = \sqrt{\lambda}\ \text{sn}\ [(v/M),\ \lambda] \quad \ldots \quad (3b)$$

$$M = K_o/\Lambda = \frac{1}{n}\left(K_o'/\Lambda'\right) \quad \ldots \quad (3c)$$

or (see Saraga's Table 1a)

$$x = \sqrt{k_o}\ \text{nd}\ (v_1,\ k_o') \quad \ldots \quad (3d)$$

$$y = \sqrt{\lambda}\ \text{nd}\ [(v_1/M),\lambda'] \quad \ldots \quad (3e)$$

It is relevant to note here that (3d), (3e) can be derived from (3a), (3b) by means of the substitution

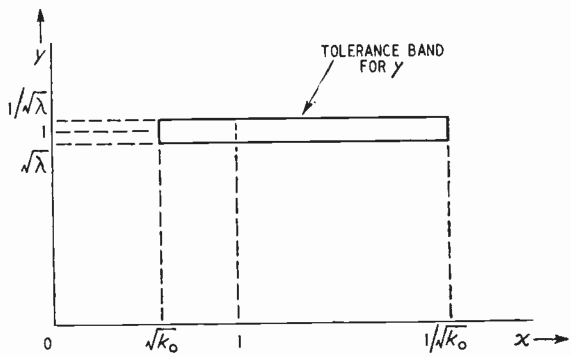
$v = K_o + \mathrm{j}\, v_1$, viz :—

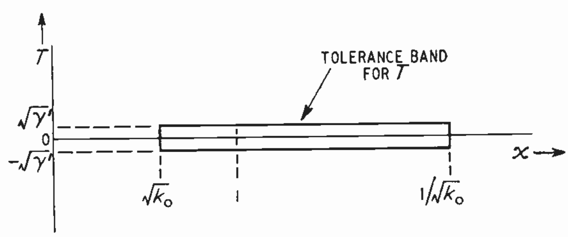
$$x = \sqrt{k_o}\,\mathrm{sn}\,[K_o + \mathrm{j}v_1,\, k_o] = \sqrt{k_o}\,\mathrm{cd}\,(\mathrm{j}v_1,\, k_o)$$
$$= \sqrt{k_o}\,\mathrm{nd}\,(v_1,\, k_o')$$
$$y = \sqrt{\lambda}\,\mathrm{sn}\,[(K_o + \mathrm{j}v_1)/M,\, \lambda] = \sqrt{\lambda}\,\mathrm{sn}\,[\Lambda + \mathrm{j}(v_1/M), \lambda]$$
$$= \sqrt{\lambda}\,\mathrm{nd}\,[(v_1/M),\, \lambda']$$

Having stated the three sets of formulæ we shall now prove their equivalence. We shall start with demonstrating that Darlington's formulæ can be obtained from Saraga's. (3c) is identical with (1c). In (3d) and (3e) we put $v_1 = K_o' + u$. Then

$$x = (1/\sqrt{k_o})\,\mathrm{dn}\,(u,\, k_o') \quad \ldots \quad (4a)$$
$$y = \sqrt{\lambda}\,\mathrm{nd}\,[n\,\Lambda' + n(\Lambda'/K_o')\,u,\, \lambda'] \quad \ldots \quad (4b)$$

(4a) is identical with (1a) as required. If n is odd, (4b) is also identical with (1b) as required. For even values of n the expression defined by (4b) is the reciprocal of that defined by (1b). However, as the change from y to $1/y$ is equivalent to interchanging the output terminals of one of the two phase-shift networks, this change is trivial and (4b) can be regarded as equivalent to (1b) for both even and odd values of n.





β_1, β_2 phase-shifts of the two networks; $y = \tan \dfrac{\beta_1 - \beta_2}{2}$; $T = \tan\left[\tfrac{1}{4}\pi - \tfrac{1}{2}(\beta_1 - \beta_2)\right] = \dfrac{1-y}{1+y}$; x = normalized frequency.

It remains to show that Orchard's expressions agree with Darlington's. Since (1a) and (2a) are identical, it is sufficient to show that (1b), (1c) satisfy (2b), (2c). From (1c) and (2c) we obtain a relation between Λ, Λ' and Γ, Γ' which can be interpreted as follows :—Let λ, k, γ be an increasing series of moduli, k being obtained by a quadric transformation from λ, and γ by the same transformation from k, and let Λ, K, Γ be the corresponding complete functions (quarter periods), then the following relations can be derived :—

$$\tfrac{1}{2}(\Lambda'/\Lambda) = K'/K = 2(\Gamma'/\Gamma)$$
$$2\,\Gamma' = (1 + k)K',\ 2K' = (1 + \lambda)\Lambda'$$
$$k = 2\sqrt{\lambda}/(1 + \lambda)\,;\quad \gamma = 2\sqrt{k}/(1 + k)$$
$$\gamma' = (1 - k)/(1 + k) = (1 - \sqrt{\lambda})^2/(1 + \sqrt{\lambda})^2$$
$$\mathrm{cd}[(1 + k)u, \gamma'] = [1 - (1 + k)\,\mathrm{sn}^2(u,\, k')]/[1 - (1 - k)\,\mathrm{sn}^2\,(u,\, k')]$$
$$\mathrm{cn}\,[(1 + \lambda)u,\, k'] = [1 - (1 + \lambda)\mathrm{sn}^2(u,\, \lambda')]/\mathrm{dn}(u,\, \lambda')$$
$$\mathrm{dn}\,[(1 + \lambda)u,\, k'] = [1 - (1 - \lambda)\,\mathrm{sn}^2\,(u,\, \lambda')]/\mathrm{dn}(u,\, \lambda')$$

Furthermore $\mathrm{sn}^2\,(\tfrac{1}{2}u,\, k') = [1 - \mathrm{cn}(u,\, k')]/[1 + \mathrm{dn}(u, k')]$

By means of these formulæ, and writing w for nu/K_o', we obtain from Orchard's expression (2b)

$$T = \sqrt{\gamma'}\,\mathrm{cd}\,[(1 + k)K'\,w,\, \gamma'] = \sqrt{\gamma'}\,[1 - (1 + k)\,\mathrm{sn}^2\,(K'w,\, k')]/[1 - (1 - k)\,\mathrm{sn}^2\,(K'w,\, k')]$$
$$= \sqrt{\gamma'}\,\{1 - (1 + k)\mathrm{sn}^2[\tfrac{1}{2}(1 + \lambda)\Lambda'w, k']\}\,/\,\{1 - (1 - k)\mathrm{sn}^2\,[\tfrac{1}{2}(1 + \lambda)\Lambda'w,\, k']\}$$
$$= \sqrt{\gamma'}\,\{1 + \mathrm{dn}[(1 + \lambda)\Lambda'w, k'] - (1 + k)[1 - \mathrm{cn}[(1 + \lambda)\Lambda'w, k']]\}\,/\,\{1 + \mathrm{dn}[(1 + \lambda)\,\Lambda'w, k'] - (1 - k)\,[1 - \mathrm{cn}\,[(1 + \lambda)\Lambda'w, k']]\}$$
$$= \frac{(1 - \sqrt{\lambda})\,[(1 + \sqrt{\lambda} + \lambda) - \sqrt{\lambda}\,\mathrm{dn}\,(\Lambda'w,\, \lambda') - (1 + \lambda)(1 + \sqrt{\lambda})\,\mathrm{sn}^2\,(\Lambda'w,\, \lambda')]}{(1 + \sqrt{\lambda})\,[(1 - \sqrt{\lambda} + \lambda) + \sqrt{\lambda}\,\mathrm{dn}\,(\Lambda'w,\, \lambda') - (1 + \lambda)(1 - \sqrt{\lambda})\,\mathrm{sn}^2\,(\Lambda'w,\, \lambda')]}$$

Substituting $\mathrm{sn}^2(\Lambda'w, \lambda') = [1/(1 - \lambda^2)]\,[1 - \mathrm{dn}^2\,(\Lambda'w, \lambda')]$, we obtain, after cancelling identical factors in numerator and denominator, $T = \{\mathrm{dn}\,[n(\Lambda'/K_o')u, \lambda'] - \sqrt{\lambda}\}\,/\,\{\mathrm{dn}\,[n(\Lambda'/K_o')u, \lambda'] + \sqrt{\lambda}\}$ and, because of (2d),

$$1/y = (1/\sqrt{\lambda})\,\mathrm{dn}\,[n(\Lambda'/K_o')\,u,\, \lambda'] \quad \ldots \quad (5)$$

It will be seen that the r.h.s. of equation (5) which represents Orchard's ($1/y$), agrees with the r.h.s. of (1b); i.e., Darlington's expression for y. Thus, in view of the irrelevance of the interchange of y and $1/y$, the equivalence of all three sets of formulæ has been demonstrated.

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[1] S. Darlington, *Bell Syst. Tech. J.*, Jan. 1950.
[2] H. J. Orchard, *Wireless Engineer*, March 1950.
[3] W. Saraga, *Proc. Inst. Radio Engrs.*, July 1950.
[4] A. Cayley, "Elliptic Functions", 2nd ed., George Bell & Sons, London, 1895.
[5] E. Baumann, *Zeitschr. f. angew. Math.u.Phys.* ("ZAMP"), Vol. 1, pp. 43-52, 1950 (publ. in Switzerland).

The Auto-Correlation Function

Sir,—One of the engineer's difficulties is that new mathematical tools are constantly being invoked for engineering problems. The auto-correlation function is one such piece of mathematics and I hope that the following comments on it will indicate its scope of application and be a guide to some of the sources of information about it. (Others may be able to add further references.)

The auto-correlation function is primarily a device for extracting any periodic components which may exist in an arbitrary function, and its main peculiarity is that it suppresses all information on the *phase* of the components, giving only the squared amplitudes of different frequency components, or 'power spectrum.' The procedure is that if, for example, $I(t)$ is a waveform of current, the corresponding auto-correlation function with interval τ is

$$\psi(\tau) = \underset{T \to \infty}{\text{Limit}} \; \frac{1}{2T} \int_{-T}^{T} I(t) \,.\, I(t+\tau)\, dt \quad \ldots \quad \text{(i)}$$

The function $I(t)$ may represent a probability distribution instead of a known current, so that $\psi(\tau)$ can be calculated for such current functions as 'noise' or a random telegraphic signal, to which ordinary Fourier methods are not strictly applicable. If $\tau = 0$, $\psi(0)$ is identically equal to the mean-square value of $I(t)$, but a second operation is necessary to reveal the frequency components :

$$w(f) = 4 \int_{0}^{\infty} \psi(\tau) . \cos 2\pi f \tau . \, d\tau \quad \ldots \quad \ldots \quad \text{(ii)}$$

(From the form of (ii) the auto-correlation process has sometimes been regarded as a generalized Fourier process.) Thus in order to find the intensity (squared amplitude, or power) at frequency f it is necessary to know $\psi(\tau)$ for all values of τ.

Apart from the frequency analysis of a time function, the auto-correlation function has application to the filtering or 'smoothing' problem. This problem is, given a combination of signal and noise, what is the optimum frequency characteristic for a filter which is to be applied at the receiving end ? In the special case that one desires to minimize the mean-square error, 'error' being defined as the difference between the instantaneous amplitude of signal plus noise and the corresponding amplitude of signal only, the optimum filter characteristic is related to the frequency spectrum of the signal via an auto-correlation function. The criterion of 'minimum mean-square error' is reasonable for an automatic-control (servo) system operating on position, etc., and so the auto-correlation function receives attention in books on control systems. In simple communication systems, however, information is distributed over the frequency band and individual frequency components are important apart from the 'error' as defined above. It is only with 'ideal coding' in Shannon's sense* that one would expect the auto-correlation solution to the filtering problem to be relevant to telecommunication systems.

An easy introduction to the subject has been given by Y. W. Lee and J. B. Wiesner, " Correlation Functions and Communication Applications," *Electronics*, June 1950, p.86.

A more detailed account of the use of an auto-correlation computer as an alternative to a narrow filter has been given by Y. W. Lee, T. P. Cheatham, Jr., and J. B. Wiesner in " Application of Correlation Analysis to the Detection of Periodic Signals in Noise," *Proc. Inst. Radio Engrs.*, Vol. 38, p. 1165 (October 1950).

The application to 'noise' and other random waveforms was discussed by S. O. Rice in Part II of " Mathematical Analysis of Random Noise," *Bell System Technical Journal*, Vol. 23, p.282 (1944).

The general properties and the application to filtering (in 'smoothing' and 'prediction' problems) have been discussed by N. Wiener in two books :—

" The Interpolation Extrapolation and Smoothing of Stationary Time Series " (Wiley, New York).

" Cybernetics " (Wiley, New York, 1948).

A rigorous proof of formula (ii) above and of the converse formula

$$\psi(\tau) = \int_{0}^{\infty} w(f) \cos 2\pi f \,\tau \, df \ldots \quad \ldots \quad \ldots \quad \text{(iii)}$$

is given in Chapter IV, Generalized Harmonic Analysis, of Wiener's book " The Fourier Integral" (Cambridge, 1933), though the auto-correlation function is here denoted simply by '$\phi(x)$' and is not named.

The function is believed to have been first introduced by G. I. Taylor in " Diffusion by Continuous Movements," *Proc. Lond. Math. Soc.* Ser. 2, Vol. 20, p.196 (1922).

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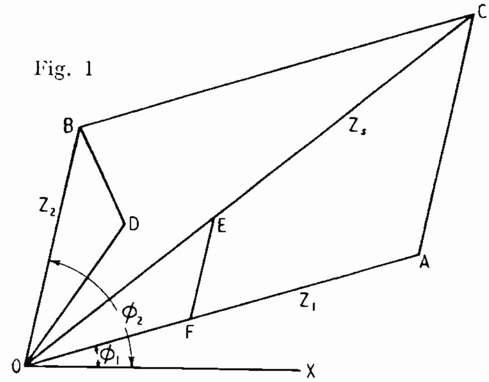
(*Note*: In Rice's paper the reference to Taylor is incorrectly dated " 1920." The paper was *read* in 1920, but published in the *Proceedings* in 1922.)

* C. E. Shannon, " Communication in the Presence of Noise." *Proc. Inst. Radio Engrs*, Vol. 37, p.10 (1949).

Impedances in Parallel

Sir,—The following construction for finding the impedance of two impedances in parallel does not appear to be well known.

Fig. 1



Let $Z_1 \equiv |Z_1| \angle\phi_1$
and $Z_2 \equiv |Z_2| \angle\phi_2$
be the two impedances, represented in Fig. 1 by OA and OB.

Their series impedance $Z_s \equiv (Z_1 + Z_2)$ is obtained from the Parallelogram Law as OC. Make angle AOD equal to angle COB, and make $OD = \frac{OA.OB}{OC}$. Then OD represents Z_p, the parallel combination of Z_1 and Z_2.

A convenient way of drawing OD is to mark off along OC a length OE equal to OB, and through E draw EF parallel to CA meeting OA at F. Then $OF = |Z_p|$. With centres O and B strike arcs of radii OF and EF meeting at D. Then OD represents Z_p.

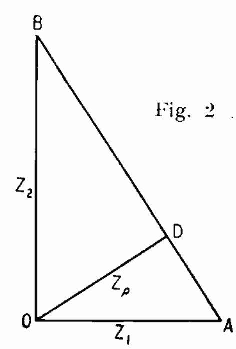


Fig. 2

Proof. $Z_p = \dfrac{Z_1 Z_2}{Z_1 + Z_2} = \dfrac{Z_1 Z_2}{Z_s}$

then $|Z_p| = \dfrac{|Z_1||Z_2|}{|Z_s|} = \dfrac{OA.OB}{OC} = \dfrac{OA}{OC} OE = OF$

and $\text{Arg}\, Z_p = \text{Arg}\, Z_1 + \text{Arg}\, Z_2 - \text{Arg}\, Z_s$
$= X\hat{O}A + X\hat{O}B - X\hat{O}C$
$= X\hat{O}D$

Hence the parallel impedance is given by OD.

In the particular case when OA and OB are at right angles, OD is most simply found as the normal from O on to AB (Fig. 2).

Yours truly,

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NEW BOOKS

Antenna Theory and Design

By H. P. Williams. Vol. I "Foundations of Antenna Theory," pp. 142. Price 21s. ; Vol. II "The Electrical Design of Antennae," pp. 522. Price 63s. Sir Isaac Pitman & Sons, Ltd., Kingsway, London, W.C.2.

These two volumes are intended to cover the entire field of aerial theory, Vol. I dealing with the fundamental theory, and Vol. II with its application to practical designs. Rationalized m.k.s. units are used throughout.

Vol. I commences with a discussion of vectors and the related theorems which enable transformations to be made between line, surface and volume integrals. Maxwell's electromagnetic-wave equations are then developed, and this leads to the conditions applying at the boundary between two different media. Plane waves are treated as a special solution of these equations, and the reflection and transmission coefficients at a plane interface derived ; the retarded vector and scalar potential functions are then developed.

At this stage, which represents approximately one half the first volume, the theory of wave propagation in space has been developed concisely and clearly, and the way is open for the application to aerial problems. The author tackles one of these problems in the last chapter, the cylindrical aerial ; the different approaches are summarized—the Poynting Vector method, the induced e.m.f. method when the current distribution is assumed, and the approximate methods of Hallen and Schelkunoff. The latter two methods are dealt with very briefly, and although the results of the respective workers are quoted, the fundamental difficulties which make an approximate method necessary are not stressed, and the method of deriving these two particular solutions is not explained. The truth is that it is very difficult to apply the general wave theory to aerial problems, and a critical analysis of these two different methods would help the reader to appreciate both the difficulties in applying the theory, and the tricks adopted to overcome them.

