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Maintaining Oscillations by the Periodic Variation of L or C

WE recently came across the statement that if, due to some disturbance, transient oscillations are excited in an oscillatory circuit, the inductance of which can be changed at any point of the oscillatory cycle, then the oscillations can be built up and maintained by the following procedure. *The inductance is increased by an amount ΔL at the moment when the current is at its maximum value I. This introduces into the circuit energy $\frac{1}{2}I^2\Delta L$. When the current has dropped to zero a quarter of a cycle later, the inductance is brought back to its original value. No energy is subtracted from the circuit since the current at this moment is zero. This is repeated in the following half-cycle. Energy is thus injected into the circuit at twice the frequency of its oscillations.*

In order to see the fundamental mistake in this argument let us first consider the case in which a steady unchanging current is automatically maintained through the variable inductance, which may consist of two coils each of inductance L_1 with a mutual inductance M, giving a total inductance $L=2L_1+2M$. The inductance can be varied by changing the distance between the coils. Assuming parallel co-axial coils wound in the same direction, they will exert an attractive force on each other and, on increasing L by moving the coils closer together, work will be done by the circuit. The back e.m.f. induced will be $IdL/dt=I2dM/dt$, and the energy supplied from the generator which is maintaining the constant current will be $I^2 2\Delta M=I^2\Delta L$. This is partly stored in the magnetic field, the energy of which has increased by $\frac{1}{2}I^2\Delta L=I^2\Delta M$, and partly expended as mechanical energy in pulling the two coils closer together, which was also $I^2\Delta M$.

If the inductance L is decreased by pulling the two coils farther apart, work has to be done equal to $-I^2\Delta M$, and the energy of the magnetic field is reduced by an amount $-I^2\Delta M$. (Since ΔM is negative these are both positive quantities.) Together these are equal to the energy supplied to the electric circuit, since the induced e.m.f. is now in the direction of the current.

Turning now to the oscillatory circuit consisting simply of the coils and a capacitor, and assuming that at the moment of maximum current in either direction the inductance L is increased by allowing the coils to come closer together, this does not introduce energy into the circuit but removes energy from the circuit. To introduce energy into the circuit, work must be done by pulling the two coils apart, thus reducing the inductance L and inducing an e.m.f. in the direction of the current at that moment. Although L is reduced, the resulting increase of current more than compensates for it, and the energy of the circuit is increased. When the current passes through zero, the two coils can be brought closer together again. Hence, to introduce energy into the circuit every half-cycle, the inductance must be decreased and not increased at the moment of maximum current.

Similar reasoning can be applied to the capacitive case. If, at the moment of zero current and therefore maximum p.d. between the plates of the capacitor, the capacitance is increased by allowing the plates to be pulled closer together, some of the electrical energy is converted into mechanical energy and thus lost to the oscillatory circuit; it would be quite wrong to say that energy was introduced into the circuit equal to $\frac{1}{2}V^2\Delta C$. To introduce energy into the circuit the capacitor plates must be pulled apart, thus converting mechanical energy into electrical energy, the resulting increase of voltage more than compensating for the decreased capacitance.

The parallelism between the two cases is clearly shown by the following formulae. In a capacitor $Q=CV$ and the energy $=\frac{1}{2}QV=\frac{1}{2}CV^2 =\frac{1}{2}Q^2/C$; the final formula shows that for a constant charge Q *the energy is inversely proportional to the capacitance.* In the case of the inductance, the linkages $(\Phi T)=LI$ and the energy $=\frac{1}{2}(\Phi T)I=\frac{1}{2}LI^2=\frac{1}{2}(\Phi T)^2/L$; here again for a constant (ΦT) *the energy is inversely proportional to the inductance.*

In the electrical case a sudden change of Q is impossible as it would cause an infinite current; similarly in the magnetic case a sudden change of (ΦT) is impossible as it would cause an infinite e.m.f. If, at the moment of maximum current I, the inductance L is suddenly halved, the current I will be suddenly doubled, and therefore the energy $\frac{1}{2}LI^2$ will also be doubled.

The above formulae bring out very clearly the close analogy between the electric charge Q of a capacitor and the magnetic charge (ΦT) of a coil. Anyone who feels uneasy at our reference to the linkages as a magnetic charge may be reassured by the fact that it has the same dimensions as pole-strength. G. W. O. H.

RADIATION FROM RESONANT QUARTER-WAVE TRANSMISSION LINES

By F. M. Leslie, M.Sc., Ph.D.

(Electrical Engineering Dept., Leeds University)

SUMMARY.—Measured values of the resonant input conductance at 100 Mc/s for three different balanced transmission lines a quarter-wavelength long are given, the lines being located in either a metal box or a trough, or set at various heights above a metal sheet.

Introduction

THE experiments were carried out in order to provide some indication of the loss due to radiation from resonant lines employed in valve and other circuits. Although such lines could be completely screened, thereby reducing the radiation to a minimum, this procedure may not always be convenient. Attention has been confined to balanced lines as these are the more usual type and, for ease of measurement, the length used was a quarter wavelength.

Measurement Technique

The technique for measuring the resonant input conductance of the lines employs a screened balanced twin transmission line as a resonant circuit which is loosely coupled to a 100-Mc/s oscillator. The voltage developed across the end of the line at resonance is then given by

$$E_1 = \frac{k}{G_c}$$

where G_c is the input conductance of the line and k is a constant. On adding a known conductance G_k across the circuit, the voltage becomes

$$E_2 = \frac{k}{G_c + G_k}$$

and hence k and G_c may be found, thereby permitting measurement of an unknown conductance connected across the line.

The arrangement of the apparatus is shown in Fig. 1. The transmission line used as the resonant circuit is shielded by a copper box, a thin perspex window at one end provides an insulating support for the lines. Also at this end is a copper screen having dimensions 90 cm by 45 cm. Coarse tuning is accomplished by movement of the shorting bar B, while fine adjustment is obtained by moving the capacitor plate P, which is in a plane parallel to that of the lines. The coupling coil C is fed from the oscillator via a short length of screened cable. The known conductance or the lines for measurement are connected across the terminals AA. A backing-off voltmeter, using the diodes D_1D_2, measures the voltage across the lines. The conductance used for calibrating the apparatus is of the solid carbon type, having a d.c. resistance of 2,200 ohms; its value at 100 Mc/s may be taken as equal to the d.c. value.

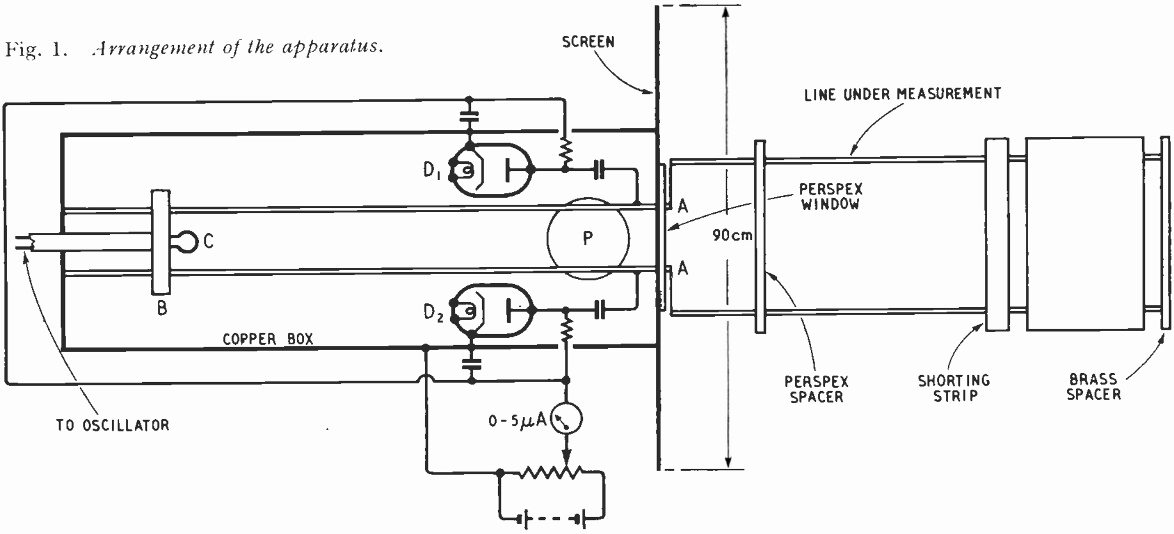
MS accepted by the Editor, May 1950

Experimental Results

The lines used in all the experiments employ the same conductors ($\frac{1}{2}$-in O.D. copper tube) but different spacings. A thin perspex spacer is used for separation near the free end, while a brass block maintains the correct separation at the other. The line spacings used are 2·85, 6·7 and 15·5 cm, corresponding to characteristic impedances 180, 282 and 382 ohms respectively. is shown in Fig. 8 of the variation in the resonant input conductance as a function of the trough width, the trough walls having a height of 10 cm, and the line being 5 cm above the trough base.

Table 1 gives the resonant input conductances for the lines totally enclosed in a copper box having dimensions 100 cm × 60 cm × 28 cm, when presumably the radiation loss will be negligible. The input conductance in this case may

Fig. 1. *Arrangement of the apparatus.*



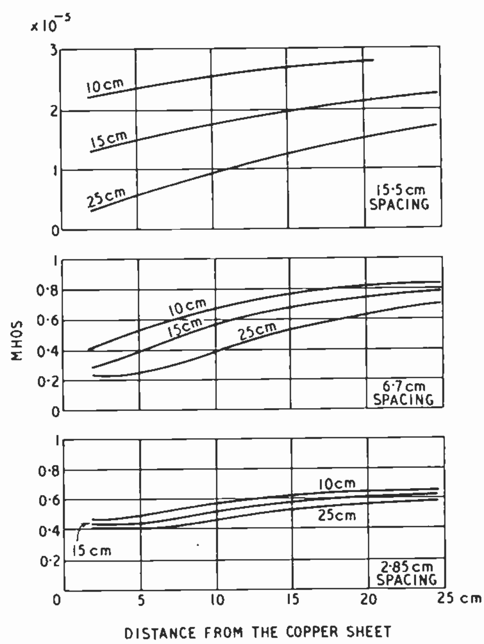
The shorting strip consists of two copper plates 5 cm wide ; resonance of the line for measurement is obtained by movement of the shorting strip, final adjustments being made by the capacitor plate P. A further shorting strip on the inactive part of the line avoids coupling with the portion under measurement.

In the experiments the line in the copper box is tuned to resonance and the voltage across the terminals AA found, the line for measurement is then connected and tuned to resonance. The voltage across AA is observed and hence the resonant input conductance of the line may be determined. In all the measurements the input conductance is for a quarter wavelength of the line.

The curves shown in Figs. 2, 3 and 4 indicate the variation in the resonant input conductance as a function of the spacing from copper sheets, having widths of 10, 15 and 25 cm respectively. The copper sheet in each case has a length of 90 cm and is placed symmetrically beneath the lines.

Figs. 5, 6 and 7 give results for the lines in a copper trough, open at each end and having a width of 25 cm, length 90 cm and wall heights of 15, 10 and 5 cm respectively.

For the line having a spacing of 6·7 cm a curve



Figs. 2, 3 and 4. *Variation of the resonant input conductance with distance from a copper sheet having widths of 10, 15 and 25 cm respectively.*

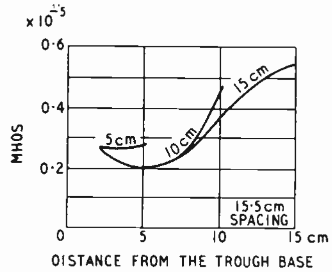
therefore be taken as the minimum value attainable for each particular line,

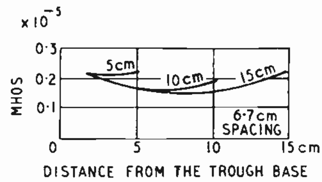
TABLE 1

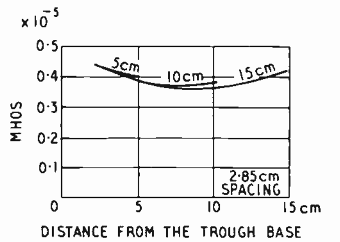
Line Spacing (cm)	Input Conductance (mhos)
15·5	$0{\cdot}09 \times 10^{-5}$
6·7	$0{\cdot}12 \times 10^{-5}$
2·85	$0{\cdot}35 \times 10^{-5}$

so that subtracting the above values from the figures in the graphs gives some indication of the losses due to radiation and the proximity of the trough or the copper sheet.

to provide some screening, with consequent reduction of the radiation loss. As would be expected, and as is evident from the curves, placing the lines too near the metal sheet or the trough walls or base effects an increase in the resonant input conductance due to the increased loss resulting from the induced currents in the metal. It appears that, provided the lines are not spaced too large a fraction of a wavelength, there is little necessity to screen the lines completely, unless it is desired to suppress the radiation for reasons other than that of decreasing the resonant input conductance.

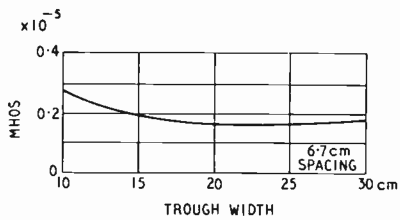






Figs. 5, 6 and 7 (above). *Variation of the resonant input conductance with distance from the trough base for troughs having wall heights of 5, 10 and 15 cm respectively.*

Fig. 8 (right). *Variation of the resonant input conductance with the trough width.*



The specific resistance of the copper tube used for the lines is 4·5 microhm cm, while that for the copper sheet is 1·9 microhm cm.

Conclusion

The curves give some indication of what reduction in the input conductance of twin transmission lines may be expected by the simple addition of a metal plate beneath the lines, or the placing of the lines in a metal trough in order

Acknowledgment

The writer desires to express his thanks to Professor Carter for suggestions in the preparation of the paper, and to Imperial Chemical Industries, Ltd., for their Fellowship.

PARABOLIC CYLINDER AERIALS

Design for Very Small Sidelobes

By D. G. Kiely, M.Sc., A. Inst. P.

(Royal Naval Scientific Service)

SUMMARY.—The method of design and the technique of development of open parabolic-cylinder aerials having maximum sidelobes 30 db below the main beam level is described. This aerial performance represents a considerable improvement over that of the cheese aerial which, at the time of writing, is used exclusively for high definition navigational radar sets.

Introduction

NAVIGATIONAL radar sets in general, and those designed for negotiating intricate waterways in particular, require a very high degree of resolution in order to distinguish clearly the many nearby objects (buoys, booms, small craft, etc.) met with in the course of their operation. Such resolution is partly dependent on the characteristics of the transmitted pulse (duration, shape and repetition rate) and partly on the aerial radiation-pattern characteristics; the former affects discrimination in *range* and the latter discrimination in *bearing*. Both bearing accuracy and bearing discrimination are dependent on the angular width of the main beam of the radiation pattern, as a narrow beam is capable of distinguishing between two closely spaced small objects which would appear as a single large object to a wider beam.

Not only must the main beam of the aerial radiation pattern be small for this reason, but the sidelobes must also be extremely small or the radar will receive echoes from objects on several different bearings at the same time which will confuse the presentation with unwanted and incorrect information.

The design of centimetric aerials having very small sidelobes has presented certain difficulties in the past and the sidelobe level of the cheese aerial,[1] used exclusively for navigational radars at the time of writing, is in general not more than 22 db below the main beam level. This figure increased to 30 db would constitute a considerable improvement in performance.

This paper describes the design and development of one type of aerial which provides the required 30-db sidelobes.

General Aerial Requirements

For shipborne radars with non-stabilized aerials the vertical beamwidth of the radiation pattern must be approximately 20° to half-power points to allow for the pitch and roll of the ship at sea and for Civil Marine application the aerial must also be designed for horizontal polarization and a wavelength of 3 cm to comply with an agreed convention. It is desirable to construct the mirror from metal rods or tubes instead of a continuous sheet of metal in order to reduce windage and consequently the load on the turning motor in the aerial pedestal.

To prevent obstruction of the radiating aperture by the feed system, which causes an increase in the sidelobe level due to the shadow effect and back radiation from the feed horn,[1] the parabolic cylinder is tilted forward by an angle θ to the vertical and the feed horn is placed with the centre of its aperture on the focal line below the mirror and is inclined upwards by an angle 2θ so that the emergent beam from the mirror is horizontal. This is illustrated in Fig. 1.

These general requirements define approximately the shape and overall structure of the aerial which will now be described in more detail.

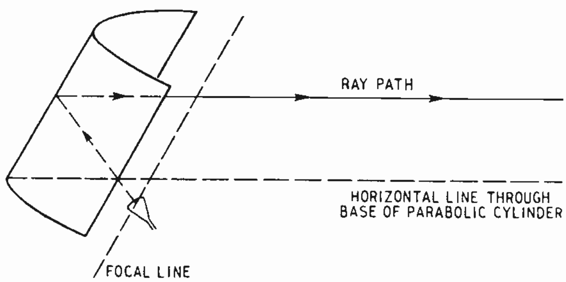


Fig. 1. *General diagram of aerial system.*

Parabolic-cylinder Reflectors

A parabolic-cylinder may be considered in two ways:—

(a) as a succession of similar horizontal parabolæ placed in steps one above the other, each being displaced forwards by a small constant amount so that their apices all lie on an inclined straight line.

(b) as a horizontal cut (frustrum) of a right parabolic cylinder tilted forwards. These are shown in Fig. 2(a) and 2(b) respectively.

In the form of reflectors made from sheet metal,

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(a) and (b) will act in the same way when excited in the same manner because they are, in fact, one and the same. However, if constructed from rods which follow the contours of the generating parabolæ in each case, it is to be expected that the radiation patterns will be different because induced currents in the reflectors will be constrained to flow along the rods. The difference in the radiation patterns of two parabolic cylinders

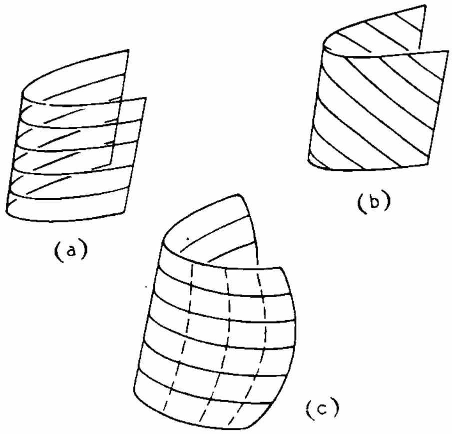


Fig. 2. *Parabolic aerials constructed from rods. In (a) the rods are horizontal and they are displaced successively forward. In (b) they are inclined, while in (c) the aerial is constructed with succeeding parabolæ of different focal lengths.*

constructed by rods as in (a) and (b) has not been investigated theoretically but it would appear reasonable to assume that for good horizontal-plane radiation-pattern characteristics a reflector constructed from a succession of rods which are parabolæ in horizontal planes would be the better of the two. Such a method of construction is also much simpler than the rod-construction method (b), and has been used in the experimental work to be described later.

It is evident that the height of open parabolic-cylinder reflectors must be considerably greater than the usual 3-in or 4-in height of cheese aerials otherwise excessive energy will be lost by 'spill-over' at the top and bottom of the mirror. To reduce this energy loss to a minimum the mirror height is normally increased to some 15 in or so (at 3-cm wavelength) and the primary feed horn is designed to be sufficiently directive in the vertical plane to produce only a very small field strength at the top and bottom of the mirror. As the mirror produces an image of the vertical radiation pattern of the horn as the vertical radiation pattern of the complete aerial, this may be too narrow for such applications as Civil Marine Radar where the aerial is not stabilized and is required to have a wide vertical beam (at least 20°) to allow for ship pitch and roll.

To compensate for this, a mirror may be constructed of rods as in Fig. 2(a) but with succeeding parabolæ of different focal lengths, increasing from the centre outwards in both directions, all the apices lying on a straight line inclined to the vertical in the plane of symmetry. This reflector, illustrated in Fig. 2(c), when fed by an off-centre horn, will produce greater phase curvature along the vertical length of the aperture and so will give a wider vertical beam than that obtained from (a), the same feed horn being used in each case. The reflector surface cannot be developed and so must be constructed with rods. Such a reflector has been designed by other workers and will be discussed later.

Of these three types of parabolic cylinders, the first is the simplest to construct and a model has been designed and examined experimentally. The vertical beamwidth was found to be adequately wide and the spill-over extremely low. The horizontal-plane sidelobe level within $\pm 10°$ of the main beam maximum was approximately 30 db below the main beam level at 9,000 Mc/s and did not exceed 28·5 db over the frequency band 9,320-9,500 Mc/s.

The second type is more difficult to construct and is probably slightly inferior in low sidelobe performance to the first type. A model of this type was not constructed.

The third type, which will here be termed a 'Corrected Parabolic-Cylinder,' has been investigated by other workers whose results will be given below. The mirror is more complicated to construct as each rod of the surface follows a different parabolic curve and the results obtained are, in general, very similar to those obtained from the uncorrected parabolic cylinder.

Open Parabolic-cylinder Aerial

An aerial system was designed having a 5-ft × 1-ft aperture mirror of focal length 1 ft 6 in. The angle of tilt of the parabolic-cylinder was 12° downwards and consequently the off-centred feed horn was inclined upwards by 24° above the horizontal to produce a horizontal emergent beam from the mirror. The reflector was rod constructed from $\frac{1}{64}$-in brass tubing spaced 0·5 in centre-to-centre, the operating wavelengths being in the 3-cm band. The method of construction and support of the feed horn may be seen in Fig. 3. The use of tubing for the mirror surface is to be recommended as a smoothly curved contour is obtained due to the elasticity of the tube. This would not be so easily obtained with solid rod, which is also much heavier. The position of the centre of the feed horn may be found from simple geometry ; it should be situated on the focal line, 1·5 in below the horizontal plane through the base of the mirror so that when directed above the horizontal by 24° it will point at the centre of the mirror.

From a design point of view the fact that the feed horn must be located and supported on struts at a point in space and not directly connected physically with the mirror is a disadvantage when compared with the ease of location of the feed horn with either the cheese, half-cheese or lens aerials, where the horn is attached directly to the other members of the aerial structure. This is the main reason why the parabolic-cylinder aerial structure may be neither compact nor very rigid, as the struts supporting the feed horn must not obstruct, or in any way interfere with, the radiating aperture of the aerial.

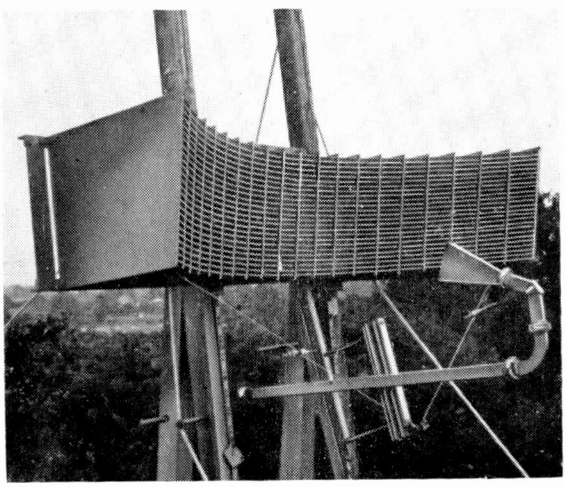


Fig. 3. *Parabolic cylinder aerial.*

Feed Horn Design

A feed horn was used having a length of 6 in, an E-plane aperture width of 1 in and an H-plane aperture width of $3\frac{1}{2}$ in with $\frac{1}{4}$-in flanges along each side of the aperture. This horn gave the required low field strength at the top and bottom of the mirror to produce very low spill-over radiation and it produced a distribution of the field across the aperture which was tapered as much as possible to keep the sidelobe-level low without causing an excessively wide main beam. The optimum horn dimensions were obtained experimentally. As the distribution taper is increased, sidelobes, in general, decrease but so also does the aerial gain. This results in a widened main beam. The aperture distribution taper was increased until the width of the main beam at the 20-db points was just under 5°.

Performance

In general the performance of this aerial is very satisfactory. The sidelobe level is low and considerably better than that of a normal cheese aerial. A typical all-round (360°) radiation pattern at 9,508 Mc/s in the horizontal (E) plane is shown in Fig. 4, where it will be noticed that the base of the main beam is rather broad (4·9° at the 20-db points) for the aperture size and energy distribution used. This is due to a slight inherent de-focusing of the system for the following reason. The feed horn is placed with the centre of its aperture in the focal line and as the axis of the horn must be raised by an angle 2θ above the horizontal to obtain a horizontal emergent beam the upper part of the horn aperture is slightly outside, and the lower part slightly inside, the line focus. This causes certain de-focusing of the system which is however, slight, as may be seen in Fig. 4.

The width of the main beam at the 3-db points is 1·7°. The sidelobe/frequency characteristic is plotted in Fig. 5 together, for comparison purposes, with the same characteristic of a typical cheese aerial; there the maximum sidelobe amplitude within ±10° of the centre of the main beam is plotted in db below the main beam level over the frequency band 9,320-9,500 Mc/s. The less important wide-angle sidelobe amplitude, outside ±10° of the centre of the main beam, is also shown. This sidelobe level is 1 to 2 db higher than the near-in sidelobe level which is quite

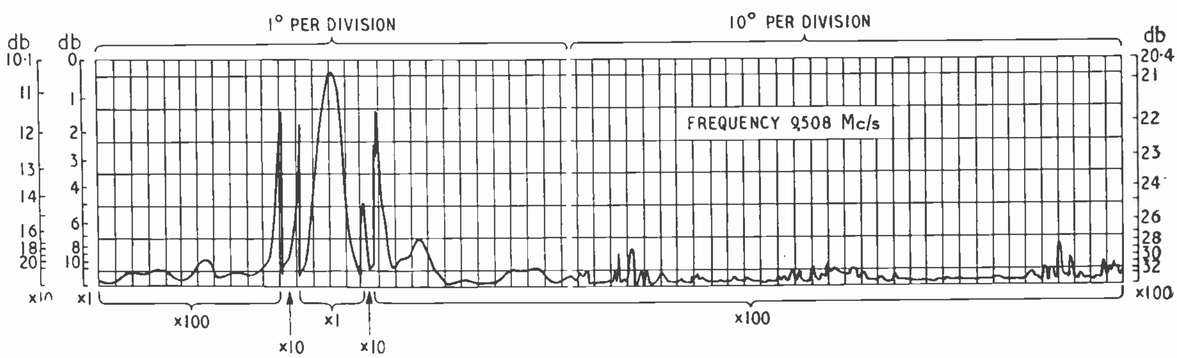


Fig. 4. *Radiation pattern of open parabolic aerial. Note the changes of scale.*

tolerable. The relatively extreme sinusoidal nature of the cheese aerial sidelobe/frequency characteristic is due to interference between the back radiation from the feed horn and the main radiation from the aerial aperture. The amplitude of the first sidelobe (usually the largest) is successively increased and decreased by this

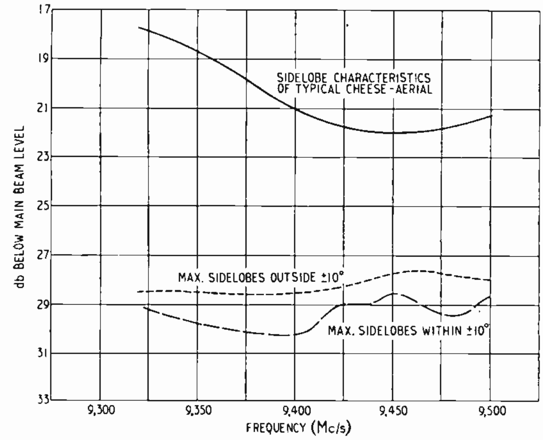


Fig. 5. *Sidelobe/frequency characteristic of open parabolic and cheese aerials.*

effect. Consequently the aerial designer must ensure that the cheese height and focal length are such that a minimum of the sidelobe characteristic coincides with the operating frequency band. As the parabolic cylinder aerial sidelobe characteristic is relatively uniform this additional complication to the design is removed.

In Fig. 6 is shown a typical vertical (H)-plane radiation pattern of the parabolic cylinder aerial. The shape of the main beam is shown in detail in (a) where it will be noted that the shape of the beam, in Cartesian co-ordinates, is predominantly rectangular. From an operational point of view this is a most desirable characteristic and was obtained by placing the feed in such a position below the mirror that the vertical quadratic phase error across the aperture was approximately $1{\cdot}3\pi$ radians. This amount of quadratic phase curvature produces a flat-topped beam. The very small amount of spill-over at the top and bottom edges of the mirror is shown in Fig. 6(b) which is an all-round (360°) vertical plane radiation pattern. This was achieved by designing the feed horn to have a vertical beamwidth such that the illumination of the top and bottom edges of the mirror was a small fraction of that at the centre.

The E-plane radiation pattern of the mirror was recorded when the aerial, used in reception, was depressed below and elevated above the plane of symmetry of the transmitted beam. Several diagrams were recorded for different angular divergences from this plane up to a maximum of 10°, the observations being taken at ±2°, ±5° and ±10°. It was found that the main beamwidth decreased, especially the width of the base of the main beam, as the angle of deviation from the symmetry plane of the system was increased in the positive direction. The main beamwidth passed through minimum values as the angle of deviation increased in the negative direction. Also, the sidelobe level, with respect to the main beam level,

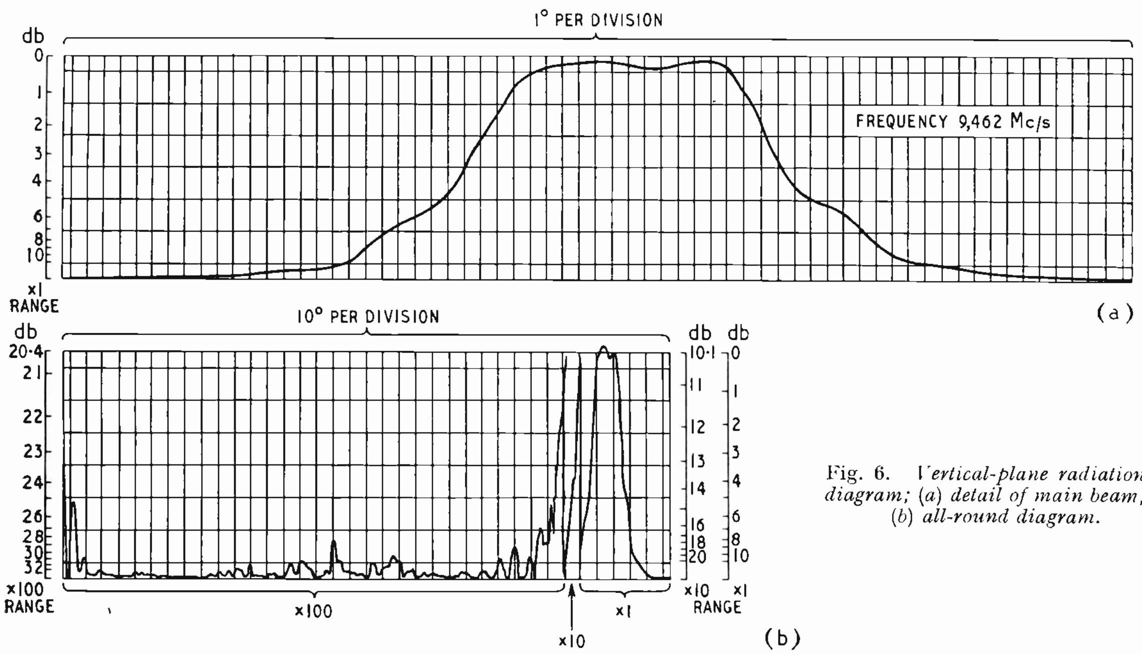
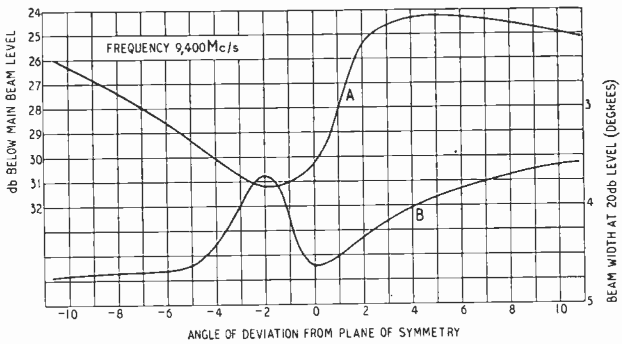


Fig. 6. *Vertical-plane radiation diagram; (a) detail of main beam, (b) all-round diagram.*

in general increased with the angle of deviation. The variation of the main beam width and sidelobe level with the angle of deviation is shown in the curves of Fig. 7. These results show the effect of ship pitch and roll on the performance of a radar aerial which is unstabilized.



Corrected Parabolic-cylinder Aerial

A brief account will be presented here of the design and performance of a parabolic cylinder, corrected as described above, by constructing it from a succession of parabolæ of differing focal lengths.

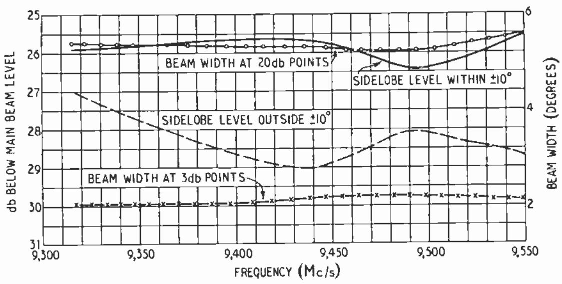
The mirror aperture was 5 ft, its height was 12 in and it was constructed from rods following parabolic curves. The focal length of the central parabola was 19·13 in and the focal lengths of the other parabolæ varied in small irregular steps increasing towards the top and bottom of the mirror to a final value of 19·60 in at the extremes. The angle of tilt of the mirror was 12° and the feed horn, which was off-centred, was elevated by 24° to produce a horizontally emergent beam. The centre of the horn aperture was situated 1·8 in below the horizontal plane through the base of the mirror. The mirror surface cannot be developed and must, therefore, be constructed from rods. The rod diameter was $\frac{11}{64}$-in and the centre-to-centre spacing was ½ in. In appearance the aerial was very much like that shown in Fig. 3.

Performance

From the experimental results the curves of Fig. 8 have been drawn. These show the type of variation with frequency of sidelobe amplitude and beamwidth and were obtained with a 4½-in (H-plane) × 1-in (E-plane) horn of length 7 in fitted with ¼-in flanges at each side of the aperture.

Fig. 7 (left). *E-plane radiation diagram. Curves A and B show respectively the sidelobe level and the beamwidth with the angle of deviation.*

Fig. 8 (below). *Variation of sidelobe amplitude and beamwidth with frequency of corrected parabolic aerial.*



In Table 1 several spot values of sidelobe amplitude and beamwidth are given for various values of the H-plane aperture and size of the horn, and for various inclinations of the horn off the normal (24°) inclination above the horizontal. These figures were all obtained at a frequency of 9,424 Mc/s and the optimum results, obtained with a 3½-in (H-plane) × 1-in (E-plane) horn inclined at 29° above the horizontal have been underlined

TABLE 1

Figures taken from E-plane diagrams.

Horn Size (H-plane)	5½ in			4 in			3½ in		
Horn Angle	0°	5°	10°	0°	5°	10°	0°	5°	10°
Beam width at 3 db ..	2·05°	2·0°	2·1°	2·05°	1·9°	1·8°	1·8°	1·9°	1·7°
Beam width at 20 db ..	5·2°	5·3°	5·6°	5·2°	5·2°	5·2°	5·3°	5·0°	4·7°
Max. Sidelobe inside ± 10° (db)	27·7	26·5	26·3	27·1	27·1	27·1	27·8	28·5	26·2
Max. Sidelobe outside ± 10° (db)	28·5	31·1	30·2	30·2	31·7	32·4	30·6	33·1	32·4

in the table. It is reasonable to assume a similar frequency variation to that shown in Fig. 8 with this feed horn arrangement.

The vertical-plane diagram of the aerial with a feed horn of the same size and in the same position as for the underlined results in Table 1 is shown in Fig. 9. This diagram shows a shallow split in the centre of the main beam which is a direct result of the additional phase curvature created along the vertical dimension of the aperture.

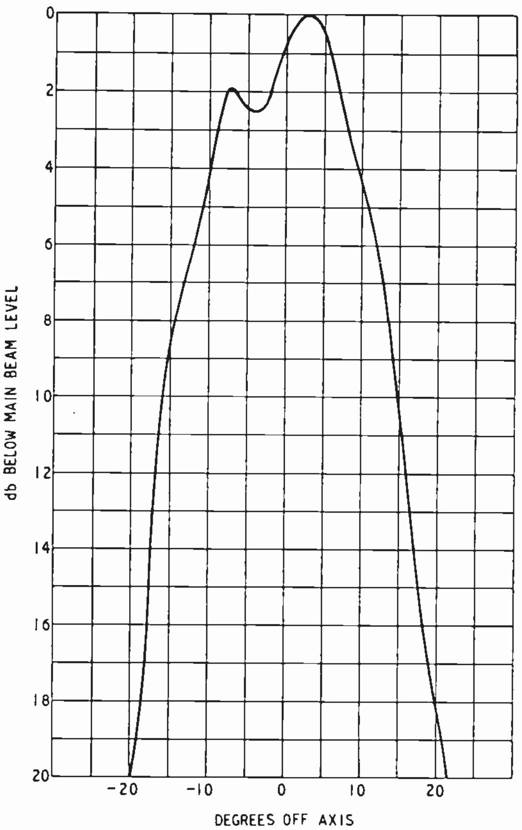


Fig. 9. *Vertical-plane diagram of aerial with the feed horn in its optimum position.*

From the results it will be seen that the performance of the corrected parabolic-cylinder is very similar to that of the uncorrected aerial and the additional complexity of correction would not appear to be necessary.

Mirror Contour Cutting

It is good design practice to cut the bounding curve of the mirror along the 15-db contour of field strength produced by the feed horn on the mirror surface. This gives an approximately elliptical shape reflector instead of the rectangular shape shown in Fig. 3. The former shape is better for the production of low sidelobes, as the actual mirror area tapers towards the extremes of the aperture as also does the aperture distribution of energy which latter taper is governed by the feed horn radiation pattern. No additional spill-over is obtained ; the mirror boundary is cut at the low field strength contour which governs the amount of spill-over.

This was not done in the above experimental work as the results obtained were already reasonably good and the determination of the contour presented considerable experimental difficulties which could not be resolved in the time available.

Conclusion

It is concluded that although the open parabolic-cylinder aerial may suffer from a small amount of inherent de-focusing it is a suitable type of aerial for the production of a fan-beam radiation pattern with very small sidelobes. The sidelobe performance has been shown to be 8 db better than that of a typical cheese aerial which means that the unwanted echo strength is decreased by 16 db. This represents a marked improvement in performance. It is also felt that the open parabolic-cylinder aerial will be less liable to trouble from ice and snow formation in the mirror than the cheese aerial, due to its relatively open construction, though at present there is little operational information on this aspect of the problem.

Acknowledgments

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 author.

The author wishes to acknowledge the assistance of Mr. S. G. Nicholls (R.N.S.S.), also the advice, assistance and information on the corrected parabolic cylinder provided by Dr. O. Bohm.

REFERENCE

[1] O. Bohm, "Cheese Aerials," *J. Instn. Elect. Engrs.*, Vol. 93 .Part IIIA No. 1, p. 45.

VISIBILITY OF RADAR ECHOES

Analysis of Intensity-Modulated Displays

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SUMMARY.—A method is described for calculating the ratio of signal-power to noise-power required for a given probability of detection with intensity-modulated radar displays, particularly when the number of signal pulses producing the echo-paint is small.

Numerical solutions are included which cover a fairly wide range of conditions, and these are used to examine the influence of various factors on the detectability of a weak signal. Biasing and limiting are also considered.

LIST OF SYMBOLS

B	Overall width of a square pass-band in c/s.
C	The trace-scale of the display in seconds/cm.
D	The speed of deflection of a range scan in a B-type display.
d	The apparent diameter in cm of the image of the electron beam on the c.r. screen.
F	The pulse-repetition frequency of the radar.
G	The ratio of the area of a display to the area of a spot.
k	A recognizable brightness ratio against a noise-background.
	The distance of a 'spot' from the centre of a p.p.i. display.
M	The number of transmitter-pulses per aerial revolution.
m, n,	Indices expressing approximate relations in Section 5.
P_N, P_S	Distribution functions for rectified noise and a mixture of noise and signal respectively.
R, W, Z,	Numbers of basic pulses in an echo or equivalent area of the noise background.
r	The number of basic pulses contributing to the intensity of a spot.
S^2	The ratio of signal-power to noise-power at the input to the detector.
$S^2_{(D)}$	The signal-to-noise (power) ratio required for a probability of detection equal to 0·9.
T	The duration of a square r.f. pulse in seconds.
w	The number of basic (noise) pulses per effective spot-size per aerial scanning period.
X	The biasing level of the display relative to σ.
x	The amplitude of the rectified output at any given instant.
Y	The limiting level of the display relative to σ.
Z	The number of basic (signal) pulses per effective spot-size per aerial scanning period.
θ	The duration of a 'basic pulse' in seconds.
$\rho(\Delta t)$	Auto-correlation co-efficient of noise.
σ	The r.m.s. amplitude of rectified noise before biasing and limiting.

1. Introduction

INTENSITY-MODULATED displays are widely used in radar, the two most common being the p.p.i. display and the B-, or range-bearing display.[1] As the name implies, the output of the radar receiver is applied to the cathode-ray tube in such a way as to modulate the intensity of the electron beam and, in most types of display, a plan-presentation of information is obtained by deflecting the electron beam to give a range trace in each pulse-repetition period of the radar, and by moving the position of this trace on the face of the tube in synchronism with a deflection of the radar beam.

The modulating grid of the c.r. tube is normally biased so that the range traces are invisible in the absence of any receiver output, and the receiver noise alone 'paints' a discontinuous, or at least a non-uniform, background. The 'grain' of this background is determined along each range trace by the duration of the noise peaks (or by the spot size of the c.r. tube if this is larger), and across each trace by the spot size. A c.r. tube screen with appreciable afterglow is normally used for intensity-modulated displays so that, although the visual intensity decays rapidly after excitation, the picture remains visible for a time comparable to the scanning period of the aerial; the intensity of the noise background is therefore built up in succeeding aerial-scanning cycles until equilibrium conditions between build-up and decay are reached.

An echo which is sufficiently strong 'paints' in a position on the display corresponding to the range and bearing of the target; the echo paint may be built up in successive aerial-scanning cycles if the target is stationary, or moving only very slowly, but there may be no build-up if the target moves an appreciable distance during the aerial-scanning period; it is customary to limit the maximum amplitude of the input signals to avoid defocusing of the electron beam with very strong signals. The size of the echo paint is determined along the range trace by the pulse length of the radar, and across the range traces by the beam width of the radar, providing that both these quantities are greater than the spot size of the c.r. tube; the presence of an echo may, therefore, be recognized either by virtue of its characteristic pattern, or by an appreciably greater brightness than the noise background, or by a combination of the two.

The form of the noise background, and the intensity of a signal paint, both vary in a random

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manner as between one aerial-scanning cycle and the next, and it has long been realized that the 'visibility' of a weak echo is most usefully described in terms of the probability that the presence of the echo is recognized.

The signal strength required for a given probability of recognition of the echo against the noise background depends upon many factors, which may conveniently be considered under three headings :—

(a) The characteristics of the radar ; e.g., the pulse duration, the pulse-repetition frequency and the beam width,

(b) The characteristics and operating conditions of the c.r. tube, and

(c) The characteristics of the observer.

Some of these aspects have been studied experimentally during the war, and the results from a few of the investigations have now been published.[2, 3, 4]. Most attention has been paid to the effects of the radar characteristics on the signal strength required to give a 'just visible' echo (the decision as to whether or not an echo was just visible being somewhat arbitrary), and absolute values for the ratio of the signal power to noise power were not always obtained. Theoretical studies have also been made, [4, 5] based upon the assumptions (a) that the visibility of an echo is proportional to the excess brightness of the echo above the mean brightness of the background divided by the standard deviation of the background brightness, and (b) that the constant of proportionality is the same for all intensity-modulated displays. The results derived are in fair agreement with experimental results when the number of pulses producing the echo paint is fairly large, but the agreement is not always good when the number of pulses is very small.

These various studies have proved very valuable in designing new radars of more or less conventional design, but there remains a need for a theoretical analysis capable of giving an absolute figure for the expected performance of a display when conditions are very different, and especially when the number of pulses producing the echo paint is greatly reduced. This is attempted in the present paper.

The problem is complicated by the large number of factors which can affect the solution, and by the present limited knowledge of the characteristics of operators. Approximations have been used to obtain a simple solution, and expressions describing the characteristics of operators have been derived by a process of argument and selection. The analysis is therefore to some extent exploratory, and requires experimental verification. It is hoped that it will be of value in designing new radars and in planning further experimental investigations of echo visibility.