The radiation from a Hertzian dipole is solved, but the more difficult boundary-condition problems arising in the case of the aerials described in Vol. II are not discussed. Instead, we deal with problems such as the radiation from a rhombic aerial in free space, and the effect of a capacitance top on the radiation resistance of a vertical aerial. In the latter problem we are asked to make "the usual assumption of a sinusoidal current distribution" without any attempt at justification, although this is not difficult in the case of a thin wire. It would be worth while devoting more attention in this volume to the application of wave theory to practical problems, or to idealized problems, thus encouraging the reader to feel that the previous work has been more worth while. Without this, the author's claim to give a "complete account of the theoretical basis of the subject" hardly appears justified. In the second half of this volume there are occasional misprints in the formulae, and in two of the diagrams, which may confuse a reader unacquainted with the subject.

Vol. II is written to be independent of Vol. I. It covers a wide field as will be evident from the following chapter headings ; general survey of antennae and propagation, long and medium wave antennae, short and ultra-short wave antennae, microwave antennae, receiving antennae, directive antennae and arrays, d.f. antennae, antennae for ships, aircraft and automobiles, propagation of radio waves, and transmission lines ; an appendix deals with the mechanical design of antennae.

In the case of single wires and arrays the characteristics are derived on the basis of assumed current distributions. When such a simple treatment is not available, as in the case of some of the microwave aerials, the theoretical results are given without proof, a reference to the source being given. Many useful examples of measured aerial performance are included for comparison with the theoretical results.

It is useful to have assembled, in the chapter on microwave aerials, information which has previously only been available in technical journals on the slot, horn and polyrod aerials, corner reflectors and parabolic mirrors ; lens aerials, on the other hand, are not described. It is inevitable, however, that, in attempting to cover such a wide field, some of the more detailed design considerations cannot be included. Vol. II will, therefore, appeal more to the practical user or designer of aerials, rather than to the specialist who will want to know much more about much less.

In some cases the arrangement of the subject matter might be improved. The comparison between the theoretical and measured impedance of cylindrical aerials is separately discussed in connection with medium wave, short wave and microwave aerials ; the radiation from a rhombic aerial in free space appears in Vol. I but the effect of the earth is postponed until Vol. II. In the chapter on long- and medium-wave aerials, the most important aspect—the radiation pattern—is dealt with last, after a lengthy section on the approximate calculation of base impedance. On the whole, however, the material is well arranged and clearly described, and provides both a useful survey of present-day aerial practice and a summary of practical design information.

In both volumes there is a good bibliography, and frequent references to it throughout the text are helpful to those who wish to pursue a particular subject further.

H. P.

Progressive Mathematics

By P. Clyne. Pp. 270, Chapman & Hall, 37 Essex Street, London, W.C.2. Price 15s.

The author is the Responsible Lecturer in Mathematics in the Engineering Department at the Mid-Essex Technical College, Chelmsford. His aim is to " develop the subject as a serial story," and to prevent it from being a stumbling-block to those who are primarily concerned with practical applications rather than with mathematics for its own sake.

The following subjects are covered in the order given : (a) a graphical approach to the idea of differentiation, (b) differentiation of sums, products, quotients, polynomials, trigonometrical functions, etc., (c) exponentials, (d) maxima, minima and curvature, (e) infinite series, (f) elementary integration and applications, (g) conic sections, (h) vectors, j and hyperbolic functions, (i) further applications and tricks of integration, (j) Fourier series and harmonic analysis, (k) differential equations and partial differentiation. Useful appendices on (i) equations and identities, (ii) finding the relations between variables, (iii) properties of the triangle, (iv) permutations, combinations and the binomial theorem, (v) curves in general, and some special curves, (vi) polar co-ordinates and (vii) determinants are included.

The ground covered " progresses from about School Certificate to Higher National Certificate." The order of subjects and method of approach are chosen because they have been successful with many students, and are original and unconventional. The differentiation of x^n, for example, is done by mathematical induction and using the rule for differentiating a function of a function, without using the binomial theorem.

The book is certainly one which deserves very serious consideration by those who teach engineering students. If they do not wholeheartedly accept the author's practical approach to his subject, their own ideas will be clarified by considering why they reject it. The one serious defect is the large number of misprints, although the difficulty of correcting proofs from a sick bed must in fairness be admitted. Misprints are most unfortunate in a book of this kind, since few students can be sufficiently sure of themselves to differ from the textbook when it is wrong without grave anxiety. Apart from actual misprints, the practice of " breaking " equations and writing them on more than one line is to be deplored when not absolutely unavoidable.

Unnecessary rigour has been deliberately excluded, but limitations of results should perhaps have been more precisely defined. For example, in section 9-77, the differentiation of a power series term by term is considered. On the circumference of the circle of convergence of such a series, it is possible for the series to be convergent although the ratio test fails ; the differentiated series will then not necessarily be convergent. But in most cases of practical importance to engineering students it is only necessary to consider points inside the circle of convergence, when the term-by-term differentiation is valid, as explained.

A book like this, whose primary object is to help the student and particularly the student who is less brilliant, or who is interested mainly in applications, is very welcome.

J. W. H.

Super-Regenerative Receivers

By J. R. WHITEHEAD, Ph.D., A.M.I.E.E. Pp. 169 + xiii. Cambridge University Press, 200 Euston Road, London, N.W.1. Price 21s.

Although much has been published on the super-regenerative receiver since its invention 28 years ago, this is the first book devoted entirely to the subject. Justification for the book goes much further than the convenience of having a comprehensive treatment between one pair of covers. It is hardly too much to say that by it the super-regenerative receiver is for the first time reduced to a normal design problem, in which the performance can be predicted with reasonable accuracy and certainty.

The organization of the book is admirable. After a short introductory chapter outlining the super-regenerative principle and its several modes of operation, the author proceeds to develop the theory, starting in the most general way possible by considering the basic oscillatory circuit, consisting of inductance, capacitance and conductance all in parallel. A super-regenerative receiver is regarded as such a circuit in which, by means of a valve, the conductance is periodically made to assume negative values. This variable conductance is then expressed in terms of the mutual conductance of the valve, and on this basis the theory of super-regeneration is developed in some detail, but still quite generally, before considering particular quenching waveforms. The linear mode is taken as typical, and the modifications due to operation on the logarithmic mode are the subject of Chapter 6. Chapter 7 deals with automatic gain-stabilization, and finally Chapter 8 is devoted to examples of super-regenerative circuits.

The implications of the mathematical exposition are clearly stated in words, and its results are crystalized in terms which, with the help of the data provided in an appendix, can be applied in practical design.

The author has taken care to make clear the limitations imposed by his simplifying assumptions, and the probable degrees of approximation resulting. That this work was tested in the severest possible way by practical experience on a large scale in the 1939-45 war gives the reader confidence in its validity, and should completely dispel any lingering association of super-regeneration with obscurity and unreliability.

Perhaps the most important feature of its wartime development was the better understanding of the linear mode of operation. Although the differences between this and the logarithmic mode are shown, it might perhaps have been made clearer why linear operation is regarded by the author as so advantageous in rôles, such as i.f.f., where linearity of demodulation is unimportant. The last chapter, in fact, does not everywhere maintain quite the high standard of exposition in the rest of the book. A valuable feature, however, is that most of the circuit diagrams are fully annotated with component values

The production of the book is excellent, and errors are few, but references to Appendix 3 (non-existent) ought to be read as " Appendix 2," and some of the references to Fig. 3.4 obviously mean 3.3. In this important diagram and some of its context one can easily become confused as to whether t_1 and possibly t_2 are time periods or values of t ; though it is true that any doubt can be dispelled by referring to the list of symbols at the end of the book. The use, or rather misuse, of the symbol μ to denote gain is very much to be depreciated, seeing that gain is a function of μ in its correct usage.

This book is one that nobody seriously concerned with super-regenerative receivers can afford to do without.

M. G. S.

B.B.C. Year Book 1951

Pp. 192. British Broadcasting Corporation, Broadcasting House, London, W.1. Price 3s. 6d.

Radio Engineering Handbook

Edited by KEITH HENNEY. Pp. 1197 + x. McGraw-Hill Publishing Co., Ltd., Aldwych House, London, W.C.2. Price (in U.K.) 85s.

The Acceleration of Particles to High Energies

Physics in Industry Series. Pp. 58 + x. The Institute of Physics, 47 Belgrave Square, London, S.W.1.

Das Trockengleichrichter-Vielfachmessgerät

By THEODOR WALCHER. Pp. 144 + x. Springer-Verlag, Mölkerbastei 5, Wien 1, Austria.

Drahtloser Überseeverkehr

By PAUL KOTOWSKI and HANS SOBOTKA. Pp. 271 + x. S. Hirzel Verlag, Goethestrasse 2, Leipzig C.1. Price D.M. 17.80.

Messungen und Untersuchungen an Rundfunkgeräten

By HUBERT GIBAS. Verlag Leemann, Zurich, Switzerland.

Radio Research 1933-1948

Pp. 59 + iv. Published for the Department of Scientific and Industrial Research by H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 2s. (50 cents U.S.A.).

This report includes a survey of the investigations carried out during 1934-1947 with a report of the Director of Radio Research for 1948.

The Heaviside Centenary Volume

Pp. 98. The Institution of Electrical Engineers, Savoy Place, London, W.C.2. Price 4s. (members), 10s. (non-members), including postage.

This volume is a collection of addresses at the Heaviside Centenary Meeting of the Institution of Electrical Engineers, together with six papers on various aspects of Heaviside's work.

ABSTRACTS and REFERENCES

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

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 the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

ACOUSTICS AND AUDIO FREQUENCIES

016 : 534 1

References to Contemporary Papers on Acoustics.—A. Taber Jones. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 643–652.) Continuation of 2682 of 1950.

534.213.4 2

On the Propagation of Sound Waves in a Cylindrical Conduit.—F. B. Daniels. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 563–564.) "The characteristic impedance and propagation constant of a cylindrical conduit are calculated on the basis of an equivalent electrical T-section. Numerical values of the results are plotted for air at 20°C, for a range of values of the independent variable which includes the region of transition from isothermal to adiabatic conditions."

534.213.4 3

On the Propagation of Sound in Narrow Conduits.—O. K. Mawardi. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 640.) Correction to paper abstracted in 2 of 1950.

534.231 4

Reaction of Medium and Acoustic Radiation Damping for a Disk.—H. Braumann. (*Z. Naturf.*, 1948, Vol. 3a, No. 6, pp. 340–350.) In order to calculate the sound field of a disk executing small harmonic oscillations in the direction of its axis, the acoustic wave equation is formulated in bipolar coordinates. For the case where the medium may be regarded as incompressible the wave equation leads to the potential equation; an exact solution is given for this. The effect of the medium on the disk is equivalent to an increase of $8R^3\rho_0/3$ in its mass, where R is the radius of the disk and ρ_0 the density of the medium. For a compressible medium there is an additional effect due to radiation damping. The time average of the radiated power is approximately $8R^6\rho_0\omega^4V^2/27\pi c^3$, where ω is the angular frequency, V the maximum velocity of the disk and c the velocity of sound.

534.231 : 534.133 5

The Sound Field of a Straubel X-Cut Crystal.—E. W. Samuel & R. S. Shankland. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 589–592.) The streaming patterns in CCl_4 were determined, using a 7.5-Mc/s crystal and measuring the velocities of sugar particles whose density is nearly that of the liquid. The results indicate that the intensity of the sound radiated by a crystal of the Straubel type is very uniform across the beam.

534.231 : 621.395.623.75 6

Response Peaks in Finite Horns.—C. T. Molloy. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 551–557.) The axial sound field of horn-type loudspeakers is calculated theoretically. The frequencies at which peaks occur in the response curves, and the dimensions of hyperbolic and exponential horns having peaks at specified points in their response curves, can be derived. A comparison between a measured and a computed axial response curve shows good agreement.

534.231.3 : 621.395.623.75 7

Resonance Characteristics of a Finite Catenoidal Horn.—G. J. Thiessen. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 558–562.) Expressions for the impedance components of a finite catenoidal horn are derived and a comparison with similar exponential and conical horns is made. The impedance of a section of a catenoidal horn is also calculated; for the finite as well as the infinite horn, this impedance approaches that of the exponential horn as more length is trimmed from the throat end.

534.232 : 517.564.3 8

On the Extension of Some Lommel Integrals to Struve Functions with an Application to Acoustic Radiation.—C. W. Horton. (*J. Math. Phys.*, April 1950, Vol. 29, No. 1, pp. 31–37.)

534.24 9

On the Non-specular Reflection of Plane Waves of Sound.—V. Twersky. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 539–546.) Mathematical analysis of the scattering of sound by various rigid non-absorbent nonporous surfaces consisting of semicylindrical or hemispherical bosses on an infinite plane. Exact solutions are given for the case of a single boss and a plane wave at an arbitrary angle of incidence. The theory is extended to the case of finite arrangements of bosses, neglecting secondary excitation effects. The solutions contain the usual Fraunhofer terms for a grating or lattice. The cases of finite and infinite random distributions are considered, and various extensions of the treatment are mentioned.

534.321.9 : 061.3 **10**

Rome Ultrasonics Convention.—G. Bradfield. (*Electronic Engng*, Sept. 1950, Vol. 22, No. 271, pp. 391–394.) Brief account of lectures and exhibited equipment, including commercial apparatus for many purposes. The advantages of $BaTiO_3$ ceramics for piezoelectric applications were pointed out. A method of investigating the properties of auditoria, using models and ultrasonic frequencies, was described.

534.321.9 : 534.614-14 **11**

A New Method for Measuring Velocities of Ultrasonic Waves in Liquids.—B. R. Rao. (*Nature, Lond.*, 28th Oct. 1950, Vol. 166, No. 4226, p. 742.) A rapid, accurate method requiring only a very small quantity of the liquid and applicable to both opaque and transparent liquids over a wide range of frequencies.

534.374 **12**

Mathematical Analysis of an Acoustic Filter.—N. Olson. (*Canad. J. Res.*, July 1950, Vol. 28, Sec. A, No. 4, pp. 377–388.) The attenuation, phase and impedance functions are calculated for acoustic filters constructed from conduits with a series of equal wider sections at regular intervals. Theoretical impedance and attenuation curves are shown and are confirmed by measurements on filters of circular and square section. Such filters are easy to construct and terminate and they may be used in parallel to form units of large cross-section.

534.612+534.641 **13**

A Method for Measuring Source Impedance and Tube Attenuation.—J. E. White. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 565–567.) A description of a sensitive and accurate method of determining attenuation and velocity of sound from sound-pressure measurements in gases at medium audio-frequencies. By using a microphone movable along an open-ended tube, the acoustic impedance of any sound source coupled to the air column can be found if the acoustic impedance of the microphone is known. All necessary formulae are derived.

534.841/.844 **14**

Reverberation Time and Sound Power required for Ordinary Rooms.—E. de Gruyter. (*Bull. schweiz. elektrotech. Ver.*, 17th Sept. 1949, Vol. 40, No. 19, pp. 757–761. In German.) A new interpretation of Sabine's formula is given which takes account of measurements of reverberation duration made in halls with good acoustical properties. Reverberation constants are derived which characterize the acoustic quality of a room for any particular purpose and which are independent of room dimensions. A formula for the necessary acoustic power is then established by analogy of the reverberation constants with the power constants of an electrical circuit. Psychological considerations affecting the question of good acoustics are discussed, in particular in connection with modern electroacoustic transmissions.

534.843 **15**

On the Acoustics of Coupled Rooms.—C. M. Harris & H. Feshbach. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 572–578.) The problem of coupled rooms is treated as a wave-theory boundary-value problem. Experimental data for isolated modes of vibration of a coupled system confirm the theoretical formulae.

534.845 **16**

Parameters for Sound Transmission in Granular Absorbing Materials.—M. Ferrero & G. Sacerdote. (*Nuovo Cim.*, 1st Dec. 1948, Vol. 5, No. 6, pp. 551–566.) The parameters are deduced from acoustic-impedance measurements on lead shot and on sand of various grain sizes and are discussed in relation to theory previously developed (*ibid.*, 1947, Vol. 4, p. 262).

534.86 **17**

The "Expressor" System for Transmission of Music.—R. Vermeulen & W. K. Westmijze. (*Philips tech. Rev.*, April 1950, Vol. 11, No. 10, pp. 281–290.) It is claimed that in the transmission of music, either by radio or via a sound-recording system, adjustment of the degree of volume compression by a capable hand has great advantages over automatic control. But with manual control the relations between the intensity of the original music and that of the input signal of the expandor is ambiguous, and special methods have to be used to ensure that the expandor always exactly compensates the compression. In the 'Expressor' system, a pilot signal consisting of impulses is transmitted via a separate channel, and causes the potentiometer of the expandor to follow continuously the movements of the compressor.

548.1 : 537 **18**

Piezoelectric Equations of State and their Application to Thickness-Vibration Transducers.—Cady. (See 99.)

621.395.61.089.6 **19**

American Standard Method for the Pressure Calibration of Laboratory Standard Microphones: Z24.4-1949 (Abridged.)—L. L. Beranek, R. K. Cook, F. F. Romanow, F. M. Wiener & B. B. Bauer. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 611–613.) The complete standard may be obtained from the American Standards Association, 70 East 45th Street, New York 17, for 75 cents.