2. General Statement of the Problem

The object is to calculate the signal-to-noise ratio necessary to give a stated probability of detection for a particular display, and to investigate optimum detection conditions. This requires a knowledge of:—

(a) The intensity distribution and pattern of the noise background.

(b) The probability that a signal paints with a certain intensity or pattern, and

(c) The degree of difference of intensity or pattern necessary to recognize the echo against the noise background (subsequently referred to as the *criterion of recognition*).

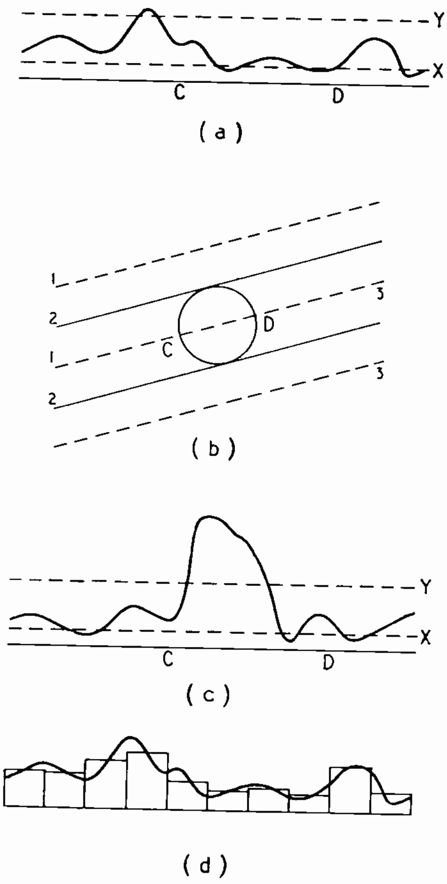

Fig. 1. *Output noise voltage (a), spot excited in three successive cycles (b), receiver output including an echo (c), and uncorrelated pulses simulating the noise form (d).*

2.1. *Intensity Distribution and Pattern of Noise Background*

The output-noise-voltage x of a receiver, which varies in a random manner along any range trace, is of the form shown in Fig. 1(a). Let σ be the r.m.s. noise voltage, and let $x/\sigma = X$ represent the biasing level of the display; i.e., the level below which the signals do not brighten the range trace: similarly, let $x/\sigma = Y$ represent the limiting level.

To determine the intensity distribution of the noise background, consider an element of area of the screen equal to the cross section of the c.r. tube-beam or to the smallest area which the eye can distinguish if this is larger; such an element is subsequently referred to as a *spot* and its diameter is usually of the order of 1 mm. In the general case, this spot is excited in each of j successive pulse-cycles [e.g., Fig. 1(b) which is drawn for $j = 3$] apart from any build up in successive aerial-scanning periods. If CD [Figs. 1(a) and (b)] represents the period in one of the range traces for which the element is excited, and if $F(x)dt$ represents the visual brightness of the phosphor due to a signal of amplitude x lasting for a time dt, the contribution of this pulse-cycle to the brightness of the spot may be represented by:—

$$\int_C^D F(x_N, X, Y)\, dt,$$

and of the j pulse-cycles by:—

$$\sum_j \int_C^D F(x_N, X, Y)\, dt.$$

The value of the last expression at any particular instant cannot, of course, be estimated, but the probability that the integral has a certain value can be estimated and, from this, the expected number of spots in a given portion of the tube face which have a certain intensity can be found. There will be some intensity level which is only attained by a very few spots in each aerial-scanning cycle, and only very occasionally will a spot have an intensity exceeding this level by an amount which the eye can distinguish; this level of the 'brightest' noise spots may be conveniently defined as the intensity level for which the expected number of spots having an equal or greater intensity is unity per aerial-scanning period. There will be more spots with an intensity which is lower by an amount which the eye can just appreciate, still more at the next lower apparent intensity level, and so on.

The pattern of the noise background is determined by the grouping of the spots at the different intensity levels. It will be very rare to find two adjacent but not overlapping spots each with an intensity corresponding to the brightest level, but there will be some lower level at which spots paint side by side. Similarly, there will be a still lower level at which three adjacent (but not overlapping) spots can paint, and so on.

This intensity distribution and pattern of the noise background is determined by the biasing level X, and the limiting level Y, for any particular radar display.

2.2. *The Intensity of a Signal Paint.*

The form of the output voltage of the receiver along a range trace including an echo is shown in Fig. 1(c). The brightness of a spot in the echo may be represented by

$$\sum_j \int_C^D F(x_S, X, Y)\, dt$$

and depends upon the amplitude and form of the signal pulse and on the ratio of the effective pulse length to the spot diameter. Since the shape of the peak including the signal is determined by the form of the noise as well as by the shape of the pulse in the absence of noise, it is again only possible to calculate the probability distribution of the brightness of an echo spot.

When a signal is present, there is a fairly high correlation in the amplitude of the receiver output measured at the corresponding range over the several range scans embraced by the beam width of the radar. There is, therefore, a good chance that the signal paints over several adjacent spots and has a characteristic pattern, but it does not necessarily follow that the signal paint is uniformly bright or that it is continuous.

2.3. *Possible Criteria for Recognition.*

Unfortunately there is very little precise information on the manner in which an operator recognizes a signal, and the criterion of recognition presents the major uncertainty in any theoretical investigation. It seems reasonable, however, to suppose that the determining factors are a difference in brightness or pattern, or both, between the signal paint and the background, and that the operator observes a condition of brightness or pattern which is rarely attained by the noise background, and then accepts as an echo any paint which satisfies, or more than satisfies, this condition. It is, therefore, necessary to consider both the probability that an echo will be recognized and the probability that some element of the noise background may be mistaken for an echo.

The minimum brightness difference necessary to recognize a uniform signal paint against a uniform background has been investigated by Hopkinson[2], and the manner in which the required contrast $\Delta L/L$ depends upon the brightness of the background, and on the area of the signal, is shown in Fig. 2, which has been drawn from his data. The required contrast at a viewing distance of 2 ft was found for four degrees of visibility of the signal:—

Condition O : just visible without recognition of the shape of the signal,
Condition A : signal shape just recognizable,
Condition B : visible with some fatigue over a long period, and
Condition C : easily visible.

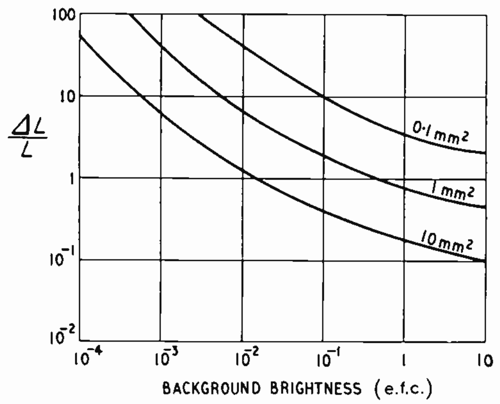

Fig. 2. *Minimum contrast required for visibility as a function of the background brightness and the area of the signal (Hopkinson).*

Condition A has been used in drawing Fig. 2, but these curves can be adapted for any of the other conditions by multiplying the contrast by a factor equal to about $\frac{1}{3}$ or $\frac{1}{4}$ to give Condition O, by 3 to give Condition B, and by 9 to give Condition C. Over the range of brightness of interest the required contrast varied approximately as the inverse two-thirds power of the signal area and as the inverse half power of the background brightness. A small amount of information was obtained for reproduced noise backgrounds, and it was found that the shape of the contrast curves was unaltered, but that the contrast ratio required for visibility was determined by the peak value of the background brightness rather than by the mean brightness.

Strictly, these results only refer to uniform signals, but they suggest that a reasonable criterion of recognition with non-uniform signals might require that the mean brightness of the echo be k times the brightness of the brightest noise spots, where k depends upon the area of the signal, the intensity of the brightest noise spots and the viewing distance. There are, however, certain theoretical objections to this criterion which are now considered.

There are no objections when the signal paint embraces only one spot, since the signal then appears uniform, and recognition of the signal can only depend upon a difference in brightness because there is no difference in pattern between an echo and a noise paint of the background. k may be obtained from Fig. 2 and may be expected to be between about 1·5 and 10, depending on the spot size, the intensity of the brightest noise spots and the viewing distance. When used for these conditions, the criterion is subsequently referred to as 'criterion A'; it is, however, probably too definite, since it is unlikely that an observer will always accept at a level of (say) $k = 2$ and reject if $k = 1{\cdot}9$, or that the level is the same for all observers, but very little is known about these aspects.

The use of the mean brightness of the echo in the criterion of recognition is not so satisfactory when the echo embraces two spots, since the intensity of the echo is not necessarily uniform and k may be expected to depend upon the precise distribution in a manner which is at present unknown. An alternative approach might be based upon the fact that such an echo should be recognizable if any included spot paints with an intensity equal to k times that of the brightest noise spot, but analysis shows that this is too pessimistic a criterion for recognition if k is greater than about 2, a result which might be expected since no use is made of the pattern of the echo. In this case a different criterion B is preferred, which introduces the pattern of the echo more specifically and which, at the same time, requires a moderately uniform brightness over the echo. This criterion is based upon the fact that the chances are very small that two adjacent spots of the noise background both paint with an intensity corresponding to the brightest level: the appearance of two adjacent spots of this intensity may therefore be taken as indicating the presence of an echo. The author thinks that this criterion closely represents his own behaviour under these conditions.

An echo which embraces three spots should be recognizable if any two adjacent spots in the echo satisfy criterion B, and this gives reasonable results, but extension of the argument to an echo of larger area results in too severe a criterion of recognition, at least for a high probability of detection. Several criteria probably hold for a large echo depending on the precise circumstances, and the best compromise is probably obtained by using the integrated brightness of an equal area of the noise background as a basis for comparison with an echo rather than the brightness of the brightest noise spots, because this introduces the area of the echo automatically; this is not inconsistent with Hopkinson's results since the two quantities are closely related for any particular display. For a large echo, therefore, criterion C is proposed which employs the intensities of the echo and an equal area of the noise background, the detection level being fixed such that the chances of confusion (i.e., the chances that noise is mistaken for a signal) are the same as for criterion B.

3. Method of Solution

A useful description of the form of the rectified noise voltage of a receiver as a function of time along any range trace is given by the distribution function of the amplitude $P_N(x)$ (i.e., the probability that the amplitude equals or exceeds a value x at any instant) and the autocorrelation function $\rho(\Delta t)$ which is a measure of the mean-square change of amplitude during an interval Δt. Both of these functions depend upon the law of the detector, and $\rho(\Delta t)$ also depends upon the pre-detector and post-detector frequency characteristics of the receiver. For a linear detector, an approximately square pre-detector pass-band of width B c/s, and negligible post-detector selectivity, we have[6]

$$P_N(x) = \exp(-x^2/\sigma^2) \quad \ldots \quad \ldots \quad (1)$$

$$\rho(\Delta t) \approx \left[\frac{\sin(\pi B \Delta t)}{\pi B \Delta t}\right]^2 \quad \ldots \quad \ldots \quad (2)$$

These conditions usually hold in radar receivers, but appropriate expressions can be used for other conditions.

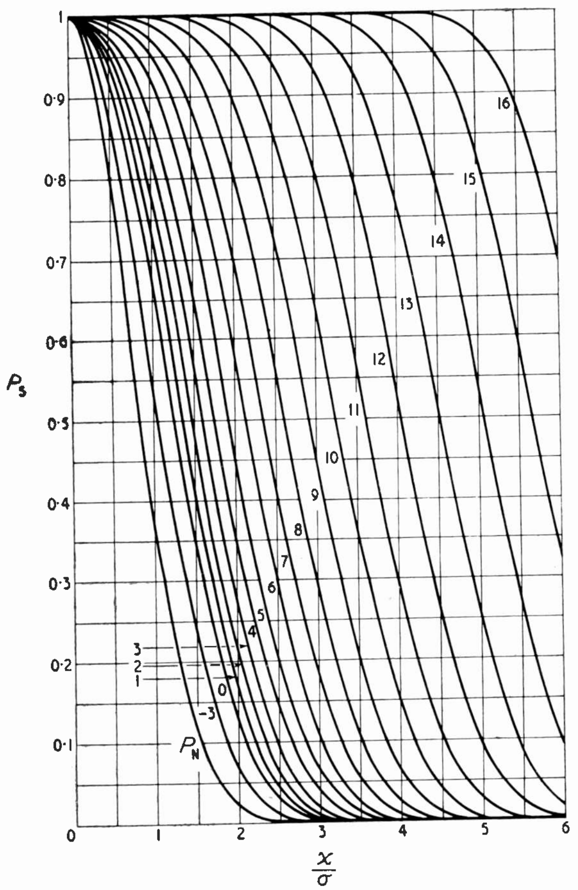

Fig. 3. *P_s as a function of x/σ for various ratios of signal power to noise power (expressed in decibels).*

For a mixture of noise and a steady c.w. signal such that the ratio of signal power to noise power is S^2 at the input to a linear detector, the probability that the output voltage lies between x and $x+dx$ is given by[6]

$$(2x/\sigma)\left[\exp(S^2 - x^2/\sigma^2)\right] I_0(2xS/\sigma) \,.\, dx/\sigma \quad \ldots \quad (3)$$

From this formula, the probability $P_s(x)$ that the amplitude equals or exceeds a value x may be obtained by numerical integration, and is given in Fig. 3 as a function of x/σ and $10 \log_{10} S^2$.

To simplify the evaluation of the integrals described in Section 2.1, the noise-form is considered to be made up of a number of uncorrelated rectangular pulses which are distributed in amplitude according to equation (1). This is shown in Fig. 1(d). The form of the noise can be simulated more closely as the duration of these pulses is made smaller and smaller, but the duration must not be too small (preferably not less than $1/B$ for a square pass-band) if the correlation between the pulses is to be neglected. There is therefore some value of the duration which gives the best approximation, and pulses having this optimum duration θ will subsequently be referred to as 'basic noise pulses'; for $\rho(\Delta t)$ given by equation (2), θ is about $1/2B$.

Similarly, a mixture of signal and noise at the output of the receiver is represented by a number of 'basic signal pulses'; i.e., uncorrelated rectangular pulses of duration θ, each of which is distributed in amplitude according to equation (3). The value of S^2 appropriate to each of these basic signal-pulses is determined by the shape of the signal in the absence of noise; i.e., by the shape of the r.f. signal pulse and the band-pass characteristic of the receiver. To determine the appropriate values of S^2, it is assumed that the nearly square pass-band postulated is obtained by seven staggered circuits such that the overall bandwidth corresponding to an attenuation of 3 db is equal to B; this represents acceptable design practice[7]. Fig. 4 then shows the shape of the output pulse in the absence of noise for different values of BT (where T is the duration of the square r.f. input pulse), omitting any overshoot at the end of the pulse. From this figure, the appropriate values of S for the component basic signal pulses may be found relative to the amplitude of the undistorted r.f. pulse, and these are given in Table 1. It is shown later (Section 4.2) that the smaller pulses in Table 1 contribute little to the visibility of a weak signal, and for many purposes it is convenient to assume that $B = 1{\cdot}5/T$ and that a signal in any pulse cycle is equivalent to two uncorrelated pulses, each of duration $1/2B$, whose amplitudes obey the probability distribution of equation (3) where S^2 is equal to the signal-to-noise (power) ratio of the undistorted rectangular r.f. pulse.

An approximation is also used for the operating condition of the c.r. tube. Under all conditions a signal of amplitude $x < X\sigma$ fails to operate the tube and a signal of amplitude $x \geqslant Y\sigma$ produces full intensity. It is now assumed that Y is only slightly greater than X, and that, after biasing and limiting, the signal is amplified to a level equal to the working grid-base of the c.r. tube; i.e., so that it produces the maximum visual intensity consistent with an acceptable degree of defocusing. Under these conditions the c.r. tube functions merely as an on-off device and all basic pulses which operate the tube contribute equally to the visual intensity. Although it must be admitted that this is not the normal operating condition of the c.r. tube, it is a perfectly practical one and offers certain advantages; the implications of this approximation are briefly examined in Section 4.4.

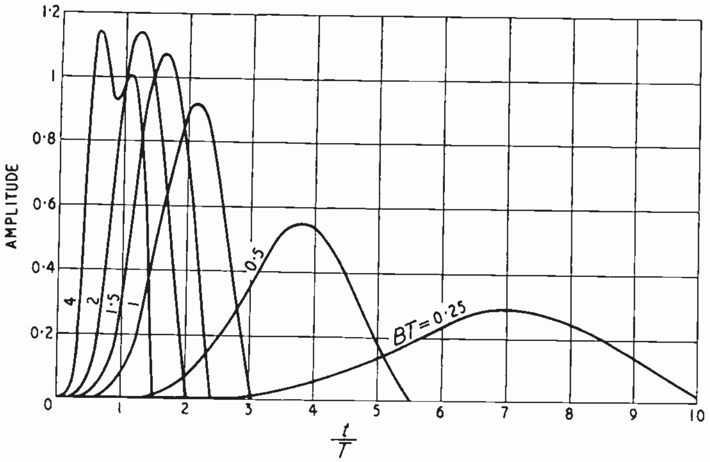

Fig. 4. *Distortion of a square pulse as a function of the receiver bandwidth.*

It is further assumed that the intensity of a spot is proportional to the number of basic pulses painting, irrespective as to whether excitation is completed during one pulse cycle or spread over several cycles. Build-up from one aerial-scanning cycle to the next is neglected for the moment, but is considered again later (Section 4.3.4.).

With these approximations, a solution can be obtained in terms of tabulated functions.

Let w be the number of 'basic noise pulses' per spot per aerial-scanning period for a p.p.i. display. If:—

C = the trace scale (seconds/cm),
d = the spot diameter in cm,
l = the distance of the spot under consideration from the centre of the display,
M = the number of transmitter pulses per aerial revolution,

then $w = (\pi d^2/4)\,(M/2\pi l)\,(C/\theta)$

Similarly, w may be found for a type B or any other intensity-modulated display. For example, with a type B display, let D be the speed of deflection of the range-scan (in synchronism with the deflection of the radar beam) expressed in cm/sec. Then if F is the pulse-repetition-frequency of the radar,

$$w = (\pi d^2/4)\,(F/D)\,(C/\theta)$$

In general, w depends upon the type of scanning system employed and also on the exact position of the spot on the display.

Having set the biasing level of the display, $(x/\sigma = X)$, we then have the probability P_X that any basic noise pulse equals or exceeds this level and contributes to a paint; the probability that the optical intensity of a noise spot is equal to, or exceeds, a value I_r is therefore equal to the probability that r or more of the w basic noise pulses paint; this is represented by $[{}_wP_r]$ and is given by the Binomial distribution :—

$$[{}_wP_r] = \sum_{y=r}^{y=w} \frac{w\,!}{y!\,(w-y)!}\,(P_X)^y(1-P_X)^{w-y} \;.\,. \quad (4)$$
$$= 1 - \Phi_{1-P_X}\,(w+1-r,\; r) \quad \text{for } w+1-r > r$$
$$= \Phi_{P_X}\,(r,\; w+1-r) \quad \text{for } w+1-r < r$$

where Φ is the incomplete Beta-function.

TABLE 1

Approximation to the form of the signal pulse for various bandwidths of the receiver

BT	$\theta(=1/2B)$	Approximation to the form of the signal pulse
4	$T/8$	Six basic pulses of amplitude 1·0
2	$T/4$	Two basic pulses of amplitude 1·10 plus two basic pulses of amplitude 0·7
1·5	$T/3$	Two basic pulses of amplitude 1·0 plus two basic pulses of amplitude 0·5
1·0	$T/2$	Two basic pulses of amplitude 0·78 plus two basic pulses of amplitude 0·3
0·5	T	Two basic pulses of amplitude 0·44 plus two basic pulses of amplitude 0·16
0·25	$2T$	Two basic pulses of amplitude 0·22 plus two basic pulses of amplitude 0·06

This function is tabulated[8] for values of w up to 50, but it is convenient to employ a graphical presentation. For higher values of w, the limiting forms of (4) based upon the normal and the Poisson distributions are probably sufficiently accurate.

If the portion of the c.r. tube-face which we appreciate at any given time is equal in area to G spots the number of basic noise pulses included in this area per aerial-scanning period is equal to Gw, and the number of ways in which different (but overlapping) clusters of w basic noise pulses can be selected is very nearly equal to Gw if G is large; (around every one of the Gw basic noise pulses we can choose a different group of $w-1$ which are nearer than any others). The expected number of overlapping noise spots in this portion of the tube face having an intensity equal to, or greater than, I_r is, therefore, equal to $Gw\ [_wP_r]$.

Since the eye cannot distinguish between overlapping spots, it is necessary to find the expected number of non-overlapping spots having a given minimum intensity. The ratio of the number of overlapping to non-overlapping spots depends on the actual distribution within the cluster of the basic noise pulses which paint, but the average value does not differ greatly from w/r. For the purpose of this analysis, it is probably sufficiently accurate to take the expected number of non-overlapping spots as equal to $Gr\ [_wP_r]$ and, by definition, the brightest spot in this portion of the tube-face is given by the value of r for which :—

$$Gr\ [_wP_r] = 1 \quad \ldots \quad (5)$$

This derivation of equation (5) is not entirely satisfactory. The value of w/r for the ratio of overlapping to non-overlapping spots was obtained by considering several special and relatively simple cases, but the expected number of non-overlapping spots has been checked for various experimental random distributions of points and found to be in fair agreement providing the expected number was not large ; obviously the expected number of non-overlapping spots of any given minimum intensity must tend to $G[_wP_r]$ as $[_wP_r]$ tends to unity. (A similar problem arises in connection with the size of photographic sensitivity specks, and the reader is referred to papers by Berg[9], Silberstein[10] and Mack[11].)

Similarly, let z be the number of basic signal pulses per spot in the echo. Referring to Table 1, which applies to a square input pulse and a receiver with a nearly square pass-band, the number of basic signal pulses along any range trace embraced by an echo is seen to be effectively equal to $2BT$ if $BT \gg 4$, and to 2 if $BT \leqslant 2$; z is obtained by multiplying by the number of pulse cycles effectively exciting the spot. If P_s is the probability that any basic signal pulse equals or exceeds the biasing level and contributes to a paint, the probability that a given spot in the echo has an intensity at least equal to I_r is :—

$$[_zP_r] = \sum_{y=r}^{y=z} \frac{z!}{y!\,(z-y)!}\ P_s^{\,y}(1-P_s)^{z-y} \quad \ldots \quad (6)$$

For an echo which embraces only one spot, the probability of detection in any one aerial-scanning cycle according to Criterion A is, therefore, given by $[_zP_{kr}]$ where r is the intensity of the brightest noise spot, and this depends upon the signal-to-noise ratio and upon the biasing level. Similarly, when the echo embraces two spots the probability of detection in any one aerial-scanning cycle according to Criterion B is given by $[_zP_r]^2$, where r is again the intensity of the brightest noise spot, and this also depends upon the signal-to-noise ratio and the biasing level.

The inverse solution is usually required ; i.e., the signal-to-noise ratio and optimum bias to give a stated probability of detection. To do this take any arbitrary value of r for the minimum intensity of a spot in a just detectable signal ; this determines the intensity of the brightest noise spot according to the criterion of recognition employed; P_N can then be found from (5) and (4), and hence the corresponding biasing level is obtained from (1). P_s is determined by the appropriate expression for the required probability of detection and from (6) and, knowing the biasing level, the necessary signal-to-noise ratio can be read off from Fig. 3 by interpolation. This process is then repeated for other intensity levels of a signal spot to find the optimum biasing level and the minimum signal-to-noise ratio.

Such an analysis is less complicated than it sounds, and examples are presented in Table 2 for $z=w=20$. It is assumed in A that the echo embraces only one spot, and Criterion A is used with a value of $k=2$; in B it is assumed that the echo embraces two spots (with $z=20$ for each spot) and Criterion B is used ; a value of $G=10^4$ is used in both tables and the solution is worked out for three probabilities of detection ; viz., 0·9, 0·5 and 0·1. It should be noted, in both cases, that the optimum biasing condition is independent of the probability of detection, and this seems to be generally true for a wide range of conditions within the limits of accuracy of S set by reading Fig. 3 ; these limits are thought to be $\pm 0{\cdot}2$ db for $S>1$ db, $\pm 0{\cdot}3$ db for $0<S<1$ db, and $\pm 0{\cdot}7$ db for $-3<S<0$ db.

To use Criterion C in the form which has been defined requires a knowledge of the probability of confusion in the case of Criterion B, that is to say, the probability that some part of the noise background will appear as two adjacent spots, each of maximum intensity ; this may be obtained as follows. By definition, the expected number of spots of maximum intensity in the portion of the noise background appreciated is unity per aerial scanning period and, if we assume that the Poisson distribution holds, the probability that there are 0, 1, 2, 3 . . . . . q spots having this intensity in any one scan is given by $P(q)=\epsilon^{-1}/q!$; only if $q \geqslant 2$ is there any chance of confusion. Consider first the case where $q=2$; the diameter of one of these spots is d, and around this we can draw another circle of diameter $3d$; then confusion arises only if the second spot is situated within the annulus contained between these two circles; the area of the annulus is $8\pi d^2/4$ and the total area under consideration is $G\pi d^2/4$, so that the probability that the second spot is situated within the annulus is $8/G$. If there are more than two noise spots of maximum intensity, the probability that any two are adjacent but not overlapping is $8/G$ times the number of possible combinations of two spots. The probability of confusion is therefore equal to :—

$$8\,(G\epsilon)^{-1}\left[\frac{1}{2!}+\frac{1}{3!}\,\frac{3!}{2!\,1!}+\frac{1}{4!}\,\frac{4!}{2!\,2!}+\ldots \frac{1}{q!}\,\frac{q!}{2!(q-2)!}+\ldots\right]=\frac{8}{2!}\cdot\frac{1}{G\epsilon}\cdot\epsilon=\frac{4}{G}$$

It is interesting to note that the estimated probability of confusion, taking $G=10^4$ as a reasonable value, is relatively small, in keeping with operational experience.

In using Criterion C, let Z be the total number of basic signal pulses in the echo, and let W be the total number of basic noise pulses in an equal area of the noise background; R is the number of basic signal pulses which paint within this area. As before, we choose a value of R which defines P_N from the relation :—

$$GR[_W P_R]=4/G \quad \ldots \quad (7)$$

and from (4), and determines the corresponding bias. The probability of detection is $[_Z P_R]$ which determines P_S, and the required signal-to-noise ratio can be read off from Fig. 3.

It should be noted that under conditions for which Criterion A is appropriate, $Z=z$ and $W=w$, and that when Criterion B is appropriate, $Z=2z$ and $W=2w$. In deriving the solution with Criterion B it is necessary to employ z and w, but otherwise it is more convenient to use Z and W.

It should also be noted that the solution has so far been developed in terms of the probability of detection p in any one aerial-scanning cycle. It is sometimes more relevant to consider a time interval equivalent to Q aerial-scanning cycles for which the probability of detection is equal to :—

$$[_Q P_1] = \sum_{y=1}^{y=Q} \frac{Q!}{y!(Q-y)!}\cdot p^y(1-p)^{Q-y}$$
$$=1-(1-p)^Q \quad \ldots \quad (8)$$

providing that p is constant over the interval under consideration.

TABLE 2

Sig. r	Noise r	Noise Gr	P_N	Bias X	Signal-to-Noise Ratio (db) for a Probability of Detection of :— 0·9	0·5	0·1
				$P_S=$	0·42	0·28	0·165
6	3	3×10^4	0·0032	2·38	6·5	5·1	3·8
				$P_S=$	0·52	0·38	0·25
8	4	4×10^4	0·0087	2·17	6·3	5·0	3·7
				$P_S=$	0·615	0·475	0·337
10	5	5×10^4	0·018	2·0	6·3	5·0	3·7
				$P_S=$	0·71	0·57	0·43
12	6	6×10^4	0·031	1·85	6·5	5·2	3·8

A. Sample solution for $z=w=20$ using Criterion A with $k=2$ and $G=10^4$. NOTE. Optimum conditions correspond to r(signal) $=9$ and bias $\approx 2{\cdot}1\sigma$; probability of confusion under optimum conditions $\approx 10^{-6}$.

Sig. r	Noise r	Noise Gr	P_N	Bias X	Signal-to-Noise Ratio (db) for a Probability of Detection of :— 0·9	0·5	0·1
				$P_S=$	0·46	0·333	0·232
6	6	6×10^4	0·031	1·85	4·1	2·7	1·3
				$P_S=$	0·56	0·435	0·325
8	8	8×10^4	0·063	1·65	4·0	2·5	1·2
				$P_S=$	0·653	0·537	0·42
10	10	10^5	0·10	1·52	4·1	2·9	1·3

B. Sample solution for $z=w=20$ using Criterion B with $G=10^4$. NOTE. $[_z P_r]=0{\cdot}95$, $0{\cdot}71$ and $0{\cdot}315$ respectively for a probability of detection equal to 0·9, 0·5 and 0·1; optimum conditions correspond to r(signal) $=8$ and bias $=1{\cdot}65\sigma$.

4. Some Numerical Solutions and their Applications

4.1. *Numerical Solutions.*

The optimum solutions for a fairly wide range of conditions are given in Table 3 for two probabilities of detection; viz., 0·9 and 0·5. The total number of basic pulses in the echo and an equivalent area of the noise background is employed throughout for the sake of uniformity, and a value of $G=10^4$ is assumed.

This value of G is fairly representative since the maximum area which the eye can appreciate at any instant is limited to about 4-in diameter at a viewing distance of 2 ft, and the spot-diameter is usually about 0·1 cm. In some cases the precise value of G may be in doubt, especially when the aerial-scanning period is long relative to the decay time of the phosphor and part of the picture fades before the remainder is painted but, fortunately, a change in the value of G from 10^3 to 10^5 (which covers the range likely to be met with in practice) only affects the signal-strength required for a given probability of detection by about 2 db.

A value of $k=2$ has been used in Table 3 for Criterion A when the echo embraces only one spot, and it must be stressed that this value is not necessarily correct for all such displays. Similarly, Criterion C is only intended for an echo which embraces several spots, a condition which is unlikely to hold when Z is small, but the table has been completed for small values of Z to permit of comparison with the other criteria of recognition.

4.2. *General Comments.*

A convenient way of presenting the solutions for a given set of conditions is by a series of curves showing the probability of detection in any one aerial-scanning cycle as a function of the signal-to-noise ratio; Fig. 5 is an example drawn for Criterion B with $Z=W$ and $G=10^4$. All such curves are similar in shape but the slope increases slightly with :—

(a) An increase in the value of Z.
(*b*) An increase in the value of W/Z.
(*c*) An increase in the value of G, and

TABLE 3

Z	W	Criterion A ($k=2$) Bias	Criterion A Prob. of Detn. 0·9	Criterion A Prob. of Detn. 0·5	Criterion B Bias	Criterion B Prob. of Detn. 0·9	Criterion B Prob. of Detn. 0·5	Criterion C Bias	Criterion C Prob. of Detn. 0·9	Criterion C Prob. of Detn. 0·5
50	50	1·9	4·0	3·1	1·6	3·2	1·9	1·5	2·0	0·9
	100	2·25	5·0	4·1	1·9	4·7	3·6	1·9	4·0	3·2
	250	2·45	6·0	5·1	2·3	5·9	4·8	2·3	5·1	4·2
	500	2·6	6·6	6·0	2·5	6·6	5·4	2·45	5·8	4·9
20	20	2·1	6·3	5·0	1·8	6·0	4·3	1·85	5·2	3·8
	40	2·3	7·2	6·0	2·0	7·1	5·6	2·1	6·4	5·3
	100	2·5	7·7	6·7	2·35	8·0	6·7	2·45	7·2	5·9
	200	2·7	8·4	7·5	2·6	8·4	7·3	2·6	7·6	6·6
14	14	2·2	7·3	5·9	1·9	7·1	5·5	1·9	6·4	4·8
	28	2·4	8·1	6·8	2·3	8·0	6·6	2·2	7·4	6·1
	70	2·6	8·7	7·6	2·5	8·7	7·4	2·45	8·2	7·0
	140	2·8	9·1	8·1	2·75	9·2	7·9	2·7	8·5	7·4
10	10	2·3	8·2	6·9	2·05	8·2	6·5	2·0	7·3	5·8
	20	2·5	8·7	7·4	2·3	8·8	7·4	2·2	8·1	6·8
	50	2·7	9·4	8·2	2·5	9·4	8·1	2·45	9·0	7·8
	100	2·9	9·8	8·9	2·9	9·8	8·6	2·75	9·3	8·2
8	8	2·4	8·8	7·4	2·2	8·9	7·3	2·1	8·1	6·5
	16	2·6	9·4	8·0	2·4	9·4	7·9	2·4	8·8	7·4
	40	2·8	10·0	8·6	2·6	10·0	8·5	2·6	9·5	8·2
	80	3·0	10·3	9·0	2·8	10·4	8·9	2·8	9·8	8·6
6	6	2·5	9·6	8·1	2·3	9·7	7·9	2·3	9·0	7·3
	12	2·7	10·1	8·6	2·55	10·1	8·6	2·5	9·6	8·1
	30	2·95	10·6	9·2	2·75	10·6	9·2	2·7	10·2	8·8
	60	3·2	10·9	9·6	3·0	10·9	9·6	2·95	10·4	9·2
4	4	2·9	10·9	9·4	2·4	10·9	9·1	2·55	10·3	8·5
	8	3·2	11·2	9·7	2·8	11·5	9·8	2·7	10·6	9·1
	20	3·4	11·5	10·1	3·1	11·8	10·2	2·85	11·0	9·5
	40	3·6	11·7	10·3	3·2	12·0	10·4	3·2	11·4	9·9
2	2	3·1	12·6	10·8	3·0	12·3	10·5	2·95	12·2	10·3
	4	3·3	12·8	11·1	3·15	12·5	10·8	3·15	12·5	10·7
	10	3·5	13·0	11·4	3·3	12·7	11·1	3·3	12·8	11·2
	20	3·7	13·2	11·6	3·4	13·0	11·3	3·4	13·0	11·3

Numerical solutions for $G=10^4$, showing the optimum bias and the ratio of signal-power to noise-power (expressed in db), for a probability of detection equal to 0·9 and 0·5.

(*d*) A decrease in the probability of confusion or, what is equivalent in the case of Criterion A, an increase in the value of k.

Referring to Table 3, it may be seen that the signal strength required for a given probability of detection is very similar for Criteria B and C, and also for Criterion A if $k \leqslant 2$. The signal strength required with Criterion B is slightly higher than with Criterion C and, since the probability of confusion is the same for both, this difference may be due to the requirement of a nearly uniform intensity over the echo in the case of Criterion B, whereas there is no such stipulation with Criterion C. For a value of $k > 2$, Criterion A requires a higher signal strength than Criterion B, that is to say, the condition where an echo embraces only one spot is not an efficient one for detection unless the brightness levels are sufficiently high to give a corresponding value of k less than 2. Mathematically, Criteria A and C are very similar, and any difference in the signal strength required is due to the fact that the probability of confusion is less with Criterion A when k is greater than about 1·5 than it is with Criterion C. To an appreciable extent the signal strength required for a given probability of detection may be regarded as a function of the probability of confusion, with the operator unconsciously setting the confusion level according to the display and operating conditions.

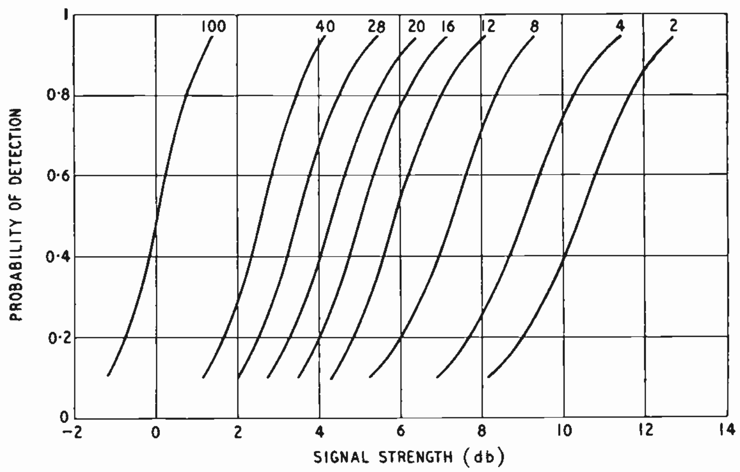

Fig. 5. *Probability of detection as a function of signal strength for various values of Z (Criterion B, $Z = W$, $G = 10^4$).*

The disadvantages of the discontinuous method of solution adopted in this paper are apparent in use, particularly if it is desired to use Criterion A with values of k greater than Z. Mathematically, it might always be better to obtain a solution in terms of the probability of confusion, but this approach is more abstract. The solution obtained using Criterion A in the manner described is also unsatisfactory in that k is properly a function of the intensity of the brightest noise spots; in other words, a different value of k should be used for each value of r (noise) in Table 2(A).

The solutions obtained using Criteria B and C are not obviously dependent on the absolute intensity level of the brightest noise spots. This follows from the definitions of the criteria, which imply that detection depends more on whether the signal paint has a characteristic pattern [i.e., that the area of the paint is large or that painting is continuous] than on the brightness, providing the latter is sufficiently high to permit of the recognition of an echo which satisfies the requirements as to pattern. Operation is easier, of course, with a brighter display. Also, in deriving the optimum conditions as a function of r (signal), it is assumed that the eye can appreciate the difference of intensity corresponding to a small change in the value of r (signal). The greater the value of the minimum perceptible brightness difference, the less critical will the optimum bias appear in practice and the greater will be the chances of mistaking the noise for a signal. Alternatively, if the operator unconsciously maintains a low level of confusion, a greater signal strength will be required for a given probability of detection. Unless these considerations are taken into account, the solutions obtained represent a theoretical performance which will never quite be met in practice.

Within these limitations, the method is capable of giving a solution when the number of pulses producing the echo paint is very small, and it appears that the display losses need not then be excessive; even when $Z = 2$ a signal-to-noise ratio of about 14 db should always suffice to give a 90% probability of detection. The author does not know whether greater signal strengths have been found necessary in practice, but if this is so it can only be due to incorrect biasing or inadequate brightness.

It is also interesting that the range of signal strength corresponding to a change in the probability of detection from 0·9 to 0·1 is fairly small (Table 2) so that the weaker basic signal pulses in Table 1 contribute little to the detectability of a just visible echo.

4.3. *Influence of Various Factors.*

Table 3 may be used to examine the influence of various factors on the signal-to-noise ratio $S^2_{(D)}$, required for detection, and the relations obtained may be compared with those determined experimentally. In the following, it is assumed that the bias is always maintained at the optimum value, and a level of 0·9 is adopted for the probability of detection; the relations developed depend slightly on this value chosen for the probability of detection, and, although a value of 0·5 might be preferable on theoretical grounds, the level of 0·9 has been employed because it has already found some favour and because it may correspond more closely to what has previously been taken as a 'just visible echo.' In comparing these relations with available experimental results it must be remembered that the conditions holding in the experiments may not have been identical with those adopted here, and the variations to be found in different experimental results may be due to different conditions holding in the several experiments.

4.3.1. *Pulse-Repetition-Frequency.*

A change in the pulse-repetition-frequency corresponds to a proportional change in Z and W, with W/Z, G and the criterion of recognition remaining unchanged. $S^2_{(D)}$ may be expressed approximately by the relation :—

$$S^2_{(D)} \propto F^{-n}$$

where n depends upon the criterion of recognition, upon G and on the ratio W/Z, and ranges from about 0·48 to 0·75. Experimental values of n have ranged from about 0·45 to 0·67 while previous theoretical analyses[4,5] give a value of 0·5.

4.3.2. *Aerial Beam Width.*

Similarly, a change in the aerial beam width corresponds to a proportional change in Z with, perhaps, a change in the criterion of recognition. If the beam width is sufficiently large for Criterion C to apply, W/Z remains constant and

$$S^2_{(D)} \propto (\text{Beam width})^{-m}$$

approximately, where m ranges from about 0·5 to 0·8 depending upon W/Z and G; similar values of m have been obtained experimentally. For some smaller beam width, Criterion B applies, and at still smaller beam widths Criterion A applies with W/Z increasing as the beam width is reduced. When Criterion A applies, the corresponding value of m depends upon the intensity of the display; i.e., on the value of k; values of m equal to about 1·0 have been found experimentally. Due to the shape of the aerial-radiation diagram, the value of S corresponding to each basic signal pulse varies over the echo, and it is often convenient to use a number of basic signal pulses which are postulated to be equally effective in contributing to the signal paint. Since a difference in S^2 of 2 db corresponds to a fairly large change in the probability of detection, it is suggested that the effective beam width for this purpose be estimated on the basis of a reduction not exceeding 1 db for one-way transmission.

4.3.3. *Pulse Duration, Receiver Bandwidth and Scale of Range Traces.*

Tables 1 and 3 may be used to find the optimum conditions in respect to the duration of the radar pulse, the bandwidth of the receiver and the scale of the range traces. It is obviously desirable that W should not be greater than Z, which means that the effective length of the signal paint along each range trace must not be less than d and, if this is so, it can be shown from Table 1 that optimum detection conditions correspond to:—

$$B = 1{\cdot}5/T$$

whatever the criterion of recognition. The output signal from the receiver in each pulse cycle is then very nearly equivalent to two basic signal pulses of duration $T/3$, and the length of the signal paint along each range trace is equal to $2T/3C$ cm. Since this must not be less than d, the second condition for optimum detection is given by :—

$$T/C \geqslant 1{\cdot}5\,d$$

if Criterion B or C holds, and by

$$T/C \geqslant 3\,d$$

if this lengthening of the signal paint effects a beneficial change from Criterion A to Criterion B. The last two relations may always be used to determine C when T is fixed, and they may also be used to determine T when C is given, provided that the mean power output of the transmitter is independent of T.

4.3.4. *Properties of the C.R. Tube.*

A reduction of the spot-size is desirable if it effects a beneficial change in the criterion of recognition (i.e., from Criterion A to Criterion B, or from Criterion B to Criterion C) or a reduction in the value of W/Z in cases where the duration of the radar pulse or the trace scale cannot be adjusted to make $W=Z$.

The characteristics of the afterglow most suitable to any display depend on the nature of the target. If the target moves so rapidly that successive 'paints' do not overlap, any afterglow from a previous aerial-scanning cycle increases the value of W without increasing the value of Z, and is therefore undesirable; the optimum duration of the afterglow under these conditions would therefore appear to be about half of the aerial-scanning period. If the target is virtually stationary, any afterglow from previous aerial-scanning cycles effectively increases the value of both Z and W and is therefore desirable. However, operational requirements or a personal preference of the observer might easily outweigh these considerations.

4.3.5. *Fluctuating Radar Signals.*

In practice, the signal obtained from a radar target is fluctuating continuously, whereas the solutions developed hold essentially for a steady signal; it is therefore desirable to obtain an idea of the effect of target fluctuations.

With sufficient accuracy for this purpose, the expected probability of detection with any display may be expressed in the form :

$$\tfrac{1}{2}\left[1-\text{erf}\,\frac{S^2{}_0-S^2}{\Delta\sqrt{2}}\right]$$

where $\text{erf}(y)=\frac{2}{\sqrt{\pi}}\int_0^y \epsilon^{-v^2}dv$ and $S^2{}_0$ and Δ depend upon Z, W, G and the criterion of recognition ; $S^2{}_0$ increases as Z decreases and W/Z increases, while $S^2{}_0/\Delta$ increases as both Z and W/Z increase.

To simplify the illustration, it is assumed that the signal strength is constant over the period for which the target is illuminated by the radar, and that it varies at random between successive aerial-scans ; it is further assumed that the signal power is equally likely to have any value between $S^2{}_m-\Psi$ and $S^2{}_m+\Psi$

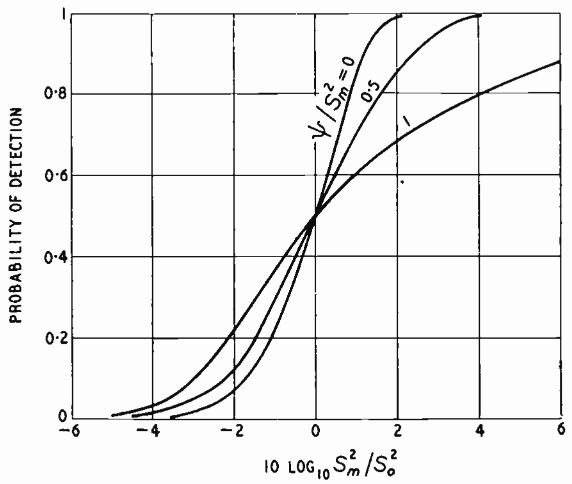

Fig. 6. *The effect of signal fluctuations.*

The expected probability of detection as a function of $S^2{}_m$ is then given by :—

$$\int_{S^2m-\Psi}^{S^2m+\Psi}(1/4\,\Psi)\left[1-\text{erf}\,\frac{S^2{}_0-S^2}{\sqrt{2}\,\Delta}\right]dS^2$$

and is illustrated in Fig. 6 for a typical value of $S^2{}_0/\Delta=4$ and values of $\Psi/S^2{}_m=0$, $\tfrac{1}{2}$ and 1. A value of $\Psi=0$ corresponds to a steady signal, and it is seen that the effect of signal fluctuations is to increase the range of mean signal power corresponding to a given difference in the probability of detection. The mean signal power required for a probability of detection of 0·9 is considerably greater when the signal is fluctuating, whereas the value for a probability of detection of 0·5 is only slightly affected ; a level of 0·5, therefore, appears to be the better basis for a comparison of the theoretical and operational performances of a radar.