621.395.613.37 **20**

A Second-Order-Gradient Noise-Canceling Microphone using a Single Diaphragm.—W. A. Beaverson & A. M. Wiggins. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 592–601.) The four openings admitting sound to the two surfaces of the microphone diaphragm are so spaced and oriented that the response depends on the second differential of the sound pressure with respect to the direction of propagation. Theoretical analysis, confirmed by experimental results, shows that a better signal/noise ratio is obtained than with first-order-gradient microphones.

621.395.623.54.089.6 **21**

American Standard Method for the Coupler Calibration of Earphones: Z24.9-1949 (Abridged).—L. L. Beranek, F. F. Romanow, K. C. Morrical, L. J. Anderson, B. B. Bauer, R. K. Cook & W. Wathen-Dunn. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 602–608.) The complete standard may be obtained from the American Standards Association, 70 East 45th Street, New York 17, for 75 cents.

621.395.625.2 : 621.396.933 **22**

An Automatic Monitoring Recorder.—(See 207.)

621.395.92 **23**

Hearing-Aid Design.—A. Poliakoff. (*Wireless World*, Aug. 1950, Vol. 56, No. 8, pp. 274–276.) Among the essential qualities of a good instrument, the most important is the provision of optimum volume to suit each patient in all reasonable conditions of use. In most cases this cannot be achieved without a.v.c. There should be no pronounced peaks in the response curve and case noise should be reduced by mounting the microphone in rubber and making the surface of the case very smooth.

621.396.822 : 621.316.8 24

A Thermal-Noise Generator for Low-Frequency Tests.—H. Meister. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Aug. 1950, Vol. 28, No. 8, pp. 320–324. In French and German.) A description is given, with a circuit diagram showing all component values, of a generator providing a continuous noise spectrum from 30 c/s to 15 kc/s. Reasons for the choice of a resistor as the primary noise source are given. The problems connected with the high amplification necessary with such a source are discussed, and means for reducing instability are indicated.

621.396.822 : 621.385.38 25

A High-Level Noise Source for the Audio-Frequency Band.—H. D. Harwood & D. E. L. Shorter. (*J. sci. Instrum.*, Sept. 1950, Vol. 27, No. 9, pp. 250–251.) An argon-filled thyratron is used to generate a continuous noise spectrum for a.f. testing. Large unwanted ultrasonic components are removed by means of a low-pass filter cutting off at 20 kc/s, leaving a noise spectrum with power distributed uniformly over the a.f. band. Where required, the power per octave band can be made uniform by adding a weighting network. The output into 600 Ω is −20 db with reference to 1 mW. The generator is mains operated.

AERIALS AND TRANSMISSION LINES

621.315.21.017.71.029.4/.6 26

The Power Rating of Radio-Frequency Cables.—R. C. Mildner. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 289–298. Discussion, p. 298.) The limitations to the power that can be transmitted by various types of r.f. cable are considered, suitable rating factors to deal with different maximum permissible cable temperatures and different ambient temperatures are proposed, and the influence of modulation, standing waves and load factor on the thermal and voltage rating is discussed. The principles outlined are applied to determine the ratings of three types of cable.

621.315.212 : 621.397.24.018.78† 27

Characteristics of Coaxial Pairs at Frequencies Involved in High-Definition Television Transmission.—G. Fuchs. (*Câbles & Transmission, Paris*, July 1950, Vol. 4, No. 3, pp. 248–254.) The distortion, caused by irregularities of cable impedance, which would occur in the transmission of a television signal of 20 Mc/s bandwidth over a distance of 1 000 km is calculated, assuming unfavourable conditions and basing the calculation on experimental results for cables (*a*) with central conductor of diameter 5 mm and outer conductor of internal diameter 18 mm, the insulation consisting of spiral ribbons of styroflex and the outer conductor formed of two half-shells of copper, (*b*) of corresponding dimensions 2.6 and 9.4 mm, disks of polythene being used for insulation. The mean-square values of phase and amplitude distortion are 0.05 μs and 1.6% respectively for a 5/18-mm pair cable. The corresponding values for a 2.6/9.4-mm pair are significantly lower: 0.001 μs and 0.04%.

621.315.212.017.71 28

Heating of Radio-Frequency Cables.—W. W. Macalpine. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 283–288.) See 3014 of 1948.

621.315.213.12 : 621.315.221 : 621.3.011.4 29

Sheathed Lecher System.—R. Gans. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 519–521.) A formula is derived for the capacitance between the two wires of a Lecher system within a sheath. The degree of approximation is considerably better than obtained with Breisig's formula. A numerical example is worked out. See also 2416 of 1950 (Wise).

621.392.211 30

The Propagation of Waves along an Endless Helix.—S. Kh. Kogan. (*C. R. Acad. Sci. U.R.S.S.*, 11th June 1949, Vol. 66, No. 5, pp. 867–870. In Russian.) An equation (12) is derived determining the current distribution along the helix and methods for its solution are indicated. The theoretical results obtained have been confirmed experimentally.

621.396.67 31

Radiation from Circular Current Sheets.—W. R. LePage, C. S. Roys & S. Seely. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1069–1072.) A theoretical treatment of radiation from a system of current elements arranged on the circumferences of concentric circles. Series formulae are given for the radiation field produced by a specified excitation of these elements. Integral formulae are given for the excitation required to produce any desired radiation pattern. There is no consideration of how the required excitation can be produced.

621.396.67 : 538.566 32

Cylindrically Diverging Electromagnetic Waves in a Medium with Nonuniform Electrical Properties (Elias-Layer) above a Semiconducting Earth.—C. T. F. van der Wyck. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 195–209.) Expressions in terms of the Hertzian vector potential are derived for the field of a vertical dipole above a flat, homogeneous, imperfectly conducting earth in a medium with refractive index depending exponentially on height. A geometrical-optical interpretation of the expressions is given, using the saddle-point method.

621.396.67 : 621.396.9 33

Radar Aerial Systems for Uniform Irradiation of a Surface.—Huynen. (See 117.)

621.396.671 34

Impedance Transformation in Folded Dipoles.—R. Guertler. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1042–1047.) Reprint. See 3342 of 1949.

621.396.671 35

Input Impedance of Horizontal Dipole Aerials at Low Heights above the Ground.—R. F. Proctor. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, p. 321.) Discussion on 2134 of 1950.

621.396.677 36

Microwave Lenses.—J. Brown & S. S. D. Jones. (*Electronic Engng*, April–July, Sept. & Oct. 1950, Vol. 22, Nos. 266–269, 271 & 272, pp. 127–131, 183–187, 227–231, 264–268, 358–362 & 429–434.) A comprehensive review of the subject, including theory of the principal types of lens.

621.396.677 37

Development of Artificial Microwave Optics in Germany.—O. M. Stuetzer. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1053–1056.) Discussion of the development of microwave delay lenses using parallel metal strips or waveguide sections. A lens of the latter type, for use on wavelengths of about 5 cm and with a diameter of 300 cm, is illustrated.

621.396.677 **38**

Factors governing the Radiation Characteristics of Dielectric-Tube Aerials.—D. G. Kiely. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 311–321.) The effects of changes of tube length, diameter and wall thickness on the radiation pattern were investigated experimentally. It is suggested that the mechanism of radiation of thin-walled dielectric tubes more closely resembles that of a lens than that of a leaking waveguide, such as a dielectric rod aerial. The gain of a dielectric-tube aerial of length 8λ, diameter $1{\cdot}16\lambda$ and wall thickness $0{\cdot}03\lambda$ is approximately 21 db.

621.396.677 **39**

Pattern Calculations for Antennas of Elliptical Aperture.—R. J. Adams & K. S. Kelleher. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, p. 1052.) The aperture illumination patterns in the directions of the major and minor axes are calculated from a knowledge of the patterns of the feed horn, and then expressed as Fourier series of up to four terms. The radiation pattern is given by

$$F(u_1,u_2) = \pi ab\Sigma\Sigma a_r + b_s G_{rs}(u_1,u_2),$$

where $u_1 = (2\pi a \sin\phi)/\lambda$, $u_2 = (2\pi b \sin\theta)/\lambda$, a and b are the semimajor and semiminor axes of the aperture, a_r and b_s coefficients of the Fourier series and G_{rs} a complicated function which has been tabulated elsewhere by the authors. Very good agreement with the theory was obtained in experiments on several horns.

621.396.677 **40**

The Radiation of 'Beam' Aerials in Particular and of Large Surfaces in General.—B. van der Pol. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 151–155.) The calculation of the power radiated by a beam aerial is simplified by imagining the system of parallel-wire radiators replaced by an equivalent extended current-carrying surface. Approximate formulae are derived for the radiated power for different limiting cases of the dimensions. Where the dimensions are large compared with λ the radiated power is independent of λ and is proportional to the area of the surface.

621.396.677 **41**

Measured Directivity Induced by a Conducting Cylinder of Arbitrary Length and Spacing Parallel to a Monopole Antenna.—F. R. Abbott & C. R. Fisher. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1040–1041.) Curves are given for determining the directivity, given the separation of the parasite from the aerial and also its height.

621.396.679.4 : 621.392.094 **42**

Effects of Linear Distortion on a Band of Frequencies Transmitted along a Long Mismatched Line.—J. Fagot. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 179–184.) The following formulae are derived for the irregularities caused by the mismatch when the frequency varies within the band considered:

period of variations $\Delta f = v/2l$

max./min. amplitude variation $= (1 + \rho\rho')/(\rho + \rho')$

phase displacement or propagation-time deviation $\Delta\tau = (\rho - 1)\,(\rho' - 1)\,l/v$

where v is the phase velocity, l the length of line, and ρ and ρ' the s.w.r. at the ends of the line. These formulae are independent of the carrier frequency and hold for the usual practical case where the terminal impedance is not highly selective.

621.396.679.4 : 621.392.094 : 621.396.619.13 **43**

Study of the Effects of a Long Line on a Frequency-Modulation Signal: Distortion, Compensation and Applications.—M. Denis. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 185–205.) The long feeder lines used in cm-wave transmission are a source of distortion; this is particularly severe when the modulated oscillator is tightly coupled to a long, slightly mismatched feeder. The only effective remedy is the insertion of an amplifier between source and feeder. The existence of several junctions in a feeder, each causing slight reflection, may transform the line into a dispersive quadripole, so that phase distortion occurs, accompanied in certain cases by nonlinear frequency distortion. Numerical examples show the importance of this. Long lines are best avoided for high-quality transmissions using a cm-wave carrier with f.m. Methods of correcting distortion and possible uses of long lines in measurement technique are discussed.

CIRCUITS AND CIRCUIT ELEMENTS

537.312.6 : 621.315.592 **44**

Semiconductors with Large Negative Temperature Coefficient: Thermistors.—N'Guyen Thien-Chi & J. Suchet. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 155–167.) Review of the development of the thermistor in the C.S.F. laboratories, and discussion of properties and applications.

621.314.12 : 621.317.088.4 **45**

The Fundamental Limitations of the Second-Harmonic Type of Magnetic Modulator as Applied to the Amplification of Small D.C. Signals.—Williams & Noble. (See 152.)

621.314.3† **46**

Dynamoelectric Amplifiers.—R. M. Saunders. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, pp. 711–716.) Basic principles are presented, five types are distinguished, salient features discussed, and methods proposed for predicting performance.

621.314.3† **47**

Analytical Determination of Characteristics of Magnetic Amplifiers with Feedback.—D. W. Ver Planck, L. A. Finzi & D. C. Beaumariage. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 565–570.) See also 2447, 2448 and 3064 of 1949 (ver Planck, Fishman & Beaumariage).

621.314.3† **48**

A New Theory of the Magnetic Amplifier.—A. G. Milnes. (*Proc. Instn elect. Engrs*, Part II, Aug. 1950, Vol. 97, No. 58, pp. 460–474. Discussion, pp. 474–483.) Assuming that the B/H curve for the core material has a constant slope up to saturation level, followed by zero slope, flux waveforms are derived and equations developed for the magnetomotive forces operating throughout the cycle for a transductor with any degree of self excitation. Analytical expressions are thence derived for the output characteristics and for the current amplification and time constant of a transductor, which are of considerable importance in design work. "An important phenomenon explained by the new theory is the variation of the current amplification with change of load resistance. This is readily detected in practice even for a simple transductor, and becomes of increasing significance as the percentage of self excitation is increased. The assumptions made in the analysis are such that the theory can be applied successfully only to transductors with cores which have high permeability and are readily saturable."

621.314.3† **49**

New Core Materials widen Scope of Saturable Reactors.—(*Elect. Mfg., N.Y.*, Sept. 1948, Vol. 42, No. 3, pp. 126 .. 214.) A general account of the subjects discussed in papers presented at a symposium on magnetic materials at the Naval Ordnance Laboratory, Washington, 15th June, 1948.

621.316.8 : 621.396.822 50

Distribution in Energy of Johnson Noise Pulses.—B. R. Gossick. (*J. appl. Phys.*, Sept. 1950, Vol. 21, No. 9, pp. 847–850.) An analysis is made using Maxwell-Boltzmann statistics with a time-energy phase space. The results are checked against pulse-height measurements made with a linear amplifier and electronic counter. The following parameters are determined from the distribution function:—(*a*) time of flight associated with a Lorentz mean free path; (*b*) number of electrons producing pulses of a given height; (*c*) the potential through which an electron falls along a Lorentz mean free path.

621.317.35 : 621.39.001.11 51

Signals with Limited Spectra and their Transformations.—J. Oswald. (*Câbles & Transmission, Paris*, July 1950, Vol. 4, No. 3, pp. 197–215.) Detailed mathematical treatment. See also 3069 of 1949.

621.318.371 : 621.392.53 52

The Compensation of Delay Distortion in Video Delay Lines.—R. A. Erickson & H. Sommer. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1036–1040.) A theoretical and practical investigation into the effect of placing isolated metal patches of various sizes in the vicinity of solenoid delay lines. These patches are equivalent to capacitors bridging sections of the solenoid. The relation between size of patch and effective capacitance is given. Relations necessary for determining the delay distortion and effective bandwidth corresponding to different amounts of capacitance are determined. Oscillograms illustrate the reduction of distortion due to patches of different sizes. See also 41 of 1947 (Kallmann).

621.319.4 53

Metallized Paper Capacitors.—J. R. Weeks. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1015–1018.) See also 134 below (McLean).

621.392 54

Simplifying Assumptions.—W. T. C. (*Wireless Engr*, Aug./Sept. 1950, Vol. 27, Nos. 323/324, pp. 217–219.) Examples are discussed which illustrate the need for great care in making simplifying assumptions. Neglect of the leakage inductance of a transformer, for instance, results in considerable discrepancy between the waveform to be expected in a branch of a television line-scanning circuit and the waveform actually observed.

621.392 55

The Distinction between Effective and Circuit Bandwidths.—W. J. Kessler. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 98–99.) See 3074 of 1949.

621.392 56

Wideband Two-Phase Networks.—N. O. Johannesson. (*Wireless Engr*, Aug./Sept. 1950, Vol. 27, Nos. 323/324, pp. 237–238.) Comment on 1356 of 1950. A method of approximation based on θ functions is given which facilitates numerical computations.

621.392 57

Application of the Methods of Synthesis of Electrical Circuits to the Construction of Quadripoles, given the Transmission Coefficient for a Finite Frequency Band.—V. A. Taft. (*Bull. Acad. Sci. U.R.S.S., tech. Sci.*, June 1950, No. 6, pp. 873–887. In Russian.) The methods used for designing a quadripole are normally based on trials of different values for circuit parameters. A general design method based on the synthesis of electrical circuits is here proposed. The theory of quadripoles is discussed and the necessary and sufficient conditions are established for the physical realization of a passive reactive quadripole. The various stages of the design work are then laid out for realizing a quadripole with a given transmission coefficient for a finite frequency band or, in other words, with given attenuation and phase-displacement coefficients for the same frequency band.

621.392 58

Summary of Transformations Useful in Constructing Analogs of Linear Vibration Problems.—J. P. Corbett. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 661–664.) Full paper. Summary noted in 834 of 1950.

621.392 : 519.272.15 59

Short-Time Autocorrelation Functions and Power Spectra.—Fano. (See 141.)

621.392 : 681.142 60

A High-Speed Multiplier for Analogue Computers.—B. N. Locanthi. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, p. 717.) Summary of A.I.E.E. Summer General Meeting paper. A circuit developed at the California Institute of Technology for multiplying together two voltages is described. One voltage is fed to a ring modulator; the output, together with the other voltage, is fed to a balanced modulator whose output provides the required product. Phase and amplitude distortion are low.

621.392.4 61

Two-Pole Compensation Networks.—A. Pinciroli. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 644–646. In French.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of the characteristics of a triode circuit equivalent to a valve with negative transconductance. Such a circuit, when connected between two points of an electrical network, can, within certain limits, compensate the resistive and capacitive parameters of the network between the two points. Applied to the output terminals of a RC amplifier, a compensation two-pole can increase the upper frequency limit considerably and also the amplification factor. See also 1882 of 1948.