4.4. *Biasing and Limiting.*

The assumption that the biasing and limiting levels are almost coincident, upon which the method of solution depends, requires further consideration since it is not the usual operating condition of the c.r. tube. The assumption undoubtedly affects the solution in respect to the optimum bias, but it is thought that the solutions in respect to $S^2{}_{(D)}$ are only slightly affected ; no general proof of this statement can be offered, but it can be shown to be true :

(a) when $z=w=1$ and Criterion B applies, and
(b) when z and w are very large and Criterion B or C applies.

An idea of the functions of biasing and limiting may also be obtained by considering these extreme cases.

It is now assumed that the visual intensity of a spot on the c.r. screen is proportional to the modulating voltage ; i.e., to $(x-X\sigma)$ for $x\leqslant Y\sigma$.

4.4.1. If $z=w=1$, the distribution functions for the intensities of a noise spot and a signal spot are given by $P_N(x)$ and $P_S(x)$ respectively in Fig. 3, and the intensity of the brightest noise spot is defined by a value $(x_1-X\sigma)$ such that $P_N(x_1)=1/G$. So long as $X\sigma<x_1<Y\sigma$ the probability of detection for Criterion B is given immediately by $[P_S(x_1)]^2$ and, apart from any considerations of brightness, is independent of both X and Y. The solution obtained by the method described in Section 3 for Criterion B and $z=w=1$ corresponds to the limiting condition,

$$X\sigma=x_1=Y\sigma$$

and is, therefore, correct in respect of $S^2{}_{(D)}$.

So long as $X<x_1/\sigma$, a change in X only affects the number of spots painting in the noise background. For example, when $X\sigma$ is much less than x_1, there are many spots in the noise background with a wide range of intensities and, as $x_1-X\sigma$ decreases, the number of noise spots painting decreases until, in the limit when $X\sigma$ is just less than x_1, only one noise spot paints (on the average) out of the G which are possible. There cannot, therefore, be said to be any optimum value of the bias in this case, so long as $X\sigma<x_1$, and the value which should be used depends only on the type of noise background

preferred by the operator. However, if $X\sigma$ is made greater than x_1, $S^2_{(D)}$ is increased and the probability of confusion decreases.

Whatever the values of X and Y may be, it is obviously desirable that the input signal be amplified, after biasing and limiting, so that $(Y-X)\sigma$ corresponds to the maximum useful driving voltage of the c.r. tube in order to produce the brightest possible display. The intensity of the brightest noise spot is then proportional to $(x_1-X\sigma)/(Y-X)\sigma$, which increases as $(Y\sigma-x_1)$ is reduced; limiting, therefore, permits of a brighter display, and the limiting level should preferably be just greater than x_1. A lower limiting level could be used in practice, in which case the probability of detection is given by $[P_s(Y\sigma)]^2$; this represents an improvement in detectability, but is undesirable in most applications since it is obtained at the expense of an increase in the probability of confusion.

4.4.2. If we write $I=x-X\sigma$ for the contribution of any basic pulse to the visual intensity of a spot, the function expressing the probability that I lies between I and $I+dI$ has a large component at $I=0$ (corresponding to all the basic pulses which do not exceed the biasing level in amplitude), a small component between $I=0$ and $I=(Y-X)\sigma$, and another component at $I=(Y-X)\sigma$ (corresponding to those basic pulses which exceed the limiting level in amplitude). In the general case it is necessary to derive the distribution of intensity of a spot having Z or W component pulses, and this is rather complicated; however, if Z and W are sufficiently large, the required function approaches a normal Gaussian function with a mean amplitude equal to Z (or W) times the mean value of I, and a variance equal to Z (or W) times the variance of I. Further, if Z is very large, only small values of S are of interest, and

$$I_0(2xS/\sigma) \approx 1+(xS/\sigma)^2$$

in equation (3); the various distributions may then be obtained without difficulty*, and the probability of detection may be found for any criterion of recognition and any value of S.

Solutions have been obtained (a) when limiting is not employed, and (b) when the biasing and limiting levels are virtually coincident, for Criteria B and C, in each of two cases :—

(1) $Z=W=10^4$ for $S^2=0{\cdot}1$ (-10 db) and $G=10^4$

and (2) $Z=10^4$, $W=1{\cdot}3\times10^4$, for $S^2=0{\cdot}25$ (-6 db) and $G=10^4$.

These have led to the following conclusions :—

(a) That there is an optimum value of the bias which depends on the limiting level, being higher when the biasing and limiting levels are almost coincident than it is if limiting is not employed; it also increases as W/Z increases. Thus in case (1) the optimum bias is equal to $0{\cdot}8\,\sigma$ if limiting is not employed, and to $1{\cdot}3\,\sigma$ if the biasing and limiting levels are coincident, while the corresponding values for case (2) are $1{\cdot}7\,\sigma$ and $2{\cdot}3\,\sigma$. The bias setting is not very critical over a range of about $0{\cdot}2\,\sigma$ on either side of the optimum.

(b) That the probability of detection is not very dependent on the limiting level so long as the bias is always adjusted to the optimum value. Thus in case (1) the probability of detection is 0·42 for Criterion B and 0·95 for Criterion C if limiting is not employed, while the corresponding values are 0·28 and 0·88 if the biasing and limiting levels are coincident.

(c) That limiting permits of a brighter display if the signal is amplified, after biasing and limiting, to the maximum extent consistent with tolerable defocusing. Thus, in case (1), the relative intensity of the brightest noise spot is about 0·5 for $(Y-X)=5$, 1·2 for $(Y-X)=2$ and 2·1 when $(Y-X)$ is very small, if the bias is always set to the optimum value.

4.4.3. When Z and W are small, it is tentatively suggested on the basis of these conclusions that $(Y-X)$ be made equal to about 0·4, with the biasing level $0{\cdot}2\,\sigma$ less, and the limiting level $0{\cdot}2\,\sigma$ greater than the value obtained for the optimum bias by the method described in this paper. These values of the optimum bias are higher than those normally used at present, and it is suggested that too small a bias has often been used to compensate for insufficient brightness; to increase the brightness of the noise background, the signal must be amplified so that $(Y-X)\,\sigma$ corresponds to the maximum usable driving voltage of the c.r. tube.

5. Conclusion

Although approximations have been used to obtain a simple solution, it is thought that those adopted in respect to the statistical properties of receiver noise and a mixture of noise and signal, and in respect to the characteristics of a cathode-ray tube, are not likely to introduce a serious error. More doubt rests with the so-called 'criteria of recognition' employed to express the behaviour of an operator in mathematical terms; there is very little practical evidence to support these criteria, but they were chosen from a number investigated because they gave the most reasonable solutions; undoubtedly, some operators are more efficient at recognizing an echo than are others, and better criteria may well be suggested when more is known about this subject.

Within these limitations, the method gives a solution for the ratio of signal power to noise power necessary for any probability of detection,

* This approach has been previously employed by W. Walkinshaw, in an unpublished paper.

and covers the case where the number of signal pulses producing the echo paint is small; it appears that display losses need not be disproportionately high under these conditions.

The relations developed to express the effect of various factors on the signal strength required for a probability of detection of 0·9 are in reasonable qualitative agreement with available experimental results, but data are not available for a check on the absolute levels.

The values derived for the optimum bias suggest that too small a bias has often been used (particularly when $W>Z$) possibly to compensate for insufficient brightness; severe limiting may be of value since it permits of the brightest possible display if the signal is amplified, after biasing and limiting, to the maximum extent consistent with tolerable defocusing of the c.r. tube.

Acknowledgments

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H.F. MAGNETIZATION OF FERROMAGNETIC LAMINAE

Application of Classical Theory

By O. I. Butler, M.Sc., M.I.E.E., and H. R. Chablani, Ph.D.

SUMMARY.—An attempt is made to improve the accuracy and consistency of calculations based on the classical theory of a.c. magnetization of ferromagnetic laminae by the simple, but logical, expedient of using a value of permeability which differs from the ratio of the peak values of B and H. The chosen value of permeability is, to some extent, dependent upon the shape of the B/H curve, which justifies its use in the case of high-frequency magnetization of the laminae.

It is found that calculated results of the power loss and apparent permeability of silicon-steel samples give fairly close agreement with experiment. A similar accuracy is obtained by a more rigorous and laborious solution which replaces the B/H curve by a Legendre polynomial series. It appears that there is a definite limitation in the accuracy of calculations based on the d.c. characteristics of the material and the inherent supposition that the material is homogeneous.

1. Introduction

THE classical theory of the a.c. magnetization of ferromagnetic laminae has been developed by Heaviside[1], J. J. Thomson[2], Steinmetz[3] and Latour[4] on the assumption that a constant value may be assigned to the d.c. permeability of the material. In general, the constant value of d.c. permeability is taken as the ratio of the peak values of B and H occurring at the surface of the laminae, and it is well known that the theoretical values of a.c. power loss and apparent permeability depart appreciably from those obtained by experiment. The discrepancy is, in all probability, mainly due to the eddy-current distribution throughout the depth of each lamination being appreciably influenced by the variation of permeability and hysteresis with effective magnetizing force, and the inhomogeneity of the magnetic material towards the surface of each lamination[5]. For the purpose of the present study of the problem, however, the full explanation of the discrepancy is of secondary importance only; the primary object is to ascertain whether the classical solution can be used in a logical manner to obtain results which are in better agreement with experiment than hitherto.

Butler and Mang[6] have attempted to take

MS accepted by the Editor, March 1950.

account of the variations in permeability and hysteresis, and their calculated values approach fairly closely to the measured values. However, their method of calculation is so complex and laborious as to discourage its general application. Despite the fact that the subject has received considerable attention, the increasing use of the laminae at higher than power frequencies has shown a practical need for a comparatively simple method of calculation, which provides at least the same consistency of results as those obtained by Butler and Mang[6]. Thus, for simplicity, it is desirable to utilize the classical solution of the problem ; and for accuracy of calculation, it is necessary to establish an effective value of d.c. permeability which takes some account of the shape and locus of the family of B/H loops occurring throughout the depth of each lamination under a.c. magnetization conditions.

Evidently, for high-frequency magnetization, the normal B/H curve is the locus of the tips of the family of B/H loops, and the effective permeability is therefore dependent upon this curve. In particular, if hysteresis is negligible, the effective value of permeability is entirely dependent upon the shape of the normal B/H curve. Thus, as a first approximation, it would appear to be permissible to take account of hysteresis by the well-known mathematical expedient of assuming that a constant angle of lag exists between B and H, while the effective value of permeability is based upon the shape of the normal B/H curve. It will be appreciated that this simplified procedure cannot be expected to provide accurate results for the case of low-frequency magnetization of materials in which appreciable hysteresis occurs.

It may be noted that Hughes[7] has attempted to calculate the average flux density over the section of mumetal lamination, corresponding to a known value of 50-c/s magnetizing force at the surface, by using an average value of the differential permeability. The latter quantity is taken as the slope of the line which is tangential to the ascending part, and passes through the tip, of the B/H loop appropriate to the surface magnetization. In reality, the hysteresis effect is neglected, and the fact that a continuous sequence of different B/H loops apply to the interior of the lamination is ignored. Hughes[7] has pointed out, however, that the method is somewhat unsatisfactory.

2. Effective Permeability

Let the point A (Fig. 1) on the normal B/H curve ODAC correspond to the peak values of magnetizing force, H_a, and flux density, B_a, occurring at the surface of a lamination subjected to a.c. magnetization. In general, the straight line OA is taken as the locus of the tips of the B/H loops corresponding to various points in the depth of a lamination. However, since the actual locus is the curve ODA, the successive peak values of B are always less than those represented by the straight-line locus OA, except at the surface of a lamination.

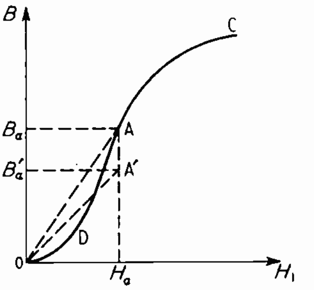

Fig. 1. *Normal B/H curve.*

A reasonable compromise is obtained by fixing a straight-line locus OA′ which crosses the actual locus, to give theoretical peak values of B which are somewhat low towards the surface of a lamination, and somewhat high towards the centre of a lamination. The evident compromise, which will be adopted here, is to fix OA′ such that the area of the triangle OA′H_a is equal to that beneath the curve ODA. Thus, the ratio of B'_a (Fig. 1) to H_a constitutes a value of permeability, μ, which is dependent to some extent upon the shape of the actual locus ODA. It follows that

$$\int_0^{H_a} B \, . \, dH = \mu \int_0^{H_a} H \, . \, dH = \tfrac{1}{2}\mu H_a^2$$

$$\text{Hence, } \mu = \frac{2}{H_a^2}\int_0^{H_a} B \, . \, dH = 2k\frac{B_a}{H_a} \quad \ldots \quad (1)$$

$$\text{where } k = \frac{1}{B_a H_a}\int_0^{H_a} B \, . \, dH \quad \ldots \quad \ldots \quad (2)$$

Thus, k is the ratio of the area under the B/H curve to the area of the rectangle $B_a H_a$. Also, μ differs from its previously accepted value of B_a/H_a by the factor $2k$.

3. Effective Hysteresis Angle

It is well known that the area enclosed by the B/H loop is a measure of the hysteresis loss per cycle for fixed maximum values of magnetizing force, H_m oersted, and flux density, B_m gauss. Hence, if the actual loop is replaced by an oblique ellipse of the same enclosed area and having the same maximum values of H and B, the hysteresis loss is accurately accounted for by considering that a constant angle of lag, σ, exists between B and H. It may be shown that the value of σ is given by the relation

$$\sin \sigma = 4w_h/B_m H_m$$

where w_h represents the hysteresis loss of the material in ergs/cycle/cm³.

However, since the presence of eddy currents results in a progressive change in the values of w_h and H_m throughout the depth of a lamination, it follows that a progressive change in the value of σ occurs throughout the depth of a lamination. The variation of σ with H_m for ring samples of 4% silicon-steel laminations, of thickness 0·33 mm and 0·153 mm, is shown in Fig. 2; the inside and outside diameters of the rings being respectively 8 and 10 cm.

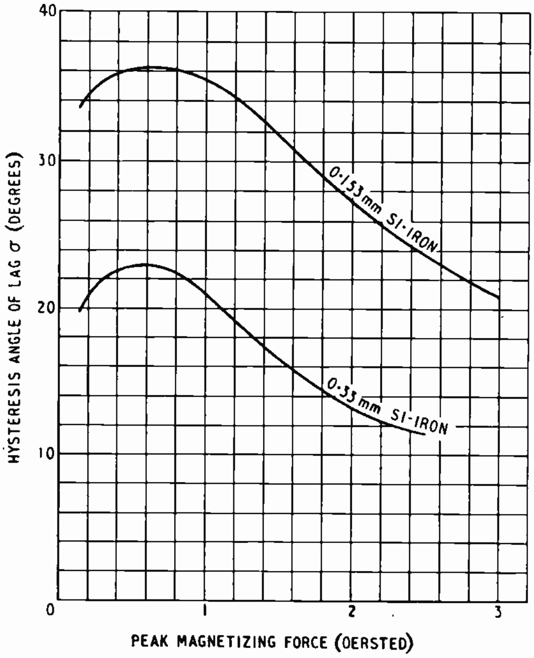

Fig. 2. *Variation of hysteresis angle of lag with peak magnetizing force.*

For simplicity, the effective value of σ may be taken as that corresponding to the mean value of the maximum magnetizing forces, H_a and H_c, say, occurring at the surface and centre, respectively, of the lamination ; the value of H_c being estimated approximately from a fixed value of H_a, on the assumption of negligible hysteresis effect and in accordance with equation (7) of the next Section.

4. Theoretical Power Loss and Apparent Permeability Relations

On the basis of sinusoidally varying B and H, and constant values of μ and σ, it has been shown by Butler and Mang[8] that the total power loss per cm³ is given by

$$W = \frac{\rho m H_a^2}{2a(0{\cdot}4\pi)^2} \cdot \frac{p \sinh 2mpa - q \sin 2mqa}{\cosh 2mpa + \cos 2mqa} \qquad (3)$$

where $2a$ = thickness of lamination (cm)

ρ = resistivity of lamination material (ohm-cm)

$m^2 = 4\pi^2\mu f/10^9\rho$

f = frequency (c/s)

$p = \cos\frac{1}{2}\sigma + \sin\frac{1}{2}\sigma$

$q = \cos\frac{1}{2}\sigma - \sin\frac{1}{2}\sigma$

Also, the mean induction, when the total flux in a lamination is a maximum, is

$$B_{max} = \mu a_0 H_a/a \quad .. \quad .. \quad .. \quad .. \qquad (4)$$

and therefore the apparent, or amplitude, permeability of a lamination subjected to a.c. magnetization is

$$\mu_a = B_{max}/H_a = \mu a_0/a \quad .. \quad .. \quad .. \qquad (5)$$

$$\text{where } a_0^2 = \frac{\cosh 2mpa - \cos 2mqa}{2m^2(\cosh 2mpa + \cos 2mqa)} \qquad (6)$$

Further, assuming no hysteresis, the amplitude of the magnetizing force at the centre of the lamination is

$$H_c = 2H_a/(2\cosh 2ma + 2\cos 2ma)^{\frac{1}{2}} \quad .. \qquad (7)$$

5. Comparison of Theoretical and Experimental Results

The silicon-steel samples (cited in Section 3) have been used to obtain a comparison of the theoretical and experimental results. It may be noted that the ring samples were those used by Butler and Mang[6]. The rings were re-annealed and pickled after punching to remove strain effects and scale. Each core was built up of 25 rings, with paper insulation of 0·002 in thickness inserted between the rings. The mean thickness of the lamination was calculated from its weight and specific gravity. Insulated excitation and search-coil windings were wound uniformly on each core.

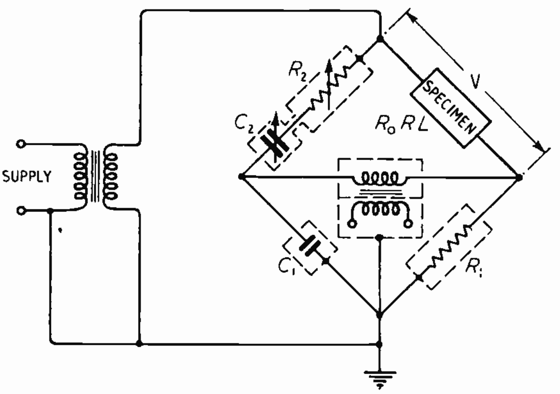

Fig. 3. *Circuit diagram of Owen bridge. R_0=d.c. resistance of the specimen; R_1=standard resistor 0·6 ohm; R_2=variable resistor 0-10,000 ohm; C_1=standard capacitor 3·897 and 9·76 μF; C_2=variable capacitor 0-1 μF; L, R=effective inductance and resistance of the specimen.*

The normal magnetization characteristic and a sequence of hysteresis loops were determined by the usual method of reversals, while the Owen bridge circuit, as shown in Fig. 3, was used to obtain the a.c. characteristics of the specimens. A low value of resistance, never exceeding 6 ohms, was utilized for the arm R_1 to ensure that the voltage applied to the specimen was as near sinusoidal as possible.

5.1. *Values of Total Power Loss.*

The foregoing relations have been used to calculate the values of μ, σ, B_{max} and W, corresponding to a sequence of fixed values of H_a, for the silicon-steel samples. The power loss results are shown as chain-line curves in Figs. 4 and 5, together with the theoretical and experimental

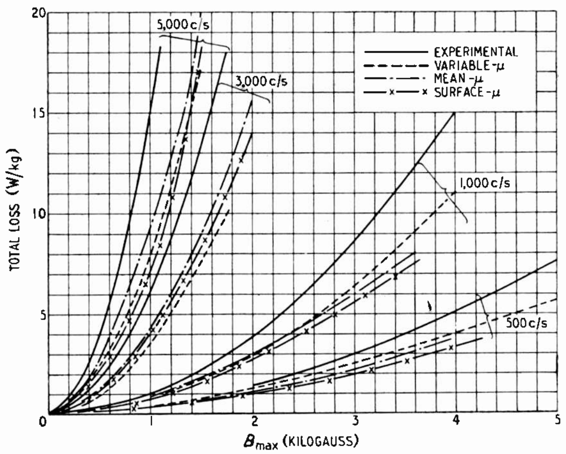

Fig. 4. *Total loss curves for 0·33-mm silicon steel.*

results of Butler and Mang[6], and the further theoretical results obtained when the usual value of permeability, B_a/H_a, is employed. For convenience, the latter will be referred to as the surface-μ method of calculation, that of Butler and Mang[6] as the variable-μ method, and that adopted here as the mean-μ method.

It will be seen from Figs. 4 and 5 that the surface-μ method gives results which are the least in agreement with experiment. Evidently, the mean-μ method gives results which are in the closest agreement with experiment throughout the recorded range of flux densities at the higher frequencies, in the case of the 0·33-mm sample, and for almost all flux-densities and frequencies in the case of the 0·153-mm sample.

It will be further seen from Figs. 4 and 5 that there is little difference between results obtained by the variable-μ and mean-μ methods; and, in general, the results are consistently optimistic.

5.2. *Values of Apparent Permeability*

Since the classical theory is based on sinusoidal variations of both B and H, it follows that no simple relation exists between the apparent permeability defined by equation (5) and the a.c. permeability measured by Webb and Ford[9] as the ratio of B_{max} to H_{max}, where the latter are not both sinusoidally varying quantities. Evidently, the conception of a.c. permeability requires careful interpretation, particularly as other definitions exist; Epolboim[10] enumerates five separate definitions of permeability.