621.392.52 : 621.396.611.3 62

Tuned Absorption Circuits.—R. E. Spencer. (*Wireless Engr*, Aug./Sept. 1950, Vol. 27, Nos. 323/324, pp. 219–224.) An analysis is given of circuits in which input and output terminals are connected to the same tuned circuit and a coupled circuit absorbs power over a comparatively narrow band of frequencies. Approximate mathematical solutions are given, with graphical illustrations of response curves and a discussion of the depth and shape of the trough between the two humps of the response curve.

621.392.52 : 621.396.619 63

Polyphase Modulation as a Solution of Certain Filtration Problems in Telecommunication.—Macdiarmid & Tucker. (See 213.)

621.392.6 64

Synthesis of 2*n*-Terminal Passive Networks.—R. Leroy. (*Câbles & Transmission, Paris*, July 1950, Vol. 4, No. 3, pp. 234–247.) Analytical investigation of certain aspects of the theory discussed in 62 of 1950 (Bayard). By extension of Gewertz's method to a positive real completely reduced matrix of order n it is possible to obtain a matrix of the same order but with elements of degree lower by $(2n-2)$. A singular type of matrix appears in the calculations when the degree of the elements is $<(2n-2)$, so that the reduction of the initial matrix generally involves the derivation from a singular matrix of a non-singular matrix of lower order, to which the Gewertz method is then applied. The corresponding network always includes only one resistor. An alternative method for effecting the synthesis of completely reduced matrices consists in determining the reactive network which includes this resistor between a supplementary pair of terminals. Further, reduced positive real matrices of row q can be realized as networks comprising q resistors.

621.392.6 65

Synthesis of a Finite 2n-Terminal Network by a Group of Networks each of which contains only One Ohmic Resistance.—Y. Oono. (*J. Math. Phys.*, April 1950, Vol. 29, No. 1, pp. 13–26.)

621.396.611.1 66

Periodic and Aperiodic Oscillations in an Oscillatory Circuit including an Iron-Cored Coil and Approximately Tuned to an Impressed Alternating Voltage.—J. M. Op den Orth. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 211–236.) The investigation relates particularly to a circuit including little or no resistance. The inductance is assumed to be only slightly nonlinear, thus permitting the circuit differential equations to be solved by an approximate method, due to Poincaré. Periodic forced oscillations are represented by singular points (generally two isolated points and a saddle-point). If damping is zero, all other solutions correspond to closed curves around one or the other of the isolated points, or around both points. If damping is not zero the curves become spirals tending to one or the other of the isolated points (corresponding to stable forced oscillations). Jump phenomena are discussed. The importance of the solution curves through the third singular point (a saddle-point representing an unstable forced oscillation) is made clear.

621.396.611.1 67

Nonharmonic Oscillations as Caused by Magnetic Saturation.—R. Rüdenberg. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 676–685.) A detailed investigation of the effect produced on the waveform by the nonlinear characteristics of circuits containing capacitors and saturated inductors. Rigorous analysis shows that the natural oscillations in such circuits remain harmonic and have constant frequency only at small amplitudes. With increasing amplitude the waveform becomes more and more distorted and the natural frequency increases. Transient and steady-state forced oscillations are treated by means of a differential equation which involves only four parameters, but which covers all possible cases. A solution is obtained by a step-by-step method. In the transient state, strange shapes are found for the flux, current and voltage curves, with no regularity as regards either symmetry or periodic repetition. Natural oscillations can be maintained by application of a voltage of definite magnitude and waveform. In series circuits a peaked voltage curve is required. Subharmonics of the supply voltage may consequently be developed. The theoretical results are illustrated by oscillograms obtained with circuits including highly saturated components.

621.396.611.1 68

The Fourier Spectrum of Forced Oscillations produced by Step and Needle Impulses.—M. Päsler & W. Reichardt. (*Frequenz*, Aug. 1950, Vol. 4, No. 8, pp. 211–215.) The combined effect of a voltage step and its derivative on an oscillatory circuit is analysed by means of Fourier integrals, and the dependence of the spectral functions on frequency and damping is investigated. The results are presented in graphs and discussed. See also 1324 of 1949 (Päsler).

621.396.611.21 69

High-Frequency Vibrations of Plates made from Isometric and Tetragonal Crystals.—E. A. Gerber. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1073–1078.) Bevelling of crystals is described as a method for obtaining a single response frequency in crystal units. Electrical characteristics and temperature coefficients of $NaClO_3$, $NaBrO_3$, $NH_4H_2PO_4$ (ADP) and KH_2PO_4 (KDP) crystal units were measured. The two cuts (*zxw*) 45° and (*zxtw*) 45°/54°44′ [see I.R.E. Standard on Piezoelectric Crystals (655 of 1950)] were used. Fair agreement was obtained with the theory presented in the paper. The $NaBrO_3$ thickness modes have about the same quality factor as that of quartz, the quality factor of ADP crystals being about one order of magnitude lower.

621.396.611.4 70

Some Perturbation Effects in Cavity Resonators.—A. Cunliffe & L. E. S. Mathias. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 367–376.) "An investigation, partly theoretical and partly experimental, has been made of some effects which occur when the boundary of a cavity is deformed slightly. First, the theory of natural electromagnetic oscillations inside lossless cavities is summarized. Then a general theory, following along the lines of conventional first-order perturbation theory, is given. The theory has been applied to the perturbation of a right-circular cylindrical cavity. Two cases have been considered: the E_{010} mode, a non-degenerate case, and the H_{011} and E_{111} modes, a triply degenerate case. These two cases have also been investigated experimentally. Theory and experiment are in reasonable agreement, even for quite large deformations, when the deformation is applied gradually over a large area of the cavity wall. For sharp abrupt changes in the geometry of the cavity wall, however, it appears that the first-order perturbation theory can be applied only for very small distortions. The general results, theoretical and experimental, which have been obtained, show that if the frequency of the operating mode is well separated from the frequencies of other modes, a deformation of the boundary changes only the frequency of the operating mode and not its electromagnetic field configuration. If the frequency of the operating mode is near to the frequencies of other modes, a slight deformation of the cavity boundary, as well as changing the frequency of the operating mode, may also change its electromagnetic field configuration. 'Lossy' material or resistance wires, introduced into a cavity with a view to damping out unwanted modes, may also affect the desired resonance if certain types of deformation are present."

621.396.615 71

The Reactance-Tube Oscillator.—A. Giger. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, p. 1096.) Comment on 326 of 1950 (Chang & Rideout), pointing out that the transconductance of the oscillator valve has a fixed value and hence cannot affect the frequency. An explanation of the observed frequency variation is given which is based on practical work in Switzerland, where the reactance-valve oscillator has been in commercial use for years.

621.396.615.17 72

Calculation of the Time Delay of a Multivibrator.—H. de Lange Dzn. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 275–291.) A general solution is derived for a linear differential equation of nth order with constant coefficients by the method of variation of parameters, in which a discontinuity of the nth order is reduced to one of zero order during integration. The solution is applied to calculate the time delay of a multivibrator by means of a differential equation of the fourth order.

621.396.615.17 : 621.317.755 **73**

Spiral Time Base.—(*Wireless Engr*, Aug./Sept. 1950, Vol. 27, Nos. 323/324, pp. 224–226.) A description of the mode of operation of the basic circuit, with particular attention to the effect of varying the time at which the trigger switch is opened. A simple circuit using a thyratron switch is shown, and a more complex switching circuit used in radar is fully described. The timebase was developed at the Radar Research Development Establishment and is the subject of British Patent No. 582419.

621.396.645 **74**

A Selective Relay Amplifier for Recording WWV Time Signals.—E. F. Carome & H. C. Nash. (*Trans. Amer. geophys. Union*, June 1949, Vol. 30, No. 3, pp. 328–329.) Full circuit details are given of an amplifier which discriminates against all frequencies except 440 c/s, the modulation frequency of the WWV signals, so that the operation of a relay in the anode circuit of the output valve is unaffected by the pulses sent out at second intervals, or by atmospherics or background noises. The selective element consists of a twin-T RC bridge.

621.396.645 : 612.8 **75**

Biological Requirements for the Design of Amplifiers.—H. Grundfest. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1018–1028.) Discussion of the nature and properties of bioelectric potentials and description of amplifiers specially suitable for investigating such potentials.

621.396.645 : 621.3.015.7† **76**

The Amplification of Pulse-Form Modulated Voltages and the Accompanying Reduction of Slope and Time Delay.—J. W. Alexander. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 237–251.) In assessing the performance of an amplifier dealing with pulse signals the criteria to be considered are the slope of the output-pulse envelope and its retardation with respect to the input pulse. According to the method developed, these factors are easier to determine than the output-pulse envelope itself. The theory is applied to amplifiers with several single-tuned circuits and to amplifiers with coupled and stagger-tuned circuits.

621.396.645.012.3 **77**

The Determination of Quiescent Voltages and Currents in Pentode Amplifiers.—A. J. Shimmins. (*Electronic Engng*, Sept. 1950, Vol. 22, No. 271, pp. 386–388.) A method is described for determining the quiescent values of anode, screen-grid and control-grid voltages and currents graphically or by calculation from a family of dynamic characteristics for various screen voltages. The solution is approximate but is useful for predicting effects due to changes in circuit parameters such as cathode and screen resistances.

621.396.645.36 **78**

"The Cathamplifier".—C. A. Parry. (*Proc. Instn Radio Engrs, Aust.*, Aug. 1950, Vol. 11, No. 8, pp. 199–204.) An amplifier circuit with high input impedance which permits push-pull operation from an unbalanced source. The input voltage is applied between earth and the grid of one of the valves, and a voltage proportional to the total circulating current is obtained from a transformer whose centre-tapped primary is connected between the two cathodes; this voltage is applied, in the correct phase, between earth and the grid of the other valve. A resistance shunted across the transformer primary is varied to obtain anode–a.c. balance. Overall performance similar to that usual in push-pull operation may be obtained. Two modes of oscillation are possible which are independently adjustable.

GENERAL PHYSICS

533.723 + 621.396.822 **79**

Spontaneous Fluctuations.—D. K. C. MacDonald. (*Rep. Progr. Phys.*, 1948-49, Vol. 12, pp. 56–79. References, pp. 79–81.) A survey of developments of fluctuations analysis, and a review of research on fluctuation phenomena in the last decade, omitting general problems treated in standard works. The correlation function is discussed, with examples of its use. Recent developments treated are mainly concerned with electrical and valve noise, and include discussion of thermal, shot, and low-frequency noise.

535.215.9 : 537.315† **80**

Contact-Potential Measurements on Irradiated Metal-Oxide Surfaces.—H. Neuert. (*Z. Naturf.*, 1948, Vol. 3a, No. 4, pp. 226–228.) Account of experimental work demonstrating that a slightly oxidized surface can be activated by s.w. ultraviolet radiation, or by ionic or electronic charging, or by mechanical treatment.

535.312 : 539.23 **81**

Reflection Reduction in Optics.—M. Auwärter. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 605–607. In German.) Paper presented at the International Television Conference, Zürich, 1948. Investigation of the properties of single and multiple surface layers.

535.317.9 : 621.397.5 **82**

The Schmidt Optical System.—H. Rinia. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 580–585. In English.) Paper presented at the International Television Conference, Zürich, 1948. An outline is given of the basic principles of the Schmidt system. The conventional form gives fifth-order coma for low magnifications. Means are indicated for compensating this coma. The cause and magnitude of the lateral spherical aberration are discussed and a new method of aberration correction is described. See also 63 and 1215 of 1949 (Rinia & van Alphen).

535.42 **83**

Critical Report on the General Laws of Diffraction, submitted to the International Optics Commission.—G. Toraldo di Francia. (*Nuovo Cim.*, 1st Dec. 1948, Vol. 5, No. 6, pp. 591–605.) A review of classical and modern theories.

537.312.5 **84**

Theory of Photoelectric Conduction in Composite Conductors.—F. Stöckmann. (*Z. Phys.*, July 1950, Vol. 128, No. 2, pp. 185–211.) The fundamental equations of electrical conduction are examined for the case of circuits including electron sources and sinks. General laws for photoelectric currents are hence derived which agree with laws derived directly by other workers, and saturation current, amplification and exponential law of loss are discussed. Nonlinear conductors and semiconductors are studied as special cases.

537.525 **85**

The High-Frequency Gas Discharge.—F. Kirchner. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 620–621.) A description is given of a simple experimental arrangement for investigating the discharge without introducing a probe. The results indicate strong positive space-charge and high positive potential within the gas. The discharge can be maintained with voltages below the ionization potential.

537.528 **86**

X-Ray Investigation of Sound Waves associated with Breakdown of Dielectrics.—W. Schaaffs & F. Trendelenburg. (*Z. Naturf.*, 1948, Vol. 3a, No. 12, pp. 656–668.)

537.533 **87**

General Properties of the Electronoptical Image.—F. Borgnis. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, p. 571. In German.) Paper presented at the International Television Conference, Zürich, 1948. See also 1351 and 2780 of 1949, for which the above U.D.C. number is preferable.

537.534 : 621.385.82 **88**

The Production of Ion Beams by means of a High-Frequency Discharge.—H. Neuert. (*Z. Naturf.*, 1948, Vol. 3a, No. 5, pp. 310–312.) An arrangement similar to that described by Thonemann (3261 of 1946) was studied. With 100 W exciting power and 10 kV field voltage an ion current of 20 mA was obtained.

538.3 **89**

A Notation for Electrodynamics Adaptable to any System of Units.—R. Fleischmann. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 492–495.) The fundamental equations of electricity and the principal formulae of four-dimensional electrodynamics are presented in a notation which is independent of the system of units and which for special cases yields the formulae valid for the usual systems of units.

538.31 + 538.65 **90**

Fields within and around Cavities in a Magnetically Strained Medium, Ponderomotive Forces acting thereon in a Magnetic Field with Current in the Cavity, and the Electric Field generated on Movement of the Cavity.—J. P. Schouten. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 163–177.) It is shown analytically that the total electric field inside a cavity moving in a medium subjected to a homogeneous magnetic field is independent of the inhomogeneity introduced by the cavity wall, and the total mechanical force on the cavity is the same as if the medium were continuous.

538.311 **91**

Formulas and Tables for the Calculation of the Magnetic Field Components of Circular Filaments and Solenoids.—F. W. Grover. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 665–675.) Existing formulae are discussed and new formulae are derived. Tables of the functions involved are presented in a form which facilitates routine calculations.

538.322 **92**

The Forces between Two Current Conductors.—B. D. H. Tellegen. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 157–161.) Conditions for steady currents in closed conductors are considered, and the total force is regarded as the resultant of attractive forces and couples due to the interaction of current elements of the two conductors.

538.56 : 535.3 **93**

Reflection and Transmission of Electromagnetic Waves by Thin Curved Shells.—J. B. Keller. (*J. appl. Phys.*, Sept. 1950, Vol. 21, No. 9, pp. 896–901.) "The scattering of an arbitrary electromagnetic field by a conducting or non-conducting obstacle is investigated. The differential equations and boundary conditions satisfied by the field are transformed into a pair of inhomogeneous linear integro-differential equations for E and H. For an obstacle which is a thin shell of constant thickness h, a formal procedure for obtaining a solution of these equations as power series in h is given. The lowest order term in this solution is the incident field. An explicit expression for the next term is found in the form of a surface integral. This integral is evaluated approximately by the method of stationary phase. The physical properties of the solution are examined in detail, and satisfactory agreement is found with many results previously obtained by other methods."

538.56 : 535.42 **94**

Rigorous Theory of the Diffraction of Electromagnetic Waves by a Perfectly Conducting Disk.—J. Meixner. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 506–518.) The solution of this problem is given and is extended to the related problem of diffraction by a circular aperture in a perfectly conducting plane sheet of infinite extent by a generalization of Babinet's principle.

538.56 : 537.56 : 523.74 **95**

The Characteristics of Radio-Frequency Radiation in an Ionized Gas, with Applications to the Transfer of Radiation in the Solar Atmosphere.—S. F. Smerd & K. C. Westfold. (*Phil. Mag.*, Aug. 1949, Vol. 40, No. 307, pp. 831–848.) The function E which determines the radiation at any point is the ratio of the emissivity to the product of the absorption coefficient and the square of the index of refraction. The intensity of 'quiet' r.f. solar radiation reaching the earth can be expressed in terms of E and the optical depth of the various ray trajectories. Formulae are derived for emissivity, absorption coefficient and refractive index, from which E can be found. The formulae are expressed in terms of the electron and ion densities and the kinetic temperature, assuming a Maxwellian velocity distribution. A heuristic theory of the absorption and emission processes in a volume element is given which takes account of the effect of the surrounding particles of the medium.

538.56.029.64 : 537.562 : 535.43 **96**

The Scattering of 3-cm Radiation by Ionized Gases.—S. N. Denno, H. A. Prime & J. D. Craggs. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, pp. 726–727.) Radiation of wavelength 3 cm is scattered by a commercial cylindrical mercury-discharge tube. Scatter at right angles to the incident radiation is received and its power measured. Curves showing the received power as a function of tube current are given for radiation polarized (*a*) perpendicular to and (*b*) parallel to the tube axis, for two tubes of diameters 3·1 cm and 6·4 cm respectively. It is intended to use the information to determine the electron concentration in the discharge.

539 **97**

Masses of Fundamental Particles.—R. Fürth. (*Nature, Lond.*, 28th Oct. 1950, Vol. 166, No. 4226, pp. 727–728.)