In general, the fundamental quantities are of most importance in assessing the effective utilization of the laminae, both from the point of view of the power loss involved and the impedance of a given circuit; that is, we generally require the values of effective series resistance and inductive reactance of ferric elements in a circuit on the basis of fundamental frequency. Thus, the apparent permeability defined by equation (5) is of considerable practical value, and it is fortunate that bridge methods of measurement readily permit its experimental determination. It should be noted, however, that the measured impedance (at fundamental frequency) of a non-linear circuit element is affected by harmonic current flow arising from the complexity of the applied

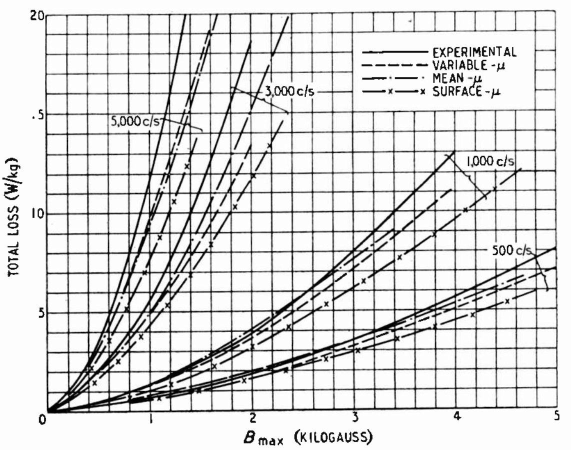

Fig 5. *Total loss curves for 0·153-mm silicon steel.*

voltage and/or the characteristics of the elements comprising the circuit[11].

The results of calculations based on equation (5), and experiments conducted on the 0·33-mm silicon-steel sample using an Owen bridge, are shown in Fig. 6. The calculated results cover the foregoing mean-μ and surface-μ methods of applying the classical theory. It should be noted that the experiments were performed with sinusoidal-total flux, and the values of the bridge components at balance permitted the simultaneous determination of the total power loss and apparent permeability of the samples.

It will be seen that the mean-μ method gives particularly good agreement with experiment for

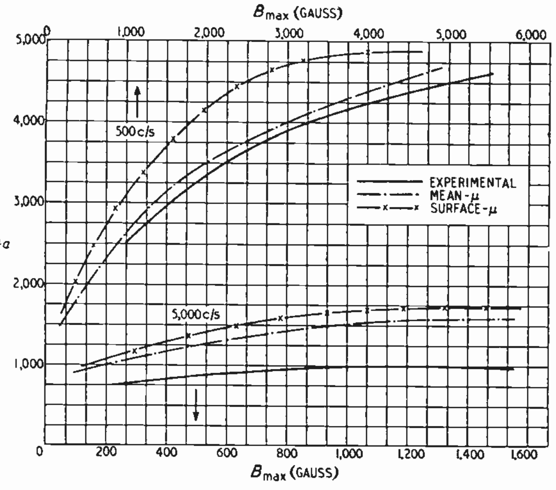

Fig. 6. *Apparent a.c. permeability curves for 0·33 mm silicon steel.*

500-c/s operation of the silicon-steel sample. With 5000-c/s operation, however, the results of the mean-μ method depart from experiment by as much as 40 to 60%, but are still an appreciable improvement on the results of the surface-μ method.

It is significant that the experimental value of the ratio B_{max}/B_a decreases with increase of frequency, indicating that the magnetic flux tends to be concentrated towards the surface of the laminae to an increased extent as the frequency is increased. The significance of this result may readily be investigated further when it is noted that $2mpa>3$ for 5000-c/s operation. Thus, the theoretical value of apparent permeability (see equation 5) may be expressed with negligible error as

$$\mu_a = \frac{\mu}{1{\cdot}414ma} = \frac{10^4}{2\pi a}\left(\frac{5\rho\mu}{f}\right)^{\frac{1}{2}} \qquad \ldots \quad (7)$$

It follows that a 50% error can occur in the estimated value of μ_a if the concentration of flux towards the surface of an inhomogeneous lamina results in approximately 50% reduction of the value of the product $\rho\mu$.

Referring to Fig. 6, it will be seen that the discrepancy rises to 50% when B_{max} is about 1000 gauss for 5000-c/s operation. The corresponding experimental value of the ratio B_{max}/B_a is 0.31, indicating that the major portion of the a.c. flux is confined to approximately one-third, or less, of the available section of each lamination. This effect is clearly demonstrated by curves showing the calculated variation of the instantaneous flux density throughout the section of a lamination[12].

Since the laminae were re-annealed after stamping it is unlikely that the value of the product $\rho\mu$ towards the surface of the laminae is less than the mean value by as much as 50%. Nevertheless, it is possible that its value in a surface depth of one-third, or less, of a lamination section is sufficiently different from the mean value to account for an appreciable portion of the discrepancy between experiment and theory. It may be noted, however, that Peterson and Wrathall[5] have worked with re-annealed laminae at very small inductions, corresponding to the initial permeability region, in order that the assumption of a permeability independent of magnetizing force may be approximated satisfactorily. They have shown that the discrepancy under these conditions was eliminated when 15%, or more, of the lamination depth was etched from each surface. A further factor, which is likely to be of some importance, is the change in the value of ρ with magnetizing force[13].

6. Results of Non-linear Solution

With the object of reducing the discrepancy between theory and experiment above the initial permeability region, a non-linear solution of the problem has been developed which replaces the B/H curve, as the locus of the tips of the B/H loops, by a Legendre polynomial series. Since B is an odd function of H, for a.c. magnetization, only odd terms of the series have been considered. Also, to reduce the computation work involved in evaluating the series for the given peak values of H_a and B_a, the B/H curve has been plotted such that both B_a and H_a are represented by unit dimension. Thus the series is of the form

$$B = A_1 \,.\, P_1(H) + A_3 \,.\, P_3(H) + \quad \ldots$$
$$+ A_n \,.\, P_n(H) + \quad \ldots \quad \ldots \quad \ldots \qquad (8)$$

where $P_n(H) = \dfrac{1}{2^n \,.\, n!} \,.\, \dfrac{d^n}{dH^n}(H^2 - 1)^n$

and $A_n = (2n+1) \displaystyle\int_0^1 B \,.\, P_n(H)$

The effect of hysteresis was taken into account by the introduction of a constant angle of lag of B behind H, in the same manner as previously.

An example of the accuracy of the series in replacing the B/H curve, when the first four terms only of equation (8) are considered, is afforded by the Table which relates to the 0·33-mm silicon-steel laminae with peak values of H and B of 0·88 oersted and 5175 gauss, respectively.

TABLE

$H/0.88$	1	0·9	0·8	0·7	0·6	0·5	0·3	0·1	0
True $B/5175$	1	0·901	0·787	0·672	0·535	0·396	0·146	0·025	0
Estimated $B/5175$	0·988	0·909	0·794	0·659	0·521	0·391	0·184	0·051	0

For brevity, the further mathematics of the method is omitted, it being sufficient to state that the calculated results of power loss have been found, in general, to be intermediate between those of the variable-μ and mean-μ results shown graphically in Figs. 4 and 5. Also, the calculated results of apparent permeability do not depart by more than a few per cent from those calculated by the mean-μ method and shown in Fig. 6.

Thus, the discrepancy between experiment and theory is affected only slightly by a non-linear treatment of the problem. It follows that the mean-μ method of applying the classical theory gives a simple first approximation to the performance of ferromagnetic laminae over a fair range of frequencies and flux densities which is not greatly improved upon by using the laborious variable-μ and polynomial-series methods.

7. Conclusions

A logical choice of the mean value of d.c. permeability enables the classical theory of a.c. magnetization of ferromagnetic laminae to be utilized to obtain a reasonably accurate and consistent estimate of performance characteristics over a frequency range from a few hundred to a few thousand cycles per second, and a wide range of flux densities. The improvement obtained by non-linear methods of calculation is insufficient to warrant the labour and complications which they involve.

Acknowledgments

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By F. A. Benson, M.Eng., A.M.I.E.E., M.I.R.E. Pp. 125 with 97 illustrations. *Electronic Engineering*, 28 Essex Street, Strand, London, W.C.2. Price 12s. 6d.

In this book the author reviews the various ways of stabilizing voltage and in three chapters he covers the three main methods depending on the use of magnetic saturation, glow-discharge tubes and thermionic valves. Some 10½ pages only are given to the first of these and the treatment is purely descriptive.

The treatment of the others is much more detailed and certain design information is given. Characteristics of typical tubes are tabulated and data on the variations of different samples and on the effect of temperature are given. Valve types are also quite fully treated and analyzed in some detail.

In a final miscellaneous chapter other methods are covered, starting with the barretter, which is really a current stabilizer,and going on to Metrosil and lamp stabilizers. Methods of stabilizing r.f. sources of power are discussed and the principles of stabilizing alternating voltages are covered. The book concludes with a 12-page bibliography.

The book should be extremely useful for reference. The treatment is hardly sufficiently detailed for it to be a designers' handbook, but the wide variety of methods described, the notes on the performance obtainable and the references to published material do make the book of considerable use to the designer.

W. T. C.

Valve and Circuit Noise

Radio Research Special Report No. 20. Pp. 19 + iv. H.M. Stationery Office, York House, Kingsway, London, W.C.2. Price 9d. (25 cents, U.S.A.).

This report of the Department of Scientific and Industrial Research provides a survey of existing knowledge and outstanding problems, and is divided into sections covering thermal noise, valve noise, noise in semiconductors and crystal rectifiers, gas discharges, magnetic-field devices, Barkhausen noise, temperature and radiation fluctuations and statistical properties of fluctuation noise. A bibliography is included.

In each section the established aspects of the matter are first considered, and an outline of the problems which require solution follows.

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.

Circuit Theorem

SIR,—I cannot find any mention of the following equivalent circuit in the text-books and I feel that it is sufficiently useful to merit attention.

Referring to Fig. 1, the voltage and current at the input end of a terminated line may conveniently be written as

$$V = V_t + V_r$$
$$I = (V_t - V_r)/Z_o$$

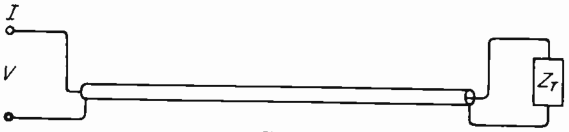


Fig I

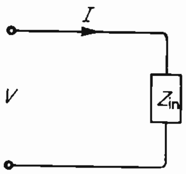


Fig.2

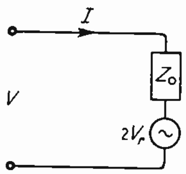


Fig.3

where V_t is the voltage component of the forward wave and V_r that of the reflected wave. Here V, V_t, V_r and I are all rotating vectors, and are really shorthand for $V \sin(\omega t + \theta_1)$, $V_t \sin(\omega t + \theta_t)$, etc: their relative phase angles $(\theta_t - \theta_1)$, etc., and their relative magnitudes V_t/V, etc., are well-known functions of Z_T and the length and attenuation of the line.

The ordinary equivalent circuit for the line is as shown in Fig. 2 where $Z_{in} = V/I$: here Z_{in} is given by the equations above, and may also be expressed as a function of Z_T and the line length and attenuation.

Unfortunately, the functions referred to are sufficiently complex to be extremely inconvenient in application in many practical problems, and an alternative equivalent circuit is desirable. From the equations above, we have:—$V - 2V_R = IZ_o$, whence we obtain the new equivalent circuit shown in Fig. 3.

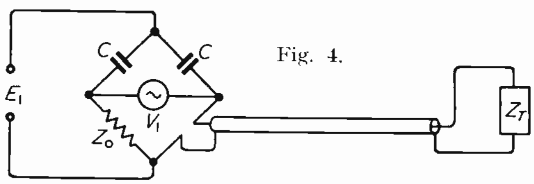


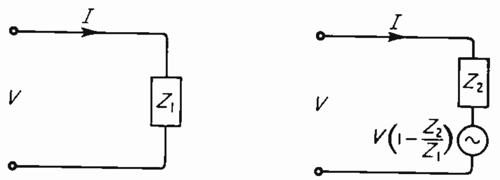
Fig. 4.

In this circuit we have the advantage of a simple known impedance (usually a resistance) in place of the complex unknown Z_{in}, but we have added a new unknown, which is a complex function of a similar nature to those referred to above. Whether we are any better off depends upon the source from which the line is being driven. For example, if the source is another line of characteristic impedance Z_o, it is convenient to be able to calculate the current in it as the sum of the current which would occur if the line were correctly terminated, plus that due to a generator of impedance Z_o and e.m.f. $2V_r$ operating in the reverse direction.

Perhaps the main advantage of the new circuit is seen when the line input is attached to a bridge (Fig. 4), as in the "Micromatch" and similar devices.

Various explanations of this device have been given: that in *QST* for April 1947 is approximately correct, but throws little light on the relation between its operation as a bridge and as a standing-wave detector. In another paper, in *Proc. Inst. Radio Engrs* for February 1948, the authors start from the fact that *when the bridge is balanced*, with a resistance equal to Z_o connected in place of the line, V_1 is zero for any value of E_1; they then implicitly assume that only the reflected wave, and not E_1, is registered at V_1 when the line with *any* termination is connected to the bridge; this assumption is certainly not justified if one thinks in terms of Fig. 2, since the bridge is then unbalanced by the substitution of Z_{in} for Z_o. However, the device does work in practice, and the reason is immediately shown by the new equivalent circuit: the detector current (or volts) is the sum of that due to E_1 with an impedance Z_o connected to the bridge, plus that due to twice the reflected voltage operating through Z_o.

It is worth noting that a more general form of this theorem exists, and that this applies also to impedances other than lines: for *any* impedance Z_1 in a network (Fig. 5) we may substitute any other impedance Z_2 provided we insert in series with the latter an e.m.f. which is readily shown to be $V(1 - Z_2/Z_1)$. Although in this form the theorem is somewhat tautologous, it does



(a) (b)

Fig. 5.

help to reconcile the use of a bridge to measure an impedance with its use to measure a reflected voltage.

E. K. Cole, Ltd., M. V. CALLENDAR.
Southend-on-Sea, Essex.
28th November, 1950

Errata

An error occurred in Equ. (18) of "Interference in Multi-Channel Circuits," by L. Lewin, which appeared in the December 1950 issue (pp. 294-304). Equ. (18) should read:—

$$G(x) = \sqrt{\alpha k r_1 r_2 (y\omega x)}\,\phi(\tau x)/2x$$

where

$$\phi(\tau x) = \left[\frac{4}{\pi}\int_0^\infty \cos y\theta \left\{ \exp(4\tau^2 x^2 \sin\theta/\theta) - 1 - 4\tau^2 x^2 \sin\theta/\theta \right\} e^{-4\tau^2 x^2} d\theta \right]^{\frac{1}{2}}$$

In the January 1951 issue, Equ. (2.7) in "Triode Transmission Networks," by A. W. Keen (pp. 56-66), should read:— $\gamma_{12} = g_{01} + \gamma_{12}^*$.

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

534.17 : 534.874.1 — 513

Maximum Directivity Index and Efficiency of Linear Arrays.—R. L. Pritchard. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 676–677.) Summary of Acoustical Society of America paper. The index is calculated as a function of the number and spacing of the elements in the array, and the efficiency as dependent on the manner of excitation and type of transducers used.

534.22 — 514

The Velocity of Sound in Sea Water.—A. Weissler & V. A. Del Grosso. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p.684.) Summary of Acoustical Society of America paper. Measurements with a 3-Mc/s ultrasonic interferometer were made on samples of Caribbean Sea water collected at various depths. The velocities found at 20°C and 30°C were about 4 m/s higher than the values in Kuwahara's tables, for which an accuracy within 3 m/s is claimed. The sound velocity, the density and the adiabatic compressibility were also determined over a wide range of concentrations for pure solutions of each of the seven salts which are the major constituents of the dissolved matter in sea water. The compressibility and sound velocity for sea water agree to within 0·1% with the values determined by summation of the effects of the individual salts, each at its proper concentration.

534.22-13 — 515

The Velocity of Sound in Helium at Temperatures −78°C to 200°C and Pressures up to 70 Atmospheres.—W. G. Schneider & G. J. Thiessen. (*Canad. J. Res.*, Sept. 1950, Vol. 28, Sec. A, No. 5, pp. 509–519.) An account of measurements made using an ultrasonic interferometer of the double-crystal type.

534.22-16 — 516

New Methods for Measuring Ultrasonic Velocity in Solids.—G. W. Willard. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 684–685.) Summary of Acoustical Society of America paper. Description of methods based on optical interference effects. Accuracy to within 1% can easily be obtained with either transparent or opaque materials.

534.23 — 517

Experimental Determination of Acoustic Wave Fronts.—P. Tamarkin, G. L. Boyer & R. T. Beyer. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 686.) Summary of Acoustical Society of America paper. Description of a method making use of a phase discriminator to locate successive points in the wave front.

534.231 — 518

Sonic Wind and Static Pressure in Intense Sound Fields.—J. P. Walker & C. H. Allen. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 680–681.) Summary of Acoustical Society of America paper. In the free field above a piston source 12 cm in diameter vibrating sinusoidally at 14·6 kc/s a sonic wind has been observed, similar to the effect obtained in water with a quartz dis'. The wind is directed away from the source along the axis and its velocity is proportional to the square of the source amplitude. Positive static excess pressures were also found on the axis, directly proportional to the sound intensity at the point of measurement. At an acoustic level of 156 db this pressure was 10 dynes/cm².

534.231 — 519

An Automatic Sound-Field Mapper.—J. J. Baruch. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 686.) Summary of Acoustical Society of America paper. Mechanism is provided for moving a microphone over a plane in the sound field, the microphone output being plotted automatically and giving contours of either constant sound-pressure level or constant phase. Five contours can be plotted simultaneously.

534.231.1 — 520

Finite Amplitude Distortion in a Spherically Diverging Sound Wave in Air.—C. H. Allen. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 680.) Summary of Acoustical Society of America paper. Measurements were made of the pressure amplitudes of each of the first six harmonics of a free progressive sound wave in air, using a piston source, of diameter about 5 λ, vibrating sinusoidally at a frequency of 14·6 kc/s. The results are discussed.

534.232 — 521

A New Expansion for the Velocity Potential of a Piston Source.—A. H. Carter & A. O. Williams, Jr. (*J. acoust.*

Soc. Amer., Sept. 1950, Vol. 22, No. 5, p. 676.) Summary of Acoustical Society of America paper.

534.24 **522**

Scattering of Sound by Cylinders and Spheres.—J. J. Faran, Jr. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Summary of Acoustical Society of America paper.

534.321.7 : 621.396.615 **523**

A Bridge-Stabilized Generator for Tuning Musical Instruments.—R. Gauger & J. Sommer. (*Funk u. Ton*, Nov. 1950, Vol. 4, No. 11, pp. 554–558.)

534.321.9 **524**

Transmission and Reflection of Ultrasonic Waves from a Solid Plate in Water.—M. S. Weinstein & W. C. Wineland. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, p. 416.) Summary of American Physical Society paper. Results of measurements at 1 Mc/s on six Al plates of thickness from $\frac{1}{32}$ in. to $\frac{1}{2}$ in. are in good agreement with the theory of Smyth & Lindsay (97 of 1945).

534.321.9 **525**

Variable Resonant Frequency Crystal Systems.—W. J. Fry, R. B. Fry & W. Hall. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 676.) Summary of Acoustical Society of America paper. Discussion of the theory and design of low-loss variable-frequency crystal units, with experimental results for a generator covering the range 40–80 kc/s.

534.321.9 : 534.22 : 546.74 : 538.69 **526**

Some Magneto-Acoustic Effects in Nickel.—Rogers & Johnson. (See 642.)

534.321.9 : 612.7 **527**

An Experimental Study of Temperatures Produced by Ultrasonic Radiations in Bone Marrow, Bone, and Adjacent Tissues.—E. J. Baldes, P. A. Nelson & J. F. Herrick. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 682.) Summary of Acoustical Society of America paper. Experiments with a 15-W 800-kc/s generator showed that dangerously high temperatures can be produced in bone and bone marrow within a few minutes, using relatively low outputs of energy. The heating of the adjacent tissues is only moderate.

534.321.9 : 612.8 **528**

Ultrasonic Irradiation of Nerve Tissue.—W. J. Fry & V. J. Wulff. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 682.) Summary of Acoustical Society of America paper. A preliminary report of investigations in progress.

534.373-14 **529**

Mechanisms of Sound Absorption in Fluids.—J. J. Markham. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 684.) Summary of Acoustical Society of America paper. A survey of suggested mechanisms, which are considered under the headings: (*a*) viscosity absorption; (*b*) relaxation absorption.

534.373-14 : 534.321.9 **530**

Absorption Measurements in Electrolytic Solutions.—M. C. Smith, R. Barrett & R. T. Beyer. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 684.) Summary of Acoustical Society of America paper. Absorption measurements for solutions of $MgSO_4$ were made at 3 Mc/s by an electrical-detection method, and in the range 12–40 Mc/s by the radiation-pressure method. At the higher frequencies there is an additional absorption process not accounted for by the compressional relaxation in the Liebermann theory.

534.373-14 : 534.321.9 **531**

Ultrasonic Absorption in Liquids.—C. J. Moen. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 684.) Summary of Acoustical Society of America paper. Results obtained at frequencies down to 140 kc/s by a reverberation method for various liquids with widely different properties are discussed. For water, benzene, glycerol and CS_2 the absorption is proportional to the square of the frequency.

534.442.2 : 621.317.335 **532**

The Analysis of Oscillations by the Search-Tone Method.—W. Meyer-Eppler. (*Arch. elekt. Übertragung*, Aug. 1950, Vol. 4, No. 8, pp. 331–338.) A mathematical explanation is given of the method in which a heterodyne search-oscillator is used to shift the components of the unknown oscillation within the range of an analysing band-pass filter. The influence of searching speed is examined; if the analysis is sufficiently slow, components of a steady oscillation, however close, can be separated. Details are given of the frequency ranges usable for analysis, these ranges being restricted by the formation of 'zones of confusion' in the course of the heterodyning. A highly simplified arrangement for audio frequencies is described in which the only equipment needed is an interrupter and a galvanometer.

534.6 681.85 **533**

Methods of Calibrating Frequency Records.—R. C. Moyer, D. R. Andrews & H. E. Roys. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1306–1313.) 1948 I.R.E. National Convention paper noted in 2430 of 1948. A record having a known amplitude at several frequencies was calibrated by four methods whose relative advantages are discussed. The optical method, which uses light reflected from the walls of the groove, is considered the best.