548.1 : 537 **98**

A Derivation and Tabulation of the Piezoelectric Equations of State.—J. F. Haskins & J. S. Hickman. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 584–585.) The conservation-of-energy principle is applied to derive the general equations, with strain, electric displacement and entropy as independent variables. The special case of constant entropy is then considered, with polarization as an additional parameter, and all possible linear adiabatic equations of state are developed, using in turn as independent variables stress and electric field, strain and polarization, and stress and polarization. Hence the relations between the elastic, electric and piezoelectric coefficients for the various pairs of independent parameters are determined and tabulated.

548.1 : 537 **99**

Piezoelectric Equations of State and their Application to Thickness-Vibration Transducers.—W. G. Cady. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 579–583.) The electromechanical equations of state are given in several forms and those most appropriate in theoretical work are indicated. A detailed treatment of the thickness-vibration transducer is given, resulting in expressions for the electrical characteristics and acoustic power. Various special cases are briefly considered.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 : [621.396.9+77] **100**

Meteor Velocities.—P. M. Millman & D. W. R. McKinley. (*Observatory*, Aug. 1950, Vol. 70, No. 857, pp. 156–158.) Photographic and radio techniques are discussed in relation to their capabilities of detecting fast meteors. Meteors with speeds as high as 150 km/s should be detectable by radio methods.

523.7 : 538.12 **101**

The Effect of Turbulence on a Magnetic Field.—P. A. Sweet. (*Mon. Not. R. astr. Soc.*, 1950, Vol. 110, No. 1, pp. 69–83.) Extension of earlier work (1677 of 1950). Mathematical analysis indicates that (*a*) turbulence reduces the effective conductivity in the core and in the outer layers of the sun, but sunspot fields are not affected; (*b*) the decay time of the sun's general magnetic field is somewhat less than 10^{10} years, while the mean field in the core, if the general field is decaying from some initial state, is irrotational; (*c*) no system of meridian-plane convection currents in the sun can provide a general amplification of a field produced by a given e.m.f., while turbulence in fact reduces the field.

523.71 **102**

The Solar Constant.—C. W. Allen. (*Observatory*, Aug. 1950, Vol. 70, No. 857, pp. 154–155.) Discussion leads to a tentative value of 1·97 cal/cm²/min.

523.72 **103**

Cosmic Radiation from the Sun.—A. Ehmert. (*Z. Naturf.*, 1948, Vol. 3a, No. 5, pp. 264–285.) The phenomena of chromosphere eruptions may be related to the ionization of chromosphere regions by protons accelerated in the varying magnetic fields of sunspots; in the same way accelerated electrons may give up their energy as u.s.w. radiation.

523.72 : 621.396.822 **104**

Solar Radio-Frequency Radiation.—J. L. Pawsey. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 290–308. Discussion, pp. 308–310.) A survey of solar-noise research from 1932 to 1948. Observed characteristics in the wavelength range from 1 cm to a few metres are described. From the intensity, region of origin, association with visual phenomena and polarization a classification is suggested. A thermal component is recognized corresponding in intensity to a black-body radiation of a temperature that rises from 10^4 °K at a wavelength of 1 cm to 10^6 °K at wavelengths of a few metres. This is believed to be associated with a rise in the region of origin from the lower chromosphere to the corona. Non-thermal components, prominent at metre wavelengths and believed to originate from electrical disturbances in the solar atmosphere, vary rapidly and have occasional peak intensities 10^3 to 10^6 times the thermal ones. 66 references are given.

523.74 : 538.56 : 537.56 **105**

The Characteristics of Radio-Frequency Radiation in an Ionized Gas, with Applications to the Transfer of Radiation in the Solar Atmosphere.—Smerd & Westfold. (See 95.)

523.74/.75 : 621.396.11 **106**

Solar Notes.—H. W. Newton. (*Observatory*, Aug. 1950, Vol. 70, No. 857, pp. 163–164.) Solar activity during the first six months of 1950 is briefly reviewed. Observed correlations between special solar phenomena, such as flares, and radio propagation conditions are described.

523.8 : 538.12 **107**

Stellar Magnetic Fields and Rotation.—S. K. Runcorn. (*Observatory*, Aug. 1950, Vol. 70, No. 857, pp. 155–156.) Using data applying to eight stars, the correlation coefficient between magnetic field and angular momentum is 0.6. Possible causes of varying and reversing magnetic fields are discussed.

538.12 : 521.12 **108**

Gravitational Field and Magnetism.—A. Maior. (*C. R. Acad. Sci., Paris*, 25th Sept. 1950, Vol. 231, No. 13, pp. 607–608.) Argument indicating that a charged body moving in a gravitational field produces a convection current accompanied by a magnetic field. Formulae are derived which are more general than the empirical formula of Blackett.

550.372 **109**

The Earth's Constants from Combined Electric and Magnetic Measurements partly in the Vicinity of the Emitter.—K. F. Niessen. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 552–558. In English.) The dielectric constant and conductivity of the earth in the vicinity of a projected transmitter are found by making measurements of E and H at points close to (distance 2λ-4λ) and remote from an experimental transmitter. The method depends on the fact that at short distances the electric and magnetic field strengths vary according to different laws. The analysis is based on Sommerfeld's vector-function formula for the radiation from an ideal dipole, and the required constants are obtained from a simple system of curves. See also 3893 of 1947.

550.38 **110**

The 'Absolute Quadrupole-Moment'—a Fundamental Magnetostatic Quantity and its Geophysical Significance.—H. G. Macht. (*Z. Naturf.*, 1948, Vol. 3a, No. 4, pp. 189–195.)

551.5 : 621.396.81.029.63/.64 **111**

A Radio Meteorological Investigation in the South Island of New Zealand.—Milnes & Unwin. (See 200.)

551.510.535 **112**

Ionosphere Observations in Adélie Land.—M. Barré & K. Rawer. (*C. R. Acad. Sci., Paris*, 16th Aug. 1950, Vol. 231, No. 7, pp. 436–437.) An interim report of observations made during the antarctic cruise of the *Commandant Charcot* (see also 3429 of 1949 and 97 of 1950). Features noted from recordings obtained during 24 hours on 3rd/4th January 1950 include: (*a*) a sporadic-E layer giving echoes at high frequencies (10 Mc/s); frequent stratification of this layer and increase of its height with frequency; (*b*) permanent diffusion of the F layer, extending with increase of frequency; (*c*) horizontal traces resembling those of the sporadic-E layer but at heights of 250–800 km; (*d*) selective absorption at about 3.5 Mc/s masking all trace of layers.

551.510.535 : 538.566 **113**

The Poynting Vector in the Ionosphere.—Scott. (See 193.)

551.594.6(729) 114

Air Weather Service Sferics Operations in the Caribbean Area.—H. F. Willey. (*Trans. Amer. geophys. Union*, June 1949, Vol. 30, No. 3, pp. 330–332.) A general description is given of the sferics 4-station network and its operation, with discussion of the correlation of sferics with weather conditions.

523.72+523.854] : 621.396.822 115

Bruits Radio-Électriques Solaires et Galactiques (Solar and Galactic Radio Noise). [Book Review]—U.R.S.I. (Union Radio Scientifique Internationale) Special Report No. 1. Brussels, 1950, 51 pp. (*HF, Brussels*, 1950, No. 7, p. 200.) A résumé of present knowledge. The report was presented at the Stockholm meeting, 1948. An English edition is also available.

LOCATION AND AIDS TO NAVIGATION

534.88 116

Sound Ranging at the Morris Dam Torpedo Ranges.—R. N. Skeeters. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, p. 718.) Summary of A.I.E.E. Summer General Meeting paper. For making accurate determinations of the trajectories of under-water missiles, the latter are caused to generate sounds which are picked up by suitably located hydrophones arrayed in groups of eight. An oscillograph record is obtained. Reduction of the data is accomplished by means of a computer which is a scale model of one of the hydrophone groups.

621.396.9 : 621.396.67 117

Radar Aerial Systems for Uniform Irradiation of a Surface.—J. R. Huynen. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 293–297.) The problem of achieving uniformity of energy at all points of a spiral scan is studied.

621.396.93 118

The Relative Merits of Presentation of Bearings by Aural-Null and Twin-Channel Cathode-Ray Direction-Finders.—S. de Walden & J. C. Swallow. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 362–365.) Discussion on 3142 of 1949.

621.396.93 119

Some Experiments on the Accuracy of Bearings taken on an Aural-Null Direction-Finder.—F. Horner. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 359–361. Discussion, pp. 362–365.) The paper describes some tests to determine how the accuracy of a bearing taken on an aural-null rotating H-Adcock direction-finder depends on the width of the minimum and on the receiver output noise-level. The results pertain to bearings taken on a steady tone-modulated signal by an experienced observer working under good conditions. They indicate that bearings taken under these conditions will have a standard deviation of between $\frac{1}{10}$ and $\frac{1}{20}$ of the arc of silence except for very small arcs, even when the bearings are derived from very few oscillations of the aerial system. Accuracy is improved if the number of complete oscillations is greater than about five. Accuracy is degraded if the angle through which the aerial is swung is increased to improve the quality of the signal at the limits of the swing.

Differences of at least two to one in the standard deviation of observed bearings may occur between different observers, and with one observer at different times. Compared with these changes, any changes due to the use of different receiver output noise-levels are considered to be small.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.787.9 120

The Pirani Effect in a Thermionic Filament as a Means of Measuring Low Pressures.—(*Brit. J. appl. Phys.*, Sept. 1950, Vol. 1, No. 9, p. 240.) Correction to paper abstracted in 1922 of 1950. W. P. Jolly is the sole author.

533.56 121

Characteristics of Diffusion Pumps.—R. Witty. (*Brit. J. appl. Phys.*, Sept. 1950, Vol. 1, No. 9, pp. 232–237.)

533.583 : 621.385 122

A Method of Measuring the Efficiency of Getters at Low Pressures.—S. Wagener. (*Brit. J. appl. Phys.*, Sept. 1950, Vol. I, No. 9, pp. 225–231.) The method is based on measurement of the pressure drop along a narrow tube connecting the bulb containing the getter to the manifold of the pumping system. The values found for the rate of absorption of air ranged from 10 cm³/s for Mg to 1 500 cm³/s for Th getter, the bulb pressure being 1.5×10^{-6} mm Hg.

535.37 123

Phosphors and Phosphorescence.—G. F. J. Garlick. (*Rep. Progr. Phys.*, 1948–49, Vol. 12, pp. 34–53. References, pp. 53–55.) Recent investigations of luminescence in crystalline impurity-activated phosphors are reviewed. The electron-energy-band model and experimental support for it are discussed. Long-duration phosphorescence, due to electrons trapped in thermally metastable levels, correlates with thermoluminescence. Advances are reported in knowledge of the structure of luminescence emission centres in sulphide and silicate phosphors. The emission spectra of manganese-activated silicates, recent studies of oxides and tungstates, and infrared-sensitive phosphors are treated. The latter need a secondary activator for marked sensitivity; infrared light appears to cause the ejection of trapped electrons, but there is no simple correlation between optical and thermal ejection.

535.37 : 546.472.21 124

The Introduction of Copper into a Luminescent Zinc Sulphide.—N. Ril' & G. Ortman. (*C. R. Acad. Sci. U.R.S.S.*, 11th June 1949, Vol. 66, No. 5, pp. 841–845. In Russian.) If copper is introduced by diffusion into ZnS crystals it may be in two states, one causing blue luminescence and the other green luminescence. An experimental study of these effects is described.

537.311.31 : 546.92 : 541.183.56 125

Resistance Variation of Platinum Foil due to Gas Adsorption.—W. Braunbek. (*Z. Naturf.*, 1948, Vol. 3a, No. 4, pp. 216–220.) Experiments made with Pt foil in oxygen, argon and helium indicate a resistance reduction of the order of 10^{-4} as compared with the value in vacuo, the effect being greatest in oxygen.

538.221 126

On Ferromagnetic States.—J. Giltay. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 253–274.) The form of Madelung's laws is criticized and new expressions are formulated covering effects observed in ferromagnetic materials. Operating-cycle diagrams derived from auxiliary loop curves are introduced

538.221 127

Magnetostriction of Permanent-Magnet Alloys.—E. A. Nesbitt. (*J. appl. Phys.*, Sept. 1950, Vol. 21, No. 9, pp. 879–889.) Magnetostriction measurements were made on various alloys having coercive forces from 50 to 600 oersted. In the older carbon-hardening permanent magnets, high coercive force and high magnetostriction appear together; for the newer carbon-free type this coincidence does not hold. These results are discussed in the light of recent theories.

548.0 : 537.228.1 **128**

Determination of the Elastic and Piezoelectric Coefficients of Monoclinic Crystals, with particular Reference to Ethylene Diamine Tartrate.—R. Bechmann. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 577–589.) Longitudinal modes of vibration were used for narrow bars, low-frequency longitudinal and face-shear modes for square plates containing the axis of symmetry, coupled modes for square plates perpendicular to the axis of symmetry, and thickness-shear modes for plates containing the axis of symmetry. New values of the coefficients and their temperature coefficients are given for EDT. Some properties are considered of face-shear vibrating square plates of EDT rotated about the axis of symmetry as functions of the orientation, and of Y-cut plates as functions of the width/length ratio.

548.0 : 549.451 **129**

Influence of Plastic Flow on the Electrical and Photographic Properties of the Alkali-Halide Crystals.—F. Seitz. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, pp. 239–243.)

620.193 : 621.315.61 **130**

Methods for Determining the Effect of Contaminants on Electrical Insulation.—K. N. Mathes, L. E. Sieffert, H. P. Walker & R. H. Lindsey. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part 1, pp. 113–118. Discussion, pp. 118–119.) The results of tests made under laboratory conditions with carefully controlled mixtures of such contaminants as are commonly encountered on board ship are tabulated according to the effects on the physical and electrical properties of insulating materials, including surface breakdown voltage, dimensional stability, etc.

621.315.61 : 621.317.331 **131**

Some Measurements of the Resistivity of Good Insulators.—N. W. Ramsey. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 590–594.) A method depending on the loss of charge on a capacitor was used. The resistances of amber, alkathene, distrene and perspex increased over a period of weeks, the final values being considerably higher than previously published figures.

621.315.612.011.5 **132**

Ceramic Dielectrics with High Permittivity. Titanates.—A. Danzin. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 230–242 & *Onde élect.*, June & July 1950, Vol. 30, Nos. 279 & 280, pp. 253–258 & 335–340.) The mode of preparation of ceramic dielectrics is described and the properties of normal mineral insulating materials and of titanates are compared. Crystal structure and anomalous temperature coefficients are discussed and methods of obtaining a specified dielectric constant are outlined. Titanates are broadly classified into two groups and applications are listed.

621.315.612.4 : 621.3.011.5 **133**

The Structure, Electrical Properties and Potential Applications of the Barium-Titanate Class of Ceramic Materials.—W. Jackson. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 285–289.) Abstract of I.E.E. lecture, March 1950, reviewing present knowledge. The 75 references given are intended to afford a preliminary guide to the published work on the subject.

621.319.4 : [621.793 : 621.315.614.6 **134**

Metallized Paper for Capacitors.—D. A. McLean. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1010–1014.) An account of development work in the Bell laboratories. Lacquering the paper prior to metallizing increases the dielectric strength and insulation resistance, reduces corrosion of the metal coating and also loss of coating by electrolysis. Special precautions are necessary to exclude moisture from metallized-paper capacitors. See also 123 of 1950 (Wehe).

666.1.037.5 **135**

The Physical Aspect of Glass/Metal Sealing in the Electronic Valve Industry: Part 2.—G. Trébuchon & J. Kiefter. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 243–258.) The processing technique for the glass alone is discussed; graphs show the optimum annealing temperature and duration, and optimum cooling rate, for glasses of different thicknesses and expansion coefficients. The effects of annealing on the quality of seal are discussed. Graphs based on polarimetric observations show the effects on the stresses produced in the seal in numerous cases. A table summarizes the effects of the different variables in the annealing cycle and also of the intrinsic properties of the materials. Part 1: 2253 of 1950.

669.15.26 : 666.1.037.5 : 621.385.832 **136**

Stainless Steel for Television.—A. S. Rose. (*Metal Progress*, June 1950, Vol. 57, No. 6, pp. 761–764.) The use of an alloy containing only 17% Cr for the metal cones of large c.r. tubes for television results in a saving in cost compared with that for the alloy previously used, which contained 28% Cr. The addition of small amounts of other metals is necessary to make the new alloy suitable for sealing to glass.

MATHEMATICS

512.31 **137**

On Certain Polynomials introduced by Tchebycheff.—H. Delange. (*C. R. Acad. Sci., Paris*, 25th Sept. 1950, Vol. 231, No. 13, pp. 602–604.) A study of the asymptotic distribution of the zeros of P_n polynomials when n becomes infinitely great.

517.564.3 : 534.232 **138**

On the Extension of Some Lommel Integrals to Struve Functions with an Application to Acoustic Radiation.—C. W. Horton. (*J. Math. Phys.*, April 1950, Vol. 29, No. 1, pp. 31–37.)

517.564.3(083.5) **139**

Tables of Integrals of Struve Functions.—M. Abramowitz. (*J. Math. Phys.*, April 1950, Vol. 29, No. 1, pp. 49–51.)

517.564.3(083.5) **140**

A Short Table of Struve Functions and of Some Integrals Involving Bessel and Struve Functions.—C. W. Horton. (*J. Math. Phys.*, April 1950, Vol. 29, No. 1, pp. 56–58.)

519.272.15 : 621.392 **141**

Short-Time Autocorrelation Functions and Power Spectra.—R. M. Fano. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 546–550.) The reciprocal relations between autocorrelation functions and power spectra, known as Wiener's theorem, are extended in a modified form to the case of experimental results obtained by means of filters with finite time-constants.

681.142 **142**

Comparison of Long-Time and Short-Time Analog Computers.—V. Paschkis. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 70–73.)

681.142 **143**

Application of the California Institute of Technology Electric Analog Computer to Nonlinear Mechanics and Servomechanisms.—G. D. McCann, C. H. Wilts & B. N. Locanthi. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 652–660.) Full paper. Summary abstracted in 918 of 1950.

681.142 : 517.512.2 **144**

A New Fourier-Coefficient Harmonic Analyzer.—S. Charp. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 644–649. Discussion, pp. 649–651.) Full paper. Summary abstracted in 674 of 1950.

681.142 : 621.392 **145**

A High-Speed Multiplier for Analogue Computers.—Locanthi. (See 60.)

501 : 517. 5 : 53 **146**

Formulas and Theorems for the Special Functions of Mathematical Physics. [Book Review]—W. Magnus & F. Oberhettinger. Publishers: Chelsea Publishing Co., New York, 1949, 172 pp. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, p. 733.) This book, which is a reference work rather than a textbook, deals with Bessel functions, spherical harmonics, hypergeometric functions and elliptic functions, and, as special cases, Laguerre, Hermite and other functions. Chapters are included on integral transformations and on coordinate transformations.

517.43 : [5+6 **147**

Operatorenrechnung und Laplacesche Transformation. [Book Review]—K. W. Wagner. Publishers: J. A. Barth, Leipzig, 1950, 471 pp., 42.80 DM. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Aug. 1950, Vol. 28, No. 8, p. 334. In German.) Second, revised edition of the book noted in 2827 of 1949.

517.9 : [5+6 **148**

Die Differentialgleichungen der Technik und Physik (Differential Equations of Technology and Physics). [Book Review]—W. Hort & A. Thoma. Publishers: J. A. Barth, Leipzig, 5th edn 1950, 576 pp., 46.80 DM. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Aug. 1950, Vol. 28, No. 8, pp. 335–336. In German.) This edition of "Die Differentialgleichungen des Ingenieurs", newly revised by Thoma, is a comprehensive textbook in eight parts dealing with the subject from elementary differential and integral calculus to differential and difference equations, Fourier series, variational calculus and integral equations. Graphical and mechanical methods of solution are described in addition to analytical methods. "The book is clearly written and is recommended both for the beginner and the practising engineer."

517.91 **149**

Differential Equations. [Book Review]—H. W. Reddick. Publishers: Wiley & Sons, New York, and Chapman & Hall, London, 2nd edn 1949, 288 pp., 24s. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, p. 733.) A relatively elementary, but clear and accurate, textbook for intending engineers; partial differential equations are not dealt with.

MEASUREMENTS AND TEST GEAR

529.1 : 529.786 **150**

On a Periodic Fluctuation in the Length of the Day.—H. F. Finch. (*Mon. Not. R. astr. Soc.*, 1950, Vol. 110, No. 1, pp. 3–14.) From a study of the performance of a number of quartz-crystal clocks used in the Greenwich Time Service, an annual periodic fluctuation in the length of the day is deduced. The variation is of the order of ± 0.001 sec and has an accumulative effect in time of approximately ± 0.060 sec. This is in very close agreement with results obtained from independent data by N. Stoyko and demonstrates the persistent character of the phenomenon. See also 2275 of 1950 (Scheibe & Adelsberger).

621.3.011.5 : 621.365.55† **151**

The Measurement of Dielectric Loss at High Frequencies and under Changing Temperature.—J. B. Whitehead & W. Rueggeberg. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 520–524.) Full paper. Summary abstracted in 137 of 1950.

621.317.088.4 : 621.314.12 **152**

The Fundamental Limitations of the Second-Harmonic Type of Magnetic Modulator as Applied to the Amplification of Small D.C. Signals.—F. C. Williams & S. W. Noble. (*Proc. Instn elect. Engrs*, Part II, Aug. 1950, Vol. 97, No. 58, pp. 445–459. Discussion, pp. 474–483.) The advantages of the second-harmonic type of magnetic modulator for the conversion of d.c. to a.c. are discussed and theoretical analysis is presented for an idealized modulator of this type, with particular reference to the influence of various controllable parameters on the signal/noise ratio and the zero error. Experimental work is described which provides qualitative verification of the theory when allowance is made for the assumption of a simplified B/H characteristic for the core material. Great care in the design of the various circuits is necessary to eliminate additional sources of noise and zero error. In apparatus described the noise output is mainly Barkhausen noise in the cores and is equivalent to a signal input of about 10^{-19}W for a bandwidth of 1 c/s, the zero drift being equivalent to an input of about 3×10^{-18}W over a 2-hour period.

621.317.2 : 621.397.62 **153**

Television Laboratory Equipment.—W. Werner. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 635–637. In English.) Paper presented at the International Television Conference, Zürich, 1948. Short descriptions of the special features and the uses of video signal generator, video distribution amplifier, h.f. signal generator, microscope c.r.o. for observing any small portion of a television waveform, wide-band c.r.o., sine-wave signal generator (up to at least 5 Mc/s), h.v. voltmeter, film scanner, camera and studio-lighting equipment.

621.317.324(083.74)† **154**

Two Standard Field-Strength Meters for Very High Frequencies.—D. D. King. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1048–1051). "Methods of field-strength measurement are reviewed briefly and the design of field meters conforming closely to the conditions imposed by antenna theory is considered. Two instruments approaching ideal theoretical conditions and suitable for reference standards are described. The first of these contains an adjustable matching network. The second utilizes very fine wires on a styrofoam support."

621.317.353.3† : 621.396.11 : 551.510.535 **155**

Ionospheric Cross-Modulation: Techniques of Measurement.—C. C. Newton, F. J. Hyde & H .G. Foster. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 616–623.) The techniques described were used for the investigations noted in 3219 of 1948 (Ratcliffe & Shaw), 194 of 1949 (Huxley, Foster & Newton) and 1220 of 1950 (Huxley). The transferred modulation was deduced from receiver measurements of the carrier voltage and the a.f. voltage of the wanted signal. The phase of the transferred modulation relative to that of the directly received disturbing signal was determined by forming a Lissajous figure; a phase changer was used to measure the phase difference. A development is described which permits modulation depth and phase to be displayed on a single c.r.o.

621.317.411† + 621.317.43 **156**

Measurement of Permeability and Magnetic Losses of Straight Samples.—P. M. Prache & R. Cazenave. (*Câbles & Transmission, Paris,* July 1950, Vol. 4, No. 3, pp. 216–233.) Advantages are gained by using a straight rod of the material under test in place of the toroidal sample normally introduced into the magnetic circuit. The calculation involved and the interpretation of results are simplified by considering the cylindrical sample replaced by an equivalent oblate spheroid and by using a coil much longer than this core so as to eliminate end effects. Practical inductance formulae are derived which may be used to determine permeability and loss coefficients.

621.317.443 **157**

A Permeameter for Magnetic Testing at Magnetizing Forces up to 300 Oersteds.—R. L. Sanford & P. H. Winter. (*Bur. Stand. J. Res.,* July 1950, Vol. 45, No. 1, pp. 17–21.) An instrument designed to test specimens up to 3 cm wide and 1 cm thick, with a preferred length of 28 cm. It is simpler and more rapid in operation than the Burrows permeameter and requires only a single specimen. Accuracy is within 1%.

621.317.444† **158**

Underwater Gaussmeter.—L. Vérain & P. Jolivet. (*Rev. gén. Élect.,* Sept. 1950, Vol. 59, No. 9, pp. 405–408.) The instrument described comprises an air-driven rotor of special design located in the unknown field and having two collector brushes connected by line to a fluxmeter. The brushes are periodically short-circuited, so that the fluxmeter needle has a steady deflection proportional to the unknown field and independent of the duration of the deflection or the speed of rotation of the rotor. Results are reported of measurements made at Algiers, in 1940, of the vertical component of the earth's magnetic field at various depths in the vicinity of a destroyer.

621.317.723 **159**

A Simple Vibrating Condenser Electrometer.—D. G. A. Thomas & H. W. Finch. (*Electronic Engng,* Sept. 1950, Vol. 22, No. 271, pp. 395–399.) The d.c. input is converted to a.c. by applying it through a series resistor to the plates of a capacitor consisting of a stainless-steel reed vibrating at 550 c/s close to a polished steel disk. The resultant alternating voltage is amplified, rectified and fed back to cancel the input voltage, the electrometer acting as a null detector. Diurnal zero drift is 1 mV on a full-scale sensitivity of 30 mV. An important application is to the measurement of ionization currents.

621.317.725 **160**

A New Expanded-Scale A.C. Voltmeter.—N. P. Millar. (*Trans. Amer. Inst. elect. Engrs,* 1949, Vol. 68, Part I, pp. 641–643.) Full paper. Summary abstracted in 687 of 1950.

621.317.725.029.5 **161**

A Thermal Millivoltmeter for Measuring Radio-Frequency Voltages.—N. Coulson. (*Proc. Instn elect. Engrs,* Part III, Sept. 1950, Vol. 97, No. 49, pp. 344–348.) The measuring element is a thermocouple milliammeter. The input impedance is varied by means of a turret switch which connects resistors in series or in parallel with the thermocouple, so that the output voltage of a source may be measured with various loads. At frequencies up to 100 Mc/s the error is less than 1% for purely resistive 70-Ω sources, but may amount to 5% when reactive elements are present.

621.317.727.025 **162**

The Polar Ammeter as an A.C. Potentiometer — The Synchropotentiometer.—E. B. Brown. (*J. sci. Instrum.,* Sept. 1950, Vol. 27, No. 9, pp. 251–252.) Description of experiments showing that the voltage generated in the moving coil of a polar ammeter (1084 of 1948) can be varied both in phase and magnitude, so that the instrument can fulfil the functions of an a.c. potentiometer. An almost linear variation of amplitude can be obtained by moving the pointer over the scale. The phase can be varied by angular adjustment of the cradled synchronous motor. Results are quoted and a description is given of the apparatus.

621.317.73 **163**

A Direct-Reading Impedance-Measuring Instrument for the U.H.F. Range.—W. R. Thurston. (*Gen. Radio Exp.,* May 1950, Vol. 24, No. 12, pp. 1–7.) This null-type instrument measures, on scales independent of frequency, conductances, and susceptances of either sign, from 1 to 400 millimhos at frequencies from 70 to 1 000 Mc/s. Three coaxial lines, one terminated by a resistance equal to its characteristic impedance, one a stub adjusted to $\lambda/8$ at the operating frequency and forming the susceptance standard, and the other connected to the unknown impedance, are fed at a common junction from a common source and have adjustable pickup loops which are so oriented that their combined output is zero. The loop-position scales are calibrated to read susceptance and conductance directly.

621.317.733.089.6 : 621.3.018.78† **164**

A Method for Calibrating Distortion-Measurement Bridges.—W. Hübner. (*Arch. tech. Messen,* July 1950, No. 174, pp. T73–T74.) Measurement of distortion with an a.c. bridge/comparator is liable to errors depending on the Q of the resonant circuit and especially on the order number of the harmonics present. In the calibration and test method described the measurement bridge is connected in the fourth arm of a resistance bridge to which, after balancing, a voltage of fundamental frequency is applied across one diagonal and a known harmonic voltage across the other diagonal. The distortion factor of the voltage appearing across the measurement bridge is thus known accurately.

621.317.755 : 621.3.015.3 **165**

Technique of Autosynchronous Observation of Transients.—F. Lepri, I. F. Quercia & B. Rispoli. (*Nuovo Cim.,* 1st Dec. 1948, Vol. 5, No. 6, pp. 569–585.) Discussion of modifications to a circuit previously described (*ibid.,* 1948, Vol. 5, p. 384.), to make the whole of the transient visible. The c.r.o. timebase is triggered by the transient, which passes through a delay line before being applied to the y-plates of the c.r.o. Operation of the boot-strap, Miller and phantastron sawtooth-wave generators and the design of delay lines are considered.

621.317.755 : 621.317.791 **166**

Polar Vector Indicator.—E. A. Walker, A. H. Waynick & P. G. Sulzer. (*Trans. Amer. Inst. elect. Engrs,* 1949, Vol. 68, Part I, pp. 154–159.) See 2569 of 1949.

621.317.757 **167**

A Frequency-Spectrum Analyser for Radio Signals.—J. Marique. (*HF, Brussels,* 1950, No. 7, pp. 177–184.) An account is given of an instrument for analysis of signals from a distance. The principal features are described and other uses indicated. Various examples of measurements are illustrated.

621.317.78.029.64 **168**

The Measurement of Microwave Power at Wavelengths of 3 cm and 10 cm.—R. Street & P. D. Whitaker. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 623–624.) A magnetron or klystron was connected via a waveguide to a matched-wedge constant-flow calorimeter. A directional coupler of known coupling factor was inserted in the waveguide. The absolute power delivered to a milliwattmeter matched to the low-power guide of the coupler can be calculated. For three types of instrument the ratios of absolute to indicated power were respectively 1·04, 1·04 and 1·10. The accuracy of the measurements is within about 2%.

621.317.79 : 551.594.6 **169**

A Subjective Method of Measuring Radio Noise.—H. A. Thomas. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 329–334.) The equipment described can be operated by inexperienced personnel. Sources of error are analysed fully. Noise levels greater than 1 μV/m over the frequency range 2·5–20 Mc/s can be measured to within $\pm$5 db.

621.317.79 : 621.396.933 **170**

Monitoring Airways Radio.—(*Wireless World*, Sept. 1950, Vol. 56, No. 9, p. 335.) A short account of the work carried out at the frequency-measurement station of the Ministry of Civil Aviation at Pailton, near Rugby, with illustrations of some of the equipment. Records are kept of all routine measurements and a monthly chart gives a day-to-day record of the frequencies of all the navigational beacons.

621.395.61.089.6 **171**

American Standard Method for the Pressure Calibration of Laboratory Standard Microphones: Z24.4-1949 (Abridged).—Beranek, Cook, Romanow, Wiener & Bauer. (See 19.)

621.395.623.54.089.6 **172**

American Standard Method for the Coupler Calibration of Earphones. Z24.9-1949 (Abridged.)—Beranek, Romanow, Morrical, Anderson, Bauer, Cook & Wathen-Dunn. (See 21.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9 : 061.3 **173**

Rome Ultrasonics Convention.—Bradfield. (See 10.)

534.321.9.001.8 : 669.71 : 621.791 **174**

Ultrasonic Soldering of Aluminium.—B. E. Noltingk & E. A. Neppiras. (*Nature, Lond.*, 7th Oct. 1950, Vol. 166, No. 4223, p. 615.) Experiments are described which show that in the process of tinning Al and its alloys by application of molten solder together with intense ultrasonic vibration, the action is that of removing the oxide skin by cavitation erosion. Relatively low frequencies were found preferable: a 50-W 18-kc/s oscillator was quite effective, while a 1-Mc/s oscillator supplied with 3 kV (r.m.s.) was ineffective.

538.569.2.047 : 621.38.001.8 **175**

Effects of Intense Microwave Radiation on Living Organisms.—J. W. Clark. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1028–1032.) Radiation of wavelength about 10 cm was found the most dangerous. With much shorter waves, surface heating is produced and underlying tissues are little affected, while with much longer waves there is a general elevation of body temperature but no particular damage to the tissue. See also 2284 of 1949 (Salisbury, Clark & Hines).

551.508.1 : 621.317.083.7 **176**

Automatic Range-Adjusting Radiosonde Recorder.—G. E. Beggs, Jr. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 602–607.) Full paper. Summary noted in 703 of 1950.

621.317.755 : 531.771 **177**

An Electronic Tachometer.—H. G. Jerrard & S. W. Punnett. (*J. sci. Instrum.*, Sept. 1950, Vol. 27, No. 9, pp. 244–245.) Details are given of an instrument capable of measuring the speed of revolution of a shaft, in any speed range, to within 0·05%. The rotation of the shaft is made to generate an alternating voltage which, after amplification, is connected to the y-plates of a c.r. tube whose x-plates are connected to a variable-frequency oscillator.

621.365.54 : .55† **178**

The Design of H.F. Generators for Industrial Use and the Development of their Application in France.—J. Girardeau. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 259–275.) Illustrated account of many different applications of dielectric-loss and induction heating in industry, and of the equipment used.

621.384.611.2† **179**

The Design of the Bevatron Magnet.—D. Sewell. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, p. 721.) Summary of A.I.E.E. Summer General Meeting paper. The ring magnet for the Berkeley proton synchrotron will consist of four spaced quadrants, with an overall diameter of 135 ft; 9 700 tons of mild-steel plate will be required.

621.384.62† **180**

Linear Accelerators.—D. W. Fry & W. Walkinshaw. (*Rep. Progr. Phys.*, 1948-49, Vol. 12, pp. 102–130. References, pp. 130–132.) The axial and the radial stability of particles in r.f. fields are examined, basic types of particle accelerator are described and the travelling-wave and standing-wave types are considered in more detail. Methods of construction are described and also methods of applying r.f. power and of particle injection. Reported performance data of different linear electron accelerators are tabulated and possible future developments are outlined. Accelerators for heavy particles are discussed briefly.