534.64 **534**

A Null-Balance Apparatus for Measuring Acoustic Impedance.—J. R. Cox, W. M. Ihde & A. P. G. Peterson. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 679.) Summary of Acoustical Society of America paper. A bridge-like device composed of two adjustable electrical networks and two acoustical networks is used. The latter consist of short cavities, each with a sound source at one end, the other ends being terminated respectively by the unknown impedance and a hard plug. The input currents to the electrical networks are proportional to the pressures in the cavities. When the electrical networks are balanced, the unknown impedance can be read directly from that of one of the adjustable networks.

534.75 **535**

Short-Duration Effects in Auditory Fatigue.—J. D. Harris. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 674.) Summary of Acoustical Society of America paper. An investigation of fatigue as a function of (*a*) duration, frequency and intensity of the tone causing fatigue, and (*b*) the duration of the recovery interval.

534.75 **536**

A Consideration of the Intensity/Loudness Function and its Bearing upon the Judgment of 'Tonal Range' and 'Volume Level'.—S. E. Stuntz. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 674.) Summary of Acoustical Society of America paper.

534.75 **537**

Observations on the Effect of High Intensity Sounds in the Ear.—H. G. Kobrak. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 674.) Summary of Acoustical Society of America paper.

534.78 538

Intelligibility of Amplitude- and Time-Quantized Speech Waves.—J. C. R. Licklider. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 677–678.) Summary of Acoustical Society of America paper.

534.78 539

A Speech Analyzer and Synthesizer.—W. A. Munson & H. C. Montgomery. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 678.) Summary of Acoustical Society of America paper. Description of the principles of operation of a resonance type of Vocoder.

534.78 540

Measurement, Portrayal, and Interpretation of some Statistical Properties of Speech Sounds.—Sze-Hou Chang, G. E. Pihl & M. W. Essigmann. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Summary of Acoustical Society of America paper. See also 1319 of 1950 (No. 14).

534.78 541

Autocorrelation Analysis of Speech Sounds.—K. N. Stevens. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Summary of Acoustical Society of America paper. Discussion of a method of speech analysis using the short-time autocorrelation function, which is defined. Apparatus for determining correlation functions is described and results for various speech sounds are analysed.

534.79 542

Calculation and Measurement of the Loudness of Sounds.—J. L. Marshall, L. L. Beranek, A. L. Cudworth & A. P. G. Peterson. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 671.) Summary of Acoustical Society of America paper.

534.79 543

The Threshold and Loudness of Repeated Bursts of Noise.—I. Pollack. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 671.) Summary of Acoustical Society of America paper.

534.79 544

Masking of a Pure Tone at a Gap in a Thermal-Noise Spectrum.—T. H. Schafer, P. O. Thompson & J. C. Webster. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 671.) Summary of Acoustical Society of America paper.

534.833.4 545

The Measurement of the Acoustic Properties of Sound-Absorbent Panels at High Hydrostatic Pressures.—W. J. Trott & C. L. Darner. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 681.) Summary of Acoustical Society of America paper. An account of the method used, with results for the underwater reflection and transmission properties of several materials in the frequency range 10–150 kc/s and at hydrostatic pressures up to 350 lb/in^2.

534.844 546

A Tentative Criterion for the Short-Term Transient Response of Auditoriums.—R. H. Bolt & P. E. Doak. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, pp. 678–679.) Summary of Acoustical Society of America paper.

534.844 : 519.272.119 547

Correlation Coefficients as Criteria for Randomness of Reverberant Sound Fields.—R. K. Cook & S. Edelman. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 678.) Summary of Acoustical Society of America paper.

534.845 548

A Long-Tube Method for Field Determinations of Sound-Absorption Coefficients.—E. Jones, S. Edelman & A. London. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 679.) Summary of Acoustical Society of America paper. A modification of the laboratory impedance tube was adapted for field measurements of absorption coefficients at a frequency of 512 c/s. The coefficient for reverberant sound is calculated on the basis of a semi-empirical development described by London (1846 of 1950).

534.846.6 549

Techniques for determining Acoustics of Amphitheatres by Scale-Model Studies with High-Frequency Sounds.—H. C. Hardy & F. G. Tyzzer. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 679.) Summary of Acoustical Society of America paper. Measurements on small-scale models of two large outdoor amphitheatres are described. Frequencies between 2 kc/s and 30 kc/s were used to determine sound levels in the stage area and distribution of sound in the audience area, absorbent materials being used to simulate the effect of an audience. The results obtained simplified the design of the sound amplifying and distributing equipment required in practice.

534.85 550

Stylus/Groove Relations in the Phonograph Playback Processes.—F. G. Miller. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 673.) Summary of Acoustical Society of America paper. Mathematical analysis of the motion of a reproducer stylus, taking account of tracing distortion and elastic deformation of the groove wall.

534.85 551

Some Applications of Square-Wave Testing Techniques to the Evaluation of Disk Recording Systems.—S. R. Bradshaw & W. Wathen-Dunn. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 673.) Summary of Acoustical Society of America paper.

621.395.61 552

Reciprocal-Resistance Relation between Piezoelectric and Electrodynamic Transducers.—F. A. Fischer. (*Arch. elekt. Übertragung*, Aug. 1950, Vol. 4, No. 8, pp. 321–324.) Completion of previous work (3320 of 1949) on the classification of transducers. Only four classes are now distinguished: these consist of two reciprocal-resistance pairs.

621.395.61 : 534.612.4 553

Reciprocity Calibration of Microphones, using a Pulse Technique.—R. L. Terry & R. B. Watson. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 672.) Summary of Acoustical Society of America paper. The microphone output is sampled before the sound pulses from the test transmitter can reach the microphone after reflection from the nearest wall. An effective free-field calibration is thus obtained.

621.395.61.001.11 554

Symmetry in the Equations for Electromechanical Coupling.—F. V. Hunt. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 672.) Summary of Acoustical Society of America paper.

621.395.623.7 : 534.874.1 555

A Unidirectional Loudspeaker System.—H. Kalusche. (*Z. angew. Phys.*, Oct. 1950, Vol. 2, No. 10, pp. 411–415.) Acoustic delay lines have been previously used with gradient microphones to obtain directional characteristics; their use in combination with loudspeakers for similar purposes is now studied, and similar considerations are found to apply. To suppress backward radiation, the delay member must have frequency-independent delay time and frequency-dependent attenuation; cotton-wool packing, damped resonators, etc., may be used. By using a linear array of loudspeakers, greatly improved directional effects can be obtained. Directional characteristics in both the horizontal and the vertical plane are shown for an array of six loudspeakers, for various frequencies from 100 c/s to 10 kc/s. Less than 10% of the sound energy is radiated backwards.

621.395.623.7 : 621.3.018.78† **556**

Nonlinear Distortion in Loudspeakers.—E. Roessler. (*Funk u. Ton*, Nov. 1950, Vol. 4, No. 11, pp. 549–553.) Discussion of a particular form of nonlinear distortion which arises in large halls or in the open air when tones of high and low pitch and of unequal intensity are emitted simultaneously.

621.395.625.3 : 534.852 **557**

Tests on Magnetic Tapes designed for a Running Speed of 15 in./sec.—P. H. Werner. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Oct. 1950, Vol. 28, No. 10, pp. 382–388. In French.) Comparison of the characteristics of the following tapes: Audio; LGH; Genotron ENA; Pyral; Scotch 111A. The frequency characteristic and the percentage distortion as a function of output level are shown graphically; they are similar for the different tapes. Some difference occurs in their background noise, analyses of which are shown for different operating conditions.

621.396.611.21 **558**

Surface Vibration Patterns of Piezoelectric Radiators.—J. D. Nixon & A. O. Williams, Jr. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 676.) Summary of Acoustical Society of America paper. A quartz X-cut crystal with one face optically polished is used as one mirror of a Michelson interferometer, the unpolished face radiating into a liquid of acoustic impedance different from that of the crystal. The interference fringes produced allow the direct observation of the vibration of the entire crystal face. Measurements at frequencies of 0·5 and 1·0 Mc/s are described.

621.396.611.21 **559**

Cylindrical Barium Titanate Transducers.—T. F. Johnston & F. D. Wertz. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 676.) Summary of Acoustical Society of America paper. Performance data, including radiation diagrams, frequency/response curves and impedance values, are given for transducers constructed from $BaTiO_3$ ceramic cylinders. To make the units waterproof and to provide additional mechanical strength, they were cast in a thermosetting resin. In general, the performance is comparable with that of crystal or magnetostrictive transducers, but the construction is much simpler.

621.396.611.21.001.8 **560**

Use of Barium Titanate Transducers for Producing Large Amplitudes of Motion and High Forces at Ultrasonic Frequencies.—W. P. Mason & R. F. Wick. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 676.) Summary of Acoustical Society of America paper. Longitudinal oscillations are produced in a $BaTiO_3$ cylinder excited by means of poles arranged radially, the resonance frequency being determined by the length of the cylinder. For a cylinder 12 cm long, resonant at 18 kc/s, the displacement at the ends can be $3{\cdot}9 \times 10^{-4}$ cm. This can be increased tenfold by soldering to the end of the cylinder a brass horn, flared exponentially and with mouth diameter ten times that of the throat. This acts as a transformer to increase the amplitude. Instruments based on such a structure have been produced for various purposes.

621.396.611.21.012.8 **561**

X-Cut Quartz Crystals.—H. Grayson. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, pp. 270–271.) An exact equivalent circuit for a quartz transducer is devised and discussed for different conditions of acoustic loading on the two crystal faces. An approximate equivalent circuit was described in 2162 of 1950 (Leslie).

AERIALS AND TRANSMISSION LINES

621.39.09 : 517.512.2 **562**

Fourier Transforms in the Theory of Inhomogeneous Transmission Lines.—F. Bolinder. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, p. 1354.) The Fourier integral theorem is applied to derive an expression for the reflection coefficient at the sending end of an inhomogeneous transmission line when the receiving end is matched. The method can be applied to acoustic waves.

621.392.09 **563**

Surface-Wave Transmission Line.—N. M. Rust: G.W.O.H. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, p. 270.) Experiments on surface-wave transmission have been described by Goubau (281 of February). It is here pointed out that the only advantage to be gained by covering the wire with dielectric is to reduce launching and collecting loss at the horns. To obtain minimum total loss, bare wire should be used between the horns; tapered dielectric loading may be used on the parts of the wire within and near the horns. This has been verified experimentally.

621.392.26† : 621.3.09 **564**

The Effect of a Diaphragm on the Field of an Electromagnetic Wave in a Tube.—E. Ruch. (*Ann. Phys., Lpz.*, 20th May 1950, Vol. 7, No. 5, pp. 248–272.) Theoretical study of refraction and reflection at a plane diaphragm, of any shape, perpendicular to the tube wall. The solution of a system of equations with an infinite number of unknowns is involved, and this problem is discussed generally. An approximate numerical calculation is performed for the case of a tube with rectangular cross-section and slit-type diaphragm, for an incident H wave.

621.392.26† : 621.3.09 **565**

Electromagnetic Waves in Wave Guides.—K. S. Knol & G. Diemer. (*Commun. News*, July 1950, Vol. 11, No. 2, pp. 33–48.) See 1851 of 1950.

621.392.26† : 621.318.572 **566**

Fabrication of a High-Power Resonant Waveguide Window.—E. V. Edwards & K. Garoff. (*Rev. sci. Instrum.*, Sept. 1950, Vol. 21, No. 9, pp. 787–789.) Higher values of the loaded Q for pre-TR and TR tube windows are recommended to withstand high transmitter powers at 3 kMc/s. The processing of a glass window, having a loaded Q of 4 and fitting a standard rectangular 1·5-in. × 3-in. waveguide, is described in detail. Tests show that such windows can withstand a working temperature of 160°C in pre-TR tubes, a temperature at which present conventional windows crack or are sucked in.

621.396.67 **567**

Effect of a Circular Groundplane on Antenna Radiation.—A. Leitner & R. D. Spence. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 1001–1006.) The field of a vertical $\lambda/4$ aerial above a circular conducting disk of zero thickness is calculated theoretically by use of the wave functions for the oblate spheroid. Assuming a sinusoidal current distribution in the aerial, calculations are made of the currents in the ground-plane, the radiation resistance and the radiation pattern of the system for various values of the ground-plane radius. These results are applied to a study of the field distortion due to finite ground-planes.

621.396.67 **568**

Circularly Grouped Aerials as Omnidirectional and Directive Radiators.—W. Burkhardtsmaier & U. Finkbein. (*Elektrotechnik, Berlin*, July & Aug. 1950, Vol. 4, Nos. 7 & 8, pp. 239–244 & 284–290.) From fundamental theory expressions are derived for the radiation characteristics, impedance, gain, etc., of an aerial system comprising a number of similar vertical elements at the vertices of a regular polygon, with or without a central radiator. Application of such systems for reduction of fading, optimum design for directional operation, and the multiple-feed system are discussed.

621.396.67 : 621.396.932 **569**

Antenna Systems for Multichannel Mobile Telephony.—W. C. Babcock & H. W. Nylund. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1324–1329.) 1949 I.R.E. National Convention paper noted in 1578 of 1949. Full-scale and model tests were made to determine the best method of mounting several vertical aerials on a single mast so as to minimize mast shielding and mutual coupling at 153 Mc/s. A staggered arrangement was found preferable to one in which the aerials were collinear.

621.396.67.018.424† **570**

Wide-Band Folded-Slot Aerials.—G. D. Monteath. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 414–418.) Modified forms of folded-slot aerial are described in which reactance compensation is achieved by the incorporation of open- or short-circuited transmission-line stubs. Calculation of input impedance is facilitated by considering an equivalent circuit which applies to 3-terminal networks of the folded-dipole or folded-slot type. Results obtained with an experimental folded-slot aerial for use in the 90-Mc/s band show a bandwidth of 7·5 Mc/s with a s.w.r. $\leqslant 1{\cdot}1$ over the whole band. A method of feeding this aerial is described.

621.396.67.018.424† **571**

Omnidirectional Wide-Band Aerials for Decametre and Metre Waves.—O. Zinke. (*Fernmeldetech. Z.*, Oct. 1950, Vol. 3, No. 10, pp. 385–390.) German version of 817 of 1950.

621.396.67.018.424† : 621.3.029.62/.63 **572**

Fundamentals of Wide-Band Aerials for Metre and Decimetre Waves.—O. Zinke. (*Funk u. Ton*, Sept. 1950, Vol. 4, No. 9, pp. 437–450.) The effect of wave change on the radiation field of different types of aerial is first summarized. Requirements for matching are discussed and examples are given of the maximum voltage s.w.r. permissible for wide-band working. Matching arrangements are then considered: the application of $\lambda/2$ and $\lambda/4$ stubs for compensation purposes in the case of thick dipoles is analysed; methods of balancing asymmetric feeders are indicated; the compensation of narrow-band $\lambda/4$ transformers to obtain wide-band characteristics is described. See also 817 and 818 of 1950.

621.396.671 **573**

The Effect of a Periodic Variation in the Field Intensity across a Radiating Aperture.—J. Brown. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 419–424.) Such variations may alter the radiation pattern and reduce the power gain of the aperture. The way in which variations arise in the field distribution across the outer surface of a microwave lens is discussed.

621.396.671 **574**

Impedance/Frequency Characteristics of some Slot Aerials.—J. W. Crompton. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, p. 459.) Discussion on 1087 of 1950.

621.396.671 **575**

The Predetermination of Antenna Characteristics by means of Models.—R. D. Boadle. (*A.W.A. tech. Rev.*, Dec. 1949, Vol. 8, No. 3, pp. 185–193.) Reprint. See 558 of 1950.

621.396.671.4 **576**

The Effect of Input Configuration on Antenna Impedance.—J. R. Whinnery. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 945–956.) A region in the vicinity of the input is considered as a transducer between the TEM mode on the feeder transmission line and the spherical nearly-TEM mode on the aerial system; the constants of this transducer are found both by calculation and by measurement for a particular case. The approximate configuration of the field was determined by means of measurements in an electrolyte tank. The analysis for the main portion of the aerial is essentially that of Schelkunoff, the TM modes in space and near the aerial being expressed as a shunt admittance at the end of the aerial in the TEM-mode equivalent circuit. This admittance is transformed to the desired reference on the aerial by a perturbation calculation, and thence to a reference on the feeder line by means of the input-network constants. Values thus calculated are compared with measured values for various monopole aerials at frequencies in the range 200–1 000 Mc/s. Agreement appears considerably better than without consideration of the input configuration.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.015.7 : 621.387.4† **577**

Differential Method of Counting in Pulse-Amplitude Selectors.—G. Valladas & J. Thénard. (*J. Phys. Radium*, Aug./Sept. 1950, Vol. 11, Nos. 8/9, pp. 501–506.) Principles of pulse-counting systems are reviewed and the circuit of a single-channel selector is described, the operation of which is independent of pulse shape and of pulse duration down to 1 μs. Dead time is of the order of 10–20 μs.

621.3.015.7 : 621.387.4† **578**

A Simple Differential Pulse-Height Analyzer.—K. I. Roulston. (*Nucleonics*, Oct. 1950, Vol. 7, No. 4, pp. 27–29.) Description of an analyser circuit suitable for use with scintillation counters. Only three valves are required for each amplitude level. The discriminators use a conventional two-valve trigger circuit and the anti-coincidence circuit for each channel consists of a phase inverter and two resistors. A cathode follower is made available by using one half of the phase-inverter double-triode. Thus, for a 10-channel differential discriminator only 33 valves are necessary, exclusive of power supply unit and scalers. Each trigger circuit responds to pulses of voltage greater than its own bias voltage. A positive pulse from the nth discriminator and a negative pulse from the $(n+1)$th level are fed differentially to the nth level counter.

621.3.016.352 **579**

Contribution to the Study of Stability.—M. Parodi. (*J. Phys. Radium*, Nov. 1949, Vol. 10, No. 11, pp. 348–352.) Equations encountered respectively in problems of mechanics and of passive electrical networks are studied in which the first elements have the form of determinants. A theorem of Ostrowski is used to determine an upper limit to the real parts of the solutions, the conditions for stability being assumed satisfied. A simpler method can be used in certain cases for electrical networks.

621.3.016.352 **580**

Nyquist Diagrams and the Routh-Hurwitz Stability Criterion.—F. E. Bothwell. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1345–1348.) The Nyquist and the Routh-Hurwitz stability criteria as methods of locating regions of stability of dynamical and electrical systems are described and compared. The superiority of the Routh-Hurwitz method in some applications is demonstrated by two examples, the first a Llewellyn 2-loop 3-stage feedback amplifier, and the second a multiloop servo system.

621.314.2 : 629.135 **581**

Small Power Transformers for Aircraft Electrical Equipments.—A. L. Morris. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 458–459.) Discussion on 3349 of 1949.

621.314.3† **582**

A New Theory of the Magnetic Amplifier.—A. G. Milnes. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 462–464.) Summary only. See 48 of January.

621.316.86 **583**

Borocarbon Resistors.—(*Bell Lab. Rec.*, Oct. 1950, Vol. 28, No. 10, p. 447.) The resistive element comprises a film of boron and carbon formed by pyrolytic deposition from suitable gaseous compounds. Stable and inexpensive resistors with temperature coefficients in the range $20–100 \times 10^{-6}$ per °C are thus produced. Resistors of high values can be made by the process; films with a resistance of 0·5 MΩ between opposite edges of a square portion are readily obtained and corresponding resistance values >1 000 MΩ have been investigated.

621.318.4.042.15.029.4/.5 **584**

High-Q Coils with Iron-Dust Cores for the Frequency Range 100 c/s–100 kc/s.—J. Sommer. (*Funk u. Ton*, Sept. 1950, Vol. 4, No. 9, pp. 458–468.) Analysis of the losses as a function of frequency and of winding space in coils with trolitul dust-filled cores. In the a.f. range the highest Q value is obtained when the available winding space is fully used. Ribs in the winding should therefore be excluded. Above 3 kc/s, higher Q values are obtainable. When the ratio $f^2/N \geqslant 0{\cdot}3$, where f is the frequency in kc/s and N is the number of turns, in order to minimize capacitive loss, the winding space should not be fully used and sectional winding on ribbed formers is preferable.

621.392 **585**

The Nonlinear Method of Circuit Analysis.—Rais Ahmed. (*Proc. nat. Inst. Sci. India*, July/Aug. 1950, Vol. 16, No. 4, pp. 255–262.) An appraisal of the usefulness of recently developed methods for solving nonlinear differential equations in their application to the analysis of valve circuits.

621.392.5 : 519.241.1 **586**

Correlation Functions and Power Spectra in Variable Networks.—L. A. Zadeh. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1342–1345.) "The problem considered is that of establishing a relation between the correlation functions and also the power spectra of the input and output of a linear varying-parameter network (variable network) whose transmission characteristics are random-periodic functions of time. The notion of the correlation function of such a network is introduced and the following theorem is established:

The correlation functions of the input and output of a variable network N may formally be regarded as the input and output of a variable network N^* whose system function is the correlation function of the system function of N.

This theorem has many practical applications, particularly in connection with the determination of the correlation functions and power spectra of various random-periodic waveforms."

621.392.5 : 621.385.029.64/.65 **587**

Delay Lines of Comb or Interdigital Type and their Equivalent Circuit.—Warnecke, Doehler & Guénard. (See 772.)

621.392.5.001.11 **588**

On the Approach to Steady State of a Linear Variable Network containing One Reactance.—A. A. Grometstein. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1349–1351.) The network must be linear and must be capable of reduction to one containing a single reactance. The input voltage and variable circuit components are periodic in value but must have the same period; all variables must possess Laplace transforms. The number of input cycles required by such a network to approach steady-state operation can be found by the method described.

621.392.52 : 539.2 **589**

Physical Basis of the Wave Filter.—J. L. Salpeter. (*Commun. News*, July 1950, Vol. 11, No. 2, pp. 48–55.) See 2197 of 1950.

621.392.52 : 621.396.645 **590**

Video-Frequency Amplifier Couplings.—G. G. Gouriet. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, pp. 257–265.) By a suitable choice of the parameters which define the design of unsymmetrical Π-section filters, simple expressions for the performance are obtained from which the steady-state or the transient response may be calculated. Curves of the amplitude characteristic and the group-delay characteristic are given for various values of the variable parameters, and cases of particular interest are discussed. Finally, the requirements of phase-equalizing networks are given.

621.392.52.012.8 **591**

Band-Pass Low-Pass Transformation in Variable Networks.—L. A. Zadeh. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1339–1341.) "An extension of the band-pass low-pass transformation to linear varying-parameter systems is developed. . . This transformation in conjunction with the use of frequency-analysis techniques can be applied with advantage to the analysis of a super-regenerator operating in the linear mode."