621.385.833 **181**

Certain Properties of Electrostatic Fields encountered in Electron Lenses.—P. A. Lindsay. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, pp. 699–702.) Fine details of the form of the equipotential lines in a bipotential electron lens are revealed by application of the relaxation method to the solution of the Laplace equation in cylindrical coordinates. Asymmetry of the field between the adjacent ends of the two cylinders forming the lens is confirmed by the same method and is found to be of the order of 2% in a particular case.

621.385.833 **182**

An Electron-Optical Apochromat.—O. Scherzer. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 544–545.) An example is calculated to show how chromatic aberration in electron lenses can be corrected by the use of plane metal foils permeable to electrons.

621.385.833 **183**

Reduction of the Spherical Aberration of Magnetic Electron Lenses.—U. F. Gianola. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, pp. 703–708.) Discussion of a method for increasing the resolving power of asymmetrical magnetic electron lenses; the lens field is reinforced with the field of a small air-cored coil.

621.385.833 184
Second-Order Beam Focusing of Charged Particles in Homogeneous Magnetic Fields.—H. Hintenberger. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 669–670.)

621.385.833 185
A Removable Intermediate Lens for Extending the Magnification Range of an Electron Microscope.—J. Hillier. (*J. appl. Phys.*, Aug. 1950, Vol. 21, No. 8, pp. 785–790.) A lens is described which increases the ratio of maximum to minimum magnification of a conventional instrument to 25 : 1 without affecting the accessibility of the objective and projection lens pole pieces, thus making available the low magnifications needed for survey purposes, etc.

621.387.4† 186
Hydrogen-Filled Geiger Counters.—B. Collinge. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, pp. 665–674.) A new quench circuit is described and the characteristics of counters with permanent-gas filling are discussed in detail.

621.387.4† 187
Temperature Dependence of Counter Characteristics in Self-Quenching Geiger-Müller Counters.—W. R. Loosemore & D. Taylor. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369B, pp. 728–729.) Comment on 1983 of 1950 (Parkash & Kapur).

621.387.4† 188
After-Effects in Ultraviolet-Sensitive Counters.—H. Neuert. (*Z. Naturf.*, 1948, Vol. 3a, No. 4, pp. 221–225.)

681.142 : 533.6 189
Electric Analogue Computing Techniques for Complex Vibration and Aeroelastic Problems.—G. D. McCann & R. H. MacNeal. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, p. 724.) Summary of A.I.E.E. Summer General Meeting paper.

621.384.6† 190
The Acceleration of Particles to High Energies. [Book Review]—Publishers : Institute of Physics, London, 58 pp., 10s. 6d. (*J. sci. Instrum.*, Sept. 1950, Vol. 27, No. 9, p. 255.) This volume in the Institute's ' Physics in Industry ' series is based on papers presented at the Institute's 1949 Convention at Buxton.

621.385.833 191
The Practice of Electron Microscopy. [Book Review]—D. G. Drummond (Ed.). Publishers: Royal Microscopical Society, London, 141 pp., 21s. (*J. sci. Instrum.*, Sept. 1950, Vol. 27, No. 9, p. 255.) A comprehensive treatise on the detailed techniques used. It was produced by a group of twelve members of the Electron Microscopy Group of the Institute of Physics.

PROPAGATION OF WAVES

538.566 192
Formulation of Huyghens' Principle.—W. Franz. (*Z. Naturf.*, 1948, Vol. 3a, Nos. 8/11, pp. 500–506.) Making use of Green's dyad, a formulation of Huyghens' principle for e.m. waves is derived which, like Kirchhoff's scalar formula, makes it clear that for selected boundary values the wave equations are satisfied. Kirchhoff's theory does not solve a boundary-value problem but a discontinuity problem. In contradistinction to Kottler, the discontinuity is regarded as basic to Kirchhoff's theory and not as a property of the ' black ' screen.

538.566 : 551.510.535 193
The Poynting Vector in the Ionosphere.—J. C. W. Scott. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1057–1068.) Formulae and curves are given for calculating the polarization and complex Poynting vector of a radio wave in the ionosphere in the most general case. Deductions are made concerning the direction of energy flow for the ordinary and extraordinary modes in a parabolic distribution of ionization, for vertical incidence. When collision is taken into account the deflection from the vertical has a small westward component for both modes. The normal ionization gradient with latitude, together with diurnal changes in the ionized region, can explain the diurnal variation in the f_x-f_o critical-frequency difference as due to the variation in the total path deflection. See also 2516 of 1949.

538.566 : 621.396.67 194
Cylindrically Diverging Electromagnetic Waves in a Medium with Nonuniform Electrical Properties (Elias-Layer) above a Semiconducting Earth.—van der Wyck. (See 32.)

621.396.11 : 523.74/.75 195
Solar Notes.—Newton. (See 106.)

621.396.11 : 621.317.353.3† 196
Gyrointeraction.— Please note that the above U.D.C. number will be used in future instead of 621.396.812.

621.396.11 : 621.317.353.3† 197
Variability of the Resonance Frequency in Gyro-interaction of Radio Waves.—M. Carlevaro. (*Nuovo Cim.*, 1st Dec. 1948, Vol. 5, No. 6, pp. 535–550.) It is suggested that small variations of ionic density in the E layer satisfactorily account for the variations in resonance frequency found experimentally (513 of 1947 and 2328 of 1950). Theoretical calculations predict a smaller range of variation than that observed, unless it is assumed that in the lower levels of the E layer the electronic density is reduced mainly by negative-ion formation, while in the upper levels it is reduced by recombination with positive ions.

621.396.11 : 621.317.353.3†: 551.510.535 198
Ionospheric Cross-Modulation: Techniques of Measurement.—Newton, Hyde & Foster. (See 155.)

621.396.11.029.62 199
Experimental Study of the Propagation of Metre Waves: Measurements in Aircraft.—H. Vigneron. (*HF, Brussels*, 1950, No. 7, pp. 191–198.) Conflicting theories of propagation are discussed. The field calculated according to the ray theory has a series of maxima and minima, and is limited to the optical range. Theories based on diffraction give a field decreasing progressively with increasing distance and extending beyond the optical range. Measurements were made of 116·1-Mc/s signals received in aircraft at heights of 300, 1 500 and 3 000 m as the transmitter was approached. At great altitudes results conform to the ray theory; at small altitudes and well below the line of sight, van der Pol curves are applicable, with a gain with height which can only be determined by systematic experiments.

621.396.81.029.63/.64 : 551.5 200
A Radio Meteorological Investigation in the South Island of New Zealand.—B. Milnes & R. S. Unwin. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 595–616.) Local conditions in New Zealand, particularly with off-shore föhn winds, are favourable to the formation of radio ducts. Modern techniques were used to explore thoroughly the atmospheric conditions over a range of 200 km from the coast and up to 600 m above sea level. The results, obtained over the period September 1946 to the end of 1947, are displayed as isopleths of the atmo-

spheric parameters and of refractive index. Contours of radio field-strength are shown for selected days for wavelengths of 300 cm, 60 cm, 10 cm, and 3 cm. The properties of the ducts and the experimental technique are fully described.

621.396.812.3 : 551.510.535 **201**

The Fading of Radio Waves of Medium and High Frequencies.—R. W. E. McNicol. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, p. 366.) Discussion on **443** of 1950.

621.396.812.4.029.64 **202**

Microwave Propagation Experiments.—L. E. Thompson. (*Proc. Instn Radio Engrs, Aust.*, Aug. 1950, Vol. 11, No. 8, pp. 204–209.) Reprint. See 2894 of 1948.

RECEPTION

551.594.6 **203**

Some Measurements of Atmospheric Noise at High Frequencies.—H. A. Thomas. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 335–343.) Measurements of atmospheric noise at a number of stations in various parts of the world have been made since 1922 over periods ranging from a few days to several years. A summary of these observations has previously been given [534 of 1948 (Thomas & Burgess)]. The frequencies used were 2·5, 5, 10, 15 and 20 Mc/s, and the method was based on aural comparison of the received noise and a locally generated noise signal of controllable amplitude (see 169 above). Some of the results obtained are presented in the form of mean values for each month and for each hour of the day, together with figures indicating the degree of scatter about the mean value. The characteristics of atmospheric noise at one location do not appear to be applicable over a large area; this and other considerations throw doubt on the concept that lightning discharges are practically the sole source of h.f. noise. It is suggested tentatively that some noise sources may be quite local, but more experimental data are required to confirm or disprove this.

621.396.621 : 621.396.619.11 **204**

The Synchrodyne as a Precision Demodulator.—D. G. Tucker & R. A. Seymour. (*Wireless Engr*, Aug./Sept. 1950, Vol. 27, Nos. 323/324, pp. 227–237.) The synchrodyne circuit, in which the modulation frequency is extracted by filtration after the detector, may lead to distortion due to phase modulation of the local oscillator at the modulation frequency. An analysis of this distortion in the basic circuit is given, and practical methods of achieving precision, stability and freedom from distortion are described. Phase modulation is limited by the use of valve reactors, and constancy of gain is achieved by application of negative feedback.

621.396.823 : 537.523.3 **205**

Radio Influence from High-Voltage Corona.—G. R. Slemon. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 198–204. Discussion, pp. 204–205.) See 1780 of 1949.

621.396.828 **206**

Reduction of Interference from Radio-Frequency Heating Equipment.—G. W. Klingaman. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 718–724. Discussion, p. 724.) Discussion of the causes of the generation of very high frequencies by r.f. heating equipment, and of measures for its reduction, particular attention being given to harmonic suppression and effective screening.

621.396.933 : 621.395.625.2 **207**

An Automatic Monitoring Recorder.—(*Engineer, Lond.*, 18th Aug. 1950, Vol. 190, No. 4934, p. 186.) Short description of equipment for continuous recording of speech signals transmitted from an aircraft to a ground control station. The speech-frequency range is limited to 500–3 000 c/s. Recording is on standard Kodak film, a sapphire needle producing lateral indents, without cutting. The recording head is traversed across the film to obtain 120 sound tracks on each side, so that 120 ft of film suffice for a 24-hour period. Any portion of the record can be reproduced without interrupting the recording.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 **208**

Photons and Waves.—D. Gabor. (*Nature, Lond.*, 28th Oct. 1950, Vol. 166, No. 4226, pp. 724–727.) Abstract of parts of a lecture delivered in Paris, 9th May 1950, on 'La Théorie des Communications et la Physique'. A comparison is made of the quantum and classical methods of describing signals. The 'information cell' is taken as a convenient unit for discussing communication problems; by the classical method this has two data associated with it, an amplitude and a phase, but by the quantum method only one datum, of the nature of an amplitude. More information is, however, gained by the latter method since the total number of distinguishable steps of the single datum is greater than the product of the numbers of distinguishable steps of the two data in the classical analysis. The theory is illustrated by a determination of the optimum conditions for interchange of energy between a weak signal and a transverse electron beam in a waveguide.

621.39.001.11 : 535.42 **209**

Diffraction and Quantity of Information.—A. Blanc-Lapierre & M. Perrot. (*C. R. Acad. Sci., Paris*, 11th Sept. 1950, Vol. 231, No. 11, pp. 539–541.) The system considered is that constituted by an aperture, an object at infinity composed of incoherent sources, and a diffraction image at infinity. From the correspondence between image and object, the quantity of information transmitted by the aperture is deduced.

621.39.001.11 : 621.317.35 **210**

Signals with Limited Spectra and their Transformations.—J. Oswald. (*Câbles & Transmission, Paris*, July 1950, Vol. 4, No. 3, pp. 197–215.) Detailed mathematical treatment. See also 3069 of 1949.

621.395.44 : 621.315.052.63 **211**

Line Tuning Equipment used with Coaxial Cable for Carrier-Current Installation on Power Lines.—H. J. Sutton. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 44–48. Discussion, pp. 48–49.)

621.396.61/.62 **212**

A Frequency-Modulated Transmitter-Receiver for Motor Cycles.—(*Engineer, Lond.*, 18th Aug. 1950, Vol. 190, No. 4934, p. 172.) A 27-valve equipment in two units mounted on either side of the rear wheel. It is crystal controlled and has a f.m. r.f. output of 10 W on a spot frequency in the band 68–100 Mc/s. Sensitivity is 1 μV carrier input for 10 db quieting. 'Standby' power consumption is only 18 W. The equipment can be used within the temperature range −40°C to 70°C. In conjunction with a 20-W control transmitter it has a specified service radius of 20 miles. A selective calling system enables any one, or all, of 90 such units to be called from the control station.

621.396.619 : 621.392.52 **213**

Polyphase Modulation as a Solution of Certain Filtration Problems in Telecommunication.—I. F. Macdiarmid & D. G. Tucker. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 349–358.) An important class of filtration problems in telecommunication is associated with frequency changing; it includes the generation and demodulation of s.s.b. carrier channels and the elimination of image-frequency interference in heterodyne demodulators, such as the superheterodyne radio receiver or the conventional wave analyser. Filters for these applications are often difficult to design or realize, or may be inconvenient on account of variable tuning, etc.

Polyphase modulation can be used as part of the frequency-changing process with great advantage. It can eliminate the need for difficult or inconvenient filters, although other design problems are introduced which may sometimes be as difficult to solve. The basis of the advantages given by polyphase working is that polyphase signals possess an identifying property additional to that of frequency, namely, sequence. By using circuits which distinguish between signals of the same frequency but opposite sequence, it is possible, without any preliminary filtration, to separate signals which lie in the same frequency band after modulation, and which, therefore, could be separated by normal means only by filters before the modulation stage.

The first section of the paper outlines the main filtration problems which can be tackled by polyphase methods, and then the necessary polyphase theory is given. This is followed by a discussion of circuit design for polyphase modulation and sequence discrimination. The list of 30 references shows that there have been many publications covering some of the separate applications of this work, but the paper is believed to present for the first time a comprehensive theory of polyphase modulation embracing all the known applications.

621.396.619.16 : 621.396.41 **214**

A Time Division Multiplexing System.—W. P. Boothroyd & E. M. Creamer, Jr. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 92–97.) See 3258 of 1949.

621.396.65 **215**

A Microwave Communication Relay System.—W. P. Boothroyd & H. J. Churchill. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 637–641.) An incoming f.m. r.f. carrier causes deviation of the output of a local oscillator in accordance with the modulation of the incoming carrier, the oscillator output being amplified and radiated as the repeated signal. The whole system constitutes a negative-feedback amplifier and a study of its performance as a repeater is made on this basis. The extreme simplicity of its electrical and mechanical design makes the use of a tower unnecessary, a simple pole being sufficient to support the repeater equipment.

621.396.65 **216**

Problems to be Solved in the Application of Microwave Equipment.—R. C. Cheek. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, p. 718.) Summary of A.I.E.E. Summer General Meeting paper. Points to be dealt with in establishing a microwave channel include determination of frequency band, selection of terminal sites and calculation of inherent losses.

621.396.65 : 621.311 **217**

Microwave Channels for Power System Applications.—*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 40–42. Discussion, pp. 42–43.) An A.I.E.E. committee report discussing the advantages and disadvantages of microwave links for telemetry, supervisory control, and communication.

621.396.65 : 621.396.43.029.6 **218**

Radio-Beam System Planning.—W. Gerber. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 648–650. In German.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of the possible international extension of the present Swiss system of high-altitude stations.

621.396.65.029.6.001.4(494) **219**

Directional Transmission Tests in the Alps contributing to the Establishment of a Swiss R/T Network.—W. Klein. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Aug. 1950, Vol. 28, No. 8, pp. 303–317.) French and Italian versions based on paper abstracted in 2326 of 1949.

621.396.65.029.64 **220**

Passive Relay Stations of the Afourer/Bin-el-Ouidane Link.—R. Chaux & J. Dascotte. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 220–229.) Expressions for the radiation pattern and gain of a plane metal mirror are derived. The link considered is between two stations in Morocco 15 km apart in mountainous country. Two intermediate relay stations are used. At one a plane duralumin mirror of area 10 m² is mounted in a rigid frame 2 m above the ground. At the other, two similar plane mirrors are supported in an open cage on a 40-m pylon. Both mirrors are hinged to facilitate adjustment. Terminal transmitter and receiver aerials use parabolic mirrors of 10-m² aperture. Polarization is vertical. $\lambda = 9{\cdot}5$ cm. Using a 1-W f.m. signal and a 1·5-Mc/s pass-band in the receivers, communication has been maintained since 1949 in extreme climatic conditions. Calculated field strength and noise level are in fair agreement with actual values.

621.396.932 **221**

Liverpool Harbour Communications.—(*Wireless World*, Aug. 1950, Vol. 56, No. 8, pp. 277–279.) See also 2633 of 1950.

SUBSIDIARY APPARATUS

621-526 **222**

Comparison of Steady-State and Transient Performance of Servomechanisms.—H. Chestnut & R. W. Mayer. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 765–777.)

621-526 **223**

Instrument Inaccuracies in Feed-Back Control Systems with Particular Reference to Backlash.—H. T. March, M. Yachter & J. Zauderer. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 778–788.)

621-526 **224**

Analyzing Contactor Servomechanisms by Frequency-Response Methods.—J. Kochenburger. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, pp. 687–692.) An approximation method which facilitates the selection of compensating networks for improving the performance of contactor servomechanisms.

621.314.6 **225**

New Developments in Rectifier Technique.—F. Kesselring. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Aug. 1950, Vol. 28, No. 8, pp. 297–303. In French and German.) Description of two types of rectifier. The first is a vibrator mechanism. The interrupter tongues are prism-shaped and weigh about 60 mg; enclosed in a sealed container with inert gas under pressure they can withstand over 10 kV. Models developed include a 200-A and a 1 000-A type. The second design is a grid-controlled rectifier valve with Cs-vapour filling. Operating voltage is low; peak voltage 800–3 000 V. Valves passing 30 A have been constructed; a 150-A type is under development.

621.316.578.1 **226**

Electrical Timing Devices.—F. E. Reeves. (*Elect. Mfg, N.Y.*, Sept. 1948, Vol. 42, No. 3, pp. 114–119..168.) Ten points to be considered in the selection and application of electrical switch timers are enumerated and a chart is given outlining the operating characteristics of commercially available equipment.

621.316.722.1 **227**

A New Precision A.C. Voltage Stabilizer.—G. N. Patchett. (*Proc. Instn elect. Engrs*, Part II, Aug. 1950, Vol. 97, No. 58, pp. 529–538. Discussion, pp. 538–540.) Various types of stabilizer are discussed and an account is given of the design and performance of a stabilizer for meter testing applications which uses a temperature-compensated thermistor bridge. The stabilization ratio for a 10-V change of mains voltage (230 V nominal) is about 1 100. An output up to 2 kVA can be obtained.

621.316.722.1 **228**

A Simple Form of Voltage Stabilizer.—N. K. Saha, B. S. Chandersekhara & M. K. Sundaresen. (*Proc. nat. Inst. Sci., India*, March/April 1950, Vol. 16, No. 2, pp. 127–133.) Operating in the range of 600–2 000 V and suitable for Geiger-Müller counters, the stabilizer consists of an air-discharge tube under variable pressure and connected, in series with a 30–40-MΩ resistor, in parallel with the rectified output of a transformer. The voltage drop across the tube remains constant, for a given pressure, over a wide range of transformer output voltage, owing to gas ionization, the stabilized voltage increasing with pressure. A deviation of about 2·5% at a stabilized voltage of 1 500 V is quoted for transformer-output variation from 2 000 to 3 500 V.

621.316.722.1 **229**

Voltage Stabilizers assure Top Performance.—(*Elect. Mfg, N.Y.*, Sept. 1948, Vol. 42, No. 3, pp. 108–113..192.) Operating principles and performance data for magnetic, electronic, and servomechanism types of equipment for supplying constant-voltage power.

621.316.722.1 **230**

A Modified Moving-Coil Voltage Regulator of High Sensitivity.—N. W. W. Ellis. (*J. sci. Instrum.*, Sept. 1950, Vol. 27, No. 9, pp. 248–249.) "Modifications to a standard commercial voltage regulator are described, which result in stabilization of a mains supply line to within ±0·1 V for changes of load or input supply voltage and frequency within the ranges normally encountered. Loads of up to 7·5 kVA may be applied."

621.316.722.1.076.7 **231**

The Cathode Follower as a Voltage Regulator.—A. P. Willmore. (*Electronic Engng*, Sept. 1950, Vol. 22, No. 271, pp. 399–400.) Since the output voltage developed across the cathode load resistor is proportional to $V_g + V_a/\mu$, where μ is the amplification factor, fluctuations of V_a are reduced by a factor depending on μ. The cathode follower may be used (*a*) to increase the current range over which stabilization is satisfactory with a particular voltage-reference tube, (*b*) to provide a high reference potential for a series-parallel type of voltage regulator.

621.352/.355 **232**

Special Purpose Batteries.—A. Fischbach. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, pp. 701–704.) Three types developed for service use are discussed.

621.355 **233**

Electric Batteries: Recent Patents.—L. Jumau. (*Rev. gén. Élect.*, Sept. 1950, Vol. 29, No. 9, pp. 372–378.) Developments in primary batteries, chiefly of the dry type, are reviewed. See also 3177 of 1950.

621.396.683 : 621.396.65 **234**

Power Supplies for Microwave Relay Systems.—H. M. Ward. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part 1, pp. 631–636.) Interruption of the main a.c. supply causes the load to be transferred to a battery-operated vibrator in under 0·1 second. This is cut out when a petrol-electric set, whose start is delayed 15 seconds to avoid unnecessary starting during very short power failures, reaches a steady operating condition. The various units of the equipment are described. Performance data for various radio-beam links indicate the high degree of reliability achieved.

771.36 : 537.228.4 **235**

An Electro-optical Shutter for Photographic Purposes.—A. M. Zarem, F. R. Marshall & F. L. Poole. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 84–91.) A description of the development of a simple and reliable optical shutter using a Kerr cell as a light valve, with which photographic studies of electric discharges have been made using an effective exposure time of 0·04 μs. The control can be made sufficiently positive and accurate to permit initiation of operation at any preselected instant to within about 0·005 μs.

TELEVISION AND PHOTOTELEGRAPHY

621.397.2 **236**

Considerations on Facsimile Transmission Speed.—H. F. Burkhard. (*Trans. Amer. Inst. elect. Engrs*, 1949, Vol. 68, Part I, pp. 418–423. Discussion, p. 423.) A résumé of the work of many investigators and mathematical analysis of the factors which limit the speed of facsimile transmission in various systems. A method capable of transmitting 640 in.^{2} of copy per minute over a channel 192 kc/s wide, or 160 in.^{2} with a channel width of 48 kc/s, is described.

621.397.2 **237**

New Facsimile System.—M. Frank. (*Ann. Geofis.*, Oct. 1949, Vol. 2, No. 4, pp. 532–544.) Suitable for transmission of weather maps, graphs and printed matter of size up to 25 cm × 30 cm, by telephone line or radio link. An electromechanical recording system is used, the modulated subcarrier being obtained by interrupting the scanning beam at 3 kc/s. The number of scanning lines can be 4 per mm or less. The subcarrier frequency, after frequency division, is used to synchronize the movements of transmitter and receiver drums. Several copies can be produced simultaneously at the receiving end.

621.397.24/.26 **238**

Long-Distance Television Links between Fixed Points.—F. Vecchiacchi. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 647–648. In French.) Paper presented at the International Television Conference, Zürich, 1948. A short discussion of the economics of cable and radio links, with examples of both types at present in use.

621.397.24 **239**

Television Distribution over Short Wire Lines.—P. Adorian. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 650–653. In English.) Paper presented at the International Television Conference, Zürich, 1948. See 2339 of 1949.

621.397.24.018.78† : 621.315.212 240
Characteristics of Coaxial Pairs at Frequencies Involved in High-Definition Television Transmission.—Fuchs. (See 27.)

621.397.26 : 621.396.615.142.2 : 621.396.621.53 241
The Klystron Mixer Applied to Television Relaying.—Learned. (See 275.)

621.397.26 : 629.135 242
First Results of Stratovision Tests in the United States of America.—E. J. Aubort. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 653–657. In French.) Paper presented at the International Television Conference, Zürich, 1948. An account of tests carried out near Pittsburg with the relay aircraft at a height of 8 000 m, when the useful ground range exceeded 400 km. A map shows corresponding ranges in Europe for an aircraft at the same height over Zürich. A second map indicates the possibilities of international programme exchange in Europe, using seven aircraft and taking account of the coaxial cable envisaged by the C.C.I.F. for 1952. See also 3801 of 1946, 3279 of 1947 (Nobles) and 233 of 1949 (Sleeper).

621.397.331.2 243
'Knight' Scanning, Method giving Improvement of Television Picture Definition without Increase of Bandwidth.—P. M. G. Toulon. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 638–641. In French.) Paper presented at the International Television Conference, Zürich, 1948. Summary abstracted in 870 of 1949.

621.397.331.2 : 778.5 244
Notes on [picture] **Analysis in Television with Continuously Moving Film.**—S. Mallein. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 603–605. In French.) Paper presented at the International Television Conference, Zürich, 1948.

621.397.331.2 : 778.5 245
Luminescent-Screen 875-Line Scanning of Film Pictures.—A. Karolus. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 566–569. In German.) Paper presented at the International Television Conference, Zürich, 1948. A description of the apparatus, with a diagram illustrating the general lay-out, is given. The c.r. tube used is identical in construction with the usual type of projection tube and is operated at 25–40 kV. The raster surface is 6 cm × 9 cm and the screen is of the low-persistence type. Experiments showed that a ZnO phosphor gave a much higher degree of modulation than other phosphors tested. Operation of the equipment, using a flat type of photocell with a semitransparent photo-layer about 6 cm in diameter, was satisfactory for both carrier-frequency and low-frequency scanning.

621.397.335 246
New Possibilities for External Synchronization of Home-Television Pictures.—W. Gerber. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 646–647. In German.) Paper presented at the International Television Conference, Zürich, 1948.

621.397.5 247
Work towards International Television.—R. Barthélemy. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 535–538. In French.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of the various problems involved, particularly the choice of the line standard and the question of interlacing.

621.397.5 248
Evolution of Television.—A. Ory. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 545–547. In French.) Paper presented at the International Television Conference, Zürich, 1948.

621.397.5 249
The Present Status of Color Television.—(*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 980–1002.) The report of the Senate Advisory Committee on Color Television, given in full. A bandwidth of 6 Mc/s is considered adequate, representing an optimum compromise between quality and quantity of service. The general principles of the C.T.I. line-sequential system, the C.B.S. field-sequential systems involving line and dot interlace, and the R.C.A. system employing a dot-sequential system with the method of mixed highs to increase definition, are explained in detail and performance characteristics, such as colour fidelity, flicker, resolution and break-up of the picture for moving objects, are tabulated for each system. Appendices reproduce official correspondence concerning the report, and also the results of tests of flicker and colour fidelity by the National Bureau of Standards.

621.397.5 250
Mixed Highs in Color Television.—A. V. Bedford. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1003–1009.) Tests on the human eye, using projected colour-test slides, are described in detail; these indicate that the acuity for resolving colour differences is less than half as great as that for differences in brightness, so that the bandwidth used for the colour transmissions can be correspondingly reduced. In the system described, the three colour signals each use a 2-Mc/s frequency band and the red and green 'mixed highs', which represent the brightness values, use an additional 2-Mc/s band, so that the total video bandwidth required will be 8 Mc/s, compared with 12 Mc/s that would be required if all the three colours required bandwidths of 4 Mc/s. The dot-interlace method, as used in the latest R.C.A. system, reduces the required bandwidth to 6 Mc/s.

621.397.5 : 534.321.9 251
Underwater Television by means of Ultrasonics.—M. Federici. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 657–659. In Italian.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of a possible system which should be quite practical for short-distance transmissions.

621.397.5 : 535.317.9 252
The Schmidt Optical System.—Rinia. (See 82.)

621.397.5 : 621.38 253
Electronics in Television.—V. K. Zworykin. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 549–560. In English.) Paper presented at the International Television Conference, Zürich, 1948. General discussion of the subject, with special reference to recent developments in electronic camera tubes, direct-viewing receiver tubes, and colour television.

621.397.5 : 778.5 254
Recording of Television Transmissions on Film with a view to International Exchange of Programmes.—Y. L. Delbord. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 7, pp. 571–580. In French.) Paper presented at the International Television Conference, Zürich, 1948. A detailed discussion of the various problems involved, description of different methods and types of equipment, and illustrations of the quality of picture possible with such systems. Summary noted in 877 of 1949.

621.397.62 : 621.317.2 **255**

Television Laboratory Equipment.—Werner. (See 153.)

TRANSMISSION

621.396.615.142.2 : 621.396.621.53 : 621.397.26 **256**

The Klystron Mixer Applied to Television Relaying.—V. Learned. (*Proc. Inst. Radio Engrs*, Sept. 1950, Vol. 38, No. 9, pp. 1033–1035.) The ph.m. sidebands obtained from a klystron amplifier with beam-voltage modulation are used to give a mixing action, and the output resonator is used to select one of the sidebands. The construction and operating details are given for a klystron amplifier, Type SAC-19, with a mixer output of 1 W over a 20-Mc/s band centred at about 6 000 Mc/s.

VALVES AND THERMIONICS

533.723 + 621.396.822 **257**

Spontaneous Fluctuations.—MacDonald. (See 79.)

621.314.65/.67 **258**

Fundamental Processes in Gaseous Tube Rectifiers.—A. W. Hull. (*Elect. Engng, N.Y.*, Aug. 1950, Vol. 69, No. 8, pp. 695–700.) Phenomena in gas-filled valves are considered in relation to the laws of thermionic emission and electron space-charge.

621.383.4 **259**

Photoconductive Cells of Cadmium Selenide.—E. Schwarz. (*Proc. phys. Soc.*, 1st Aug. 1950, Vol. 63, No. 368B, pp. 624–625.) Operating characteristics are given for a cell produced by methods described in 1102 of 1949. The theory given in 3578 of 1949 is supported by the present experimental results.

621.385.029.63/.65 **260**

The Anticyclotron, a New Type of Travelling-Wave Valve with Magnetic Field.—G. Mourier. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 206–219.) Steady-state conditions possible in valves with magnetic fields are discussed. The principle of the projected valve, which is ring shaped and has no radial field, is analogous to that of the cyclotron; but in this case the electron beam is slowed down as a result of its synchronism with a retarded travelling wave. The interaction of the two may be compared to the oscillations in a magnetron. A first approximation based on Doehler's theory (250, 261 & 1544 of 1949) shows the theoretical gain to be of the same order as in a helix travelling-wave valve, while the efficiency and d.c. input may be much higher. The induction field required is comparatively very small. According to the relative value of this field, the valve behaves like a linear travelling-wave of the Kompfner-Pierce type or like one with a transverse magnetic field. On account of the low field-strength required, the anti-cyclotron may possibly be used to generate mm waves.

621.385.029.63/.64 **261**

Small-Signal Theory of Wave Propagation in a Uniform Electron Beam.—G. G. Macfarlane & A. M. Woodward. (*Proc. Instn elect. Engrs*, Part III, Sept. 1950, Vol. 97, No. 49, pp. 322–328.) Analysis is presented for the three systems constituted by a planar uniform beam (*a*) between conducting sheets, (*b*) in free space, (*c*) between reactive-impedance sheets, the last being a simple form of travelling-wave valve. For small signals, the e.m. field in a travelling-wave valve may be split up into an infinite set of modes and for each mode there can be two forward and two reverse waves. The amount of each mode present depends on the method of excitation. At high frequencies the maximum amplification occurs when the ratio of beam velocity to phase velocity is slightly greater than unity.

621.385.029.63/.64 : 537.525.92 **262**

On Certain Effects of the Space Charge in Travelling-Wave Valves.—R. Berterottière & G. Convert. (*Ann. Radioélect.*, July 1950, Vol. 5, No. 21, pp. 168–178.) The effects of space charge are investigated theoretically by introducing into the equations for the electron dispersion a complex coefficient analogous to the coupling resistance function for the beam and the field. Electron trajectories are assumed to be rectilinear. For signals of small amplitude the theory may be applied up to the limiting case of a very weak focusing field, when space-charge effects are negligible. In the case of signals of large amplitude the effects are complex; they may result in increased efficiency.

621.385.032.216 **263**

The Barium-Oxide-on-Tungsten Cathode Interface.—E. B. Hensley & J. H. Affleck. (*J. appl. Phys.*, Sept. 1950, Vol. 21, No. 9, pp. 938–939.) The compound formed at the interface between a W cathode base and its BaO coating has been identified, by X-ray diffraction, as principally $BaWO_3$. Corresponding tungstites are found when SrO or the solid solution (BaSr)O is used for the coating.

621.385.032.24 : 537.311.315 **264**

Variations of Grid Contact Potential and Associated Grid Currents.—H. B. Michaelson. (*J. Franklin Inst.*, June 1950, Vol. 249, No. 6, pp. 455–473.) A review of the subject, with a comprehensive bibliography. The grid/cathode Volta potential, or 'true contact potential', is shown to be the difference between the work functions of the grid and cathode; it differs essentially from the quantity called 'contact potential' that is generally measured in routine tests of valves. When the potential of the grid is negative, the current in the external grid circuit consists of several small currents due to various causes which change during the life of the valve and thus alter the valve characteristics. Methods that have been suggested for controlling these changes are outlined. Thermionic work functions are listed for 44 pure metals, for monolayers of various substances on Ni, Mo or W bases, and also for oxide coatings. Another list gives the effect of various gases and vapours on the work function of 15 metals.

621.385.4 **265**

The Internal Resistance of a Pentode.—J. L. H. Jonker. (*Tijdschr. ned. Radiogenoot.*, July/Sept. 1950, Vol. 15, Nos. 4/5, pp. 179–194.) For output pentodes the main factor determining the internal resistance is the direct effect of anode voltage on cathode current. For h.f. pentodes two further effects are of importance, viz., (*a*) the absorption by the screen grid of electrons repelled by the suppressor, and (*b*) the absorption by the screen grid of electrons reflected by the anode and transmitted by the suppressor. Both these effects again depend on the anode voltage. Measured values of the resistance are compared with values calculated from theory, and the discrepancies are related to the simplifying assumptions made regarding the operation of the valve.

MISCELLANEOUS

621.396 : 061.4 **266**

The 17th National Radio Exhibition, Castle Bromwich, September 6 to 16, 1950.—(*Electronic Engng*, Sept. 1950, Vol. 22, No. 271, pp. 378–384.) Brief descriptions of selected radio and television equipment and accessories, compiled from information supplied by the manufacturers.