621.392.6 **592**

Definition and Characteristics of 'Superposed' Circuits.—L. Collet. (*Ann. Télécommun.*, Feb. 1949, Vol. 4, No. 2, pp. 42–56.) Splitting up a Kirchhoff network into closed meshes affords two systems of analysis, one with reference to currents, the other to potential differences. The matrix of one system may be derived from that of the other. This applies also to open meshes. The algebraic transformations corresponding to these operations must satisfy certain conditions which may themselves be expressed by a correlation of matrices. An analogous method applied to linear networks brings out the most important circuit properties. Comparison of an open network to the equivalent group of 'superposed' meshes leads to generalizations of theorems such as those of Thévenin and Breisig for quadripoles. Examples are given illustrating the application of the method in line and circuit problems, and comparison is made with the method of symmetrical co-ordinates for the study of polyphase systems.

621.392.6 **593**

Solution of the Problem of Synthesis of Kirchhoff Networks by Determination of Purely Reactive Networks.—M. Bayard. (*Câbles & Transmission, Paris*, Oct. 1950, Vol. 4, No. 4, pp. 281–296.) The methods of network synthesis described are based on the determination of the impedance matrix of a purely reactive network which, when completed with certain resistances, gives the required matrix. In the first method, which gives the general solution, the chain matrix of the auxiliary network is found by considering it as a generalized quadripole in the sense of Collet's definition (592 above). A second and easier method, of more restricted application, makes use of a generalization of Leroy's method (64 of January) for completely reduced matrices.

621.396.6 : 681.85 **594**

Pickup Input Circuits.—R. L. West & S. Kelly. (*Wireless World*, Nov. 1950, Vol. 56, No. 11, pp. 386–391.) Discussion of the design and selection of input arrangements suitable for standard-speed (78 r.p.m.) and long-playing ($33\frac{1}{3}$ r.p.m.) records.

621.396.611.1 : 534.014.1 **595**

An Electrical Network with Varying Parameters.—C. P. Gadsden. (*Quart. appl. Math.*, July 1950, Vol. 8, No. 2, pp. 199–205.) Analysis of the time variation of voltage and current (or of charge q and flux Φ) in a series LCR circuit in which the elements are continuous functions of t with continuous derivatives. The vibrations can be oscillatory or non-oscillatory and transient. Theorems are deduced concerning the criteria of oscillation and stability.

621.396.611.21.012.8 **596**

X-Cut Quartz Crystals.—Grayson. (See 561.)

621.396.615 **597**

The Wien Bridge as Phase-Shift Element of the RC Oscillator.—W. Taeger. (*Funk u. Ton*, Nov. 1950, Vol. 4, No. 11, pp. 569–575.) Generators having an even number of stages require in-phase feedback, and this is provided by the Wien bridge, but only at one particular frequency. The effect of detuning on circuit performance is investigated mathematically.

621.396.615 **598**

Phase-Shift Oscillators.—W. G. Raistrick. (*Wireless World*, Nov. 1950, Vol. 56, No. 11, pp. 409–411.) A variable-frequency oscillator giving an output of nearly constant amplitude can be obtained from two phase-shift stages each consisting of a phase-splitting valve circuit and a RC network. Suitable circuit values are given for a complete oscillator with two phase-shift stages and an amplifier stage, and with resistive or capacitive single- or double-element tuning control.

621.396.645 **599**

Amplifier with a Negative-Resistance Load.—R. Adler. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, p. 270.) Comment on 2170 of 1950 (Tombs & McKenna).

621.396.645.37 **600**

A Tunable Audio-Frequency Amplifier of Variable Selectivity.—E. A. G. Shaw. (*J. sci. Instrum.*, Nov. 1950, Vol. 27, No. 11, pp. 295–298.) Design theory and practical details of an amplifier with feedback via a Wien-bridge network. Frequency range is 30 c/s–20 kc/s, and operation with values of $Q > 1\,000$ is possible for short periods.

621.396.662 : 621.396.615.14 **601**

Combined Search and Automatic Frequency Control of Mechanically Tuned Oscillators.—J. G. Stephenson. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1314–1317.) 1949 I.R.E. National Convention paper noted in 1612 of 1949. A receiver-oscillator sweeps continuously over its tuning range until a signal appears. It then locks automatically so as to produce a constant difference frequency. The system was applied to the control of an oscillator covering 100 Mc/s at 1 300 Mc/s, whose frequency was thus held automatically to within 15 parts in 10^6. The i.f. bandwidth was 2·5 Mc/s at 30 Mc/s.

621.3.013.78† **602**

Die Elektromagnetische Schirmung in der Fernmelde- und Hochfrequenztechnik. (Electromagnetic Screening in Telecommunication and H.F. Technology) [Book Review]—H. Kaden. Publishers: Springer Verlag, Vienna, 274 pp. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, pp. 273–274.) "The treatment throughout is very thorough, and necessarily of a mathematical character, as many of the problems involve Bessel and Hankel functions."

621.318.42 **603**

The Theory and Design of Inductance Coils. [Book Review]—V. G. Welsby. Publishers: Macdonald & Co., 43 Ludgate Hill, London, 180 pp., 18s. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, p. 272.) Largely concerned with problems of coil losses and of iron-cored coils at high frequencies. "This is a book that every communication engineer ought to study."

GENERAL PHYSICS

530.145 **604**

Research on the Bases of the Quantum Calculus of Probabilities in Pure Cases (Hilbert Space. Wave Principle).—G. Bodiou. (*Ann. Phys., Paris*, July/Aug. 1950, Vol. 5, pp. 451–536.)

534.01 **605**

Magneto-Hydrodynamic Shocks.—F. de Hoffmann & E. Teller. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 692–703.) A mathematical treatment of the coupled motion of hydrodynamic flow and e.m. fields is given, assuming that the motion can be described by a plane shock wave and that the medium is a perfect conductor. Special consideration is given to weak shocks, i.e., sound waves. The waves degenerate into common sound waves in the case of very weak magnetic fields and into common e.m. waves for very strong fields.

534.321.9 : 534.11 **606**

Surface Vibration Patterns of Piezoelectric Radiators.—Nixon & Williams. (See 558.)

535.215.2 + 535.215.6 **607**

The Surface Photoelectric Effect.—M. J. Buckingham. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 704–708.) "Theoretical expressions describing the photoelectric emission from a metal surface are derived, taking account of the dependence, established by Bardeen, of the effective surface barrier on the momentum of the impinging electron, due to exchange and correlation forces in the interior. This generalization reduces by a significant factor the magnitude of the theoretical expression for the absolute photoelectric yield."

537.224 **608**

On Certain Matters pertaining to Electrets.—W. F. G. Swann. (*J. Franklin Inst.*, Sept. 1950, Vol. 250, No. 3, pp. 219–248.) Mathematical development based on the assumptions made in an earlier paper (2187 of 1950).

537.226.2 **609**

Dielectric Constants of Non-Polar Fluids: Part 1—Theory.—W. F. Brown, Jr. (*J. chem. Phys.*, Sept. 1950, Vol. 18, No. 9, pp. 1193–1200.) "The dielectric constant of a classical fluid, composed of spherically symmetric molecules with dipole-dipole interactions, is calculated by a method that leads to formulas previously derived by Yvon but is more direct and yields additional results. The relations of the formulas of Lorentz, Yvon, Kirkwood, and Böttcher to one another are clarified." Part 2: 669 below.

537.228.1 : 548.0 **610**

Matrices of Piezoelectric, Elastic, and Dielectric Constants.—K. S. Van Dyke. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 681.) Summary of Acoustical Society of America paper. The systematic arrangement of the complex array of piezoelectric and associated data simplifies computation, particularly when solutions of higher order than the first are required. The Manual of Piezoelectric Data, by K. S. Van Dyke & G. D. Gordon, is a collection of constants arranged in matrix form and includes complete data for twelve piezoelectric crystals of present-day interest, and in addition the computed matrices for several of these crystals referred to axes other than the crystallographic axes. The use of such matrices in combination with the recent I.R.E. Standard on Piezoelectric Crystals (655 of 1950) greatly simplifies instruction in this subject.

537.291 **611**

Note on Stability of Electron Flow in the Presence of Positive Ions.—J. R. Pierce. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, p. 1063.) Amplification and clarification of earlier work (689 of 1949). Experiments seem generally to indicate that electron flow becomes unstable for currents nearer to those calculated assuming no positive ions, than to the larger currents calculated under the assumption that positive ions are present.

537.311.33 : 621.315.592† **612**

Note on the Theory of Resistance of a Cubic Semiconductor in a Magnetic Field.—F. Seitz. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, pp. 372–375.) Theory applicable to a classical electron gas in combined electric and magnetic fields, developed by Gans and extended by Sommerfeld and Davis, is applied to a system possessing cubic symmetry. Simplifying assumptions are made and the treatment is limited to the case in which terms involving powers of the magnetic field higher than the second can be neglected.

537.523/.525 **613**

The Initiation of Breakdown in Gases subject to High-Frequency Electric Fields.—W. A. Prowse. (*J. Brit. Instn Radio Engrs*, Nov. 1950, Vol. 10, No. 11, pp. 333–347.) A discussion of the literature dealing with the experimental aspect. Frequencies up to 9 kMc/s are considered. 46 references are included.

537.525 : 621.396.822 **614**

The Occurrence of Random Electron Oscillations (Noise) in an Electrodeless High-Frequency Discharge subjected to a Steady Magnetic Field.—B. Koch & H. Neuert. (*Ann. Phys., Lpz.*, 10th Feb. 1950, Vol. 7, Nos. 1/2, pp. 97–102.) During experiments on resonance phenomena in a h.f. discharge subjected to a steady magnetic field, intense random oscillations (noise) were observed over a range of pressures (around 10^{-3} Torr) depending on the dimensions of the vessel. This noise was studied as a function of the steady magnetic field and in relation to the power absorbed by the discharge at resonance. A close relation is demonstrated between intensity and frequency range of the noise with unusually high alternating magnetic field strength inside the discharge.

537.525.5 : 538.561.029.6 **615**

Resonance Phenomena in Controlled Low-Pressure Mercury Arcs at Ultra-Short Wavelengths.—A. Haug. (*Z. angew. Phys.*, 15th Aug. 1950, Vol. 2, No. 8, pp. 323–329.) An equivalent circuit is derived for the arc. In this the grid layer is represented as a capacitance and the plasma as a parallel resonant circuit comprising grid/anode capacitance, plasma inductance and plasma resistance, which are involved in the expression for the complex conductivity of the arc. Two resonances occur: (*a*) a parallel resonance in agreement with the Langmuir frequency and due to the plasma properties alone, and (*b*) a series resonance between the plasma and the grid-layer capacitance. Resonance curves obtained experimentally at wavelengths between 70 cm and 270 cm are in qualitative agreement with theory.

537.533 + 535.317] : 535.23 **616**

On the Energy-Flow Distribution in Certain Types of Paraxial Beams.—R. Dorrestein. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 116–127.) "In a paraxial beam proceeding along the axis of a rotationally symmetric (light-optical or electrostatic) refractive medium, special pairs of cross-sections may exist in which the corresponding distributions of energy current density (or intensity) are mutually independent. They are called 'independent' cross-sections. From the intensity distributions in two such independent cross-sections, one can calculate the intensity distributions in any other cross-section by means of a suitable composition-product integral. The 'Gaussian beam' is defined by a Gaussian intensity distribution and a Gaussian angular energy-flow distribution in one cross-section. This class of beams possesses an infinite number of pairs of independent cross-sections. The equation for the effective radius s, as a function of the distance z along the axis, is identical with the paraxial-ray equation for $r(z)$ in cylindrical coordinates z, r, ϕ."

538.114 **617**

Ferromagnetism and Antiferromagnetism.—(*Nature, Lond.*, 4th Nov. 1950, Vol. 166, No. 4227, pp. 777–779.) A report summarizing some of the papers presented at a conference held at Grenoble, July 1950, under the auspices of the Centre National de la Recherche Scientifique, with assistance from the Rockefeller Foundation. The proceedings are to be published in a single volume towards the end of 1950.

538.3 **618**

Tentative Nonlinear Theory of Electrodynamics.—K. Bechert. (*Ann. Phys., Lpz.*, 20th July 1950, Vol. 7, Nos. 7/8, pp. 369–409.)

538.569.4.029.64 : 539.13 **619**

Centimetre Waves and Molecular Structure.—R. Freymann. (*Onde élect.*, Oct. 1950, Vol. 30, No. 283, pp. 416–424.) Measurement techniques used to determine the microwave absorption spectra of solids, liquids and gases are described. Theoretical interpretations of the occurrence of different types of absorption band are reviewed. The structure and properties of various molecules, including simple chlorides, CH_3Cl, H_2O, NH_3 and O_2, and the application of microwave absorption technique in chemical analysis, are discussed.

538.632 : 538.221 **620**

On the Hall Effect in Ferromagnetics.—E. M. Pugh, N. Rostoker & A. Schindler. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 688–692.) Measurements with magnetic fields well above those required for saturation show that the Hall electric field per unit current-density consists of two distinct parts, the 'ordinary' effect caused by a uniform field (the magnetizing force) and the 'extra-ordinary' effect due to magnetization.

539.2 : 621.392.52 **621**

Physical Basis of the Wave Filter.—J. L. Salpeter. (*Commun. News*, July 1950, Vol. 11, No. 2, pp. 48–55.) See 2197 of 1950.

538.1 **622**

Electromagnetic Theory, Vols. 1, 2 & 3. [Book Review] —O. Heaviside. Publishers: Dover, New York, reprint

1950, 386 pp., $7.50. (*Science*, 10th Nov. 1950, Vol. 112, No. 2915, p. 566.) Four pages of the original are reproduced photographically on one page of the new edition, with little reduction, the page size being 12 in. × 9 in. "Dealing with fields in which great changes have taken place in the past 50 years, some major sections of E.M.T. could easily be used as textbooks for graduate courses to-day."

538.3 **623**

The Principles of Electromagnetism. [Book Review]—E. B. Moullin. Publishers: Oxford University Press, London, 2nd edn, 20s. (*Engineer, Lond.*, 15th Sept. 1950, Vol. 190, No. 4938, p. 269.) The first edition of this book was published in 1932. A new appendix to the chapter on skin effect deals also with the effect on self inductance of the internal field, and with dielectric loss. Mainly for advanced students of electrical engineering.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72 : 621.396.822 **624**

On Bailey's Theory of Growing Circularly Polarized Waves in a Sunspot.—R. Q. Twiss. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 767–768.) Bailey's theory (1909 of 1950) is criticized briefly. The author hopes to publish a detailed criticism later, with particular attention to the physical aspects, together with an alternative explanation for the excess noise from sunspots.

523.72 : 621.396.822 **625**

A Radio-Frequency Representation of the Solar Atmosphere.—S. F. Smerd. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 447–452.) A collection of solar data derived from optical observations and originally compiled for use in studies of solar r.f. noise.

523.72 : 621.396.822 **626**

Detection of Solar R.F. Radiation Reflected by the Moon.—J. L. Steinberg & S. Zisler. (*C. R. Acad. Sci., Paris*, 23rd Oct. 1949, Vol. 229, No. 17, pp. 811–812.) From observations made with the radiotelescope at Marcoussis, operating at 158 Mc/s with a modulation (interruption) frequency of 530 c/s, a reflection coefficient of the order of 10% is deduced.

523.72 : 621.396.822 **627**

Comparison of R.F. Radiation received from the Sun on Two Neighbouring Frequencies.—E. J. Blum & J. F. Denisse. (*C. R. Acad. Sci., Paris*, 27th Nov. 1950, Vol. 231, No. 22, pp. 1214–1216.) Simultaneous observations were made on 156 and 164 Mc/s. Carefully stabilized receivers, each having a bandwidth of 2 Mc/s, use a common aerial passing the frequencies 155–175 Mc/s and located at the focus of the C.N.R.S. parabolic mirror at Marcoussis. Observations show that (*a*) calm periods lasting for several days are common to the two frequencies, with mean received intensities of 4 to 5 × 10^{-22} W/m² per cycle and infrequent disturbances generally coinciding; (*b*) low-intensity radio storms, probably confined to a band of a few Mc/s, do not appear simultaneously on the two frequencies; (*c*) during the storms, occasional selective-extinction phenomena last some tens of minutes, corresponding to obscuration of the source of disturbance by an absorber of the lower-frequency radiation.

523.746 "1950.4/.6" **628**

Provisional Sunspot-Numbers for April to June 1950.—M. Waldmeier. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, p. 340.)

523.852.32 : 621.396.822 **629**

Radio-Frequency Radiation from the Great Nebula in Andromeda (M.31).—R. H. Brown & C. Hazard. (*Nature, Lond.*, 25th Nov. 1950, Vol. 166, No. 4230, pp. 901–902.) Experiments at a frequency of 158·5 Mc/s, using a paraboloid aerial (aperture 218 ft and focal length 126 ft) with a beam width of about 2°, indicate that radiation comparable with that from the galaxy is received from the Andromeda nebula, the noise source having apparent dimensions of $\frac{3}{4}$° and $\frac{1}{2}$° along the right-ascension and declination axes respectively.

550.38 "1950.1/.3" **630**

International Data on Magnetic Disturbances, First Quarter 1950.—J. Bartels & J. Veldkamp. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, pp. 337–339.)

550.38 "1950.4/.6" **631**

Cheltenham Three-Hour-Range Indices *K* for April to June 1950.—R. R. Bodle. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, p. 340.)

550.385 "1950.4/.6" **632**

Principal Magnetic Storms [Jan.–June 1950].—(*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, pp. 341–343.)

551.510.535 : 538.566 **633**

Computation of Propagation in the Ionosphere.—Scott. (See 720.)

551.510.535 : 550.38 **634**

World-Wide F_2 Ionization.—R. Eyfrig, E. Harnischmacher & K. Rawer. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, pp. 261–266.) The distributions of f_0F_2 and (M3000) F_2 with latitude are examined month by month for Far Eastern stations. In all months the trough at the magnetic equator is evident, but no marked seasonal change can be seen in the daily maximum values of f_0F_2 considered; the daily minimum values show a strong seasonal influence but no trough. Contrary to the observations of Lung (3427 of 1949), the midnight values show a trough in most months, but there is also a seasonal effect.

551.510.535 : 621.396.11 **635**

Note on the D-Layer at Very Low Frequencies.—R. E. Burgess. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, p. 350.) Discussion on 723 of 1950 (Pfister).

551.594.5 **636**

Evidence for the Entry into the Upper Atmosphere of High-Speed Protons during Auroral Activity.—A. B. Meinel. (*Science*, 17th Nov. 1950, Vol. 112, No. 2916, p. 590.) Spectrograph observations made on the night of August 19–20, 1950, establish for the first time that protons of probably solar origin are streaming into the upper atmosphere at velocities of the order of 2 500–3 000 km/s.

551.594.6 **637**

Radiogoniometer Measurements of Atmospherics on board the *Commandant Charcot*. Identification of a Centre in West Africa.—R. Bureau & M. Barré. (*C. R. Acad. Sci., Paris*, 6th Nov. 1950, Vol. 231, No. 19, pp. 975–977.) During the second voyage of the *Commandant Charcot* to Adélie Land, the study of atmospherics undertaken the previous year (97 of 1950) was continued. A new direction finder was used, operating on 27·5 kc/s and making a photographic record every two hours or oftener, with 2-min exposures, using the method of Rivault & Haubert. Observations confirm the existence, at least in autumn, of centre A3 detected in 1934. Goniograms for 29th Sept. and 8th Oct. 1949 are reproduced; these indicate location of the centre in a region around Bamako and covering Guinea and part of Liberia and the Ivory Coast; the period of activity is about 1400 to 1800 local time.

621.396.821+551.594.221 **638**

'Sferics' and the Lightning Discharge.—R. H. Golde. (*Met. Mag.*, Oct. 1950, Vol. 79, No. 940, pp. 277–286.) Discussion of the characteristics of lightning flashes which are directly concerned in the development of atmospherics. The oscillatory wave pattern giving rise to atmospherics is found to be the result of the intense return stroke of a lightning discharge to earth, and all thunderstorms within about 4 000 miles of an observation station are potential sources of the atmospherics recorded there.

LOCATION AND AIDS TO NAVIGATION

621.396.9 **639**

The Radio Background of Radar.—H. Guerlac. (*J. Franklin Inst.*, Oct. 1950, Vol. 250, No. 4, pp. 285–308.) Historical account of the scientific developments and military requirements that led to the birth of radar.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.787.9 **640**

The Pirani Effect in a Thermionic Filament as a means of Measuring Low Pressures.—J. Blears: W. P. Jolly. (*Brit. J. appl. Phys.*, Nov. 1950, Vol. 1, No. 11, pp. 301–302.) Comment on 1922 of 1950 and author's reply.

533.5 : 061.3 **641**

Conference on Vacuum Physics — Birmingham, 1950.—L. Riddiford. (*Brit. J. appl. Phys.*, Nov. 1950, Vol. 1, No. 11, pp. 273–274.) Brief account of papers given and apparatus exhibited at the conference arranged by the Midland Branch of the Institute of Physics. It is intended to publish the papers and the discussion on them in a special issue of the *Journal of Scientific Instruments* during 1951.

534.321.9 : 534.22 : 546.74 : 538.69 **642**

Some Magneto-Acoustic Effects in Nickel.—T. F. Rogers & S. J. Johnson. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 1067–1068.) Initial results of an investigation of the effects produced by a magnetic field on the ultrasonic propagation properties of ferromagnetic substances. A large decrease of attenuation was observed on applying a longitudinal field to a rod of commercially pure Ni, the amplitude of the pulses received after transmission through the rod increasing to about 100 times the normal value. The velocity of propagation in the rod increased very considerably on applying a field of about 500 oersted.

535.215.1 : 539.234 **643**

Photoelectric Properties and Emission Mechanism of Caesium/Antimony Films.—W. Veith. (*J. Phys. Radium*, Aug./Sept. 1950, Vol. 11, Nos. 8/9, pp. 507–513.) Photoelectric Cs/Sb layers are produced by an evaporation process. Sensitivity and conductivity are measured at each stage of the production. At maximum sensitivity the layers may be considered as semiconductors. The effect of added oxygen is discussed.

535.37 **644**

Effect of Temperature Rise on Electrophotoluminescence Phenomena.—G. Destriau & J. Mattler. (*J. Phys. Radium*, Oct. 1950, Vol. 11, No. 10, pp. 529–541.) In general, the degree of permanent quenching of sulphides increases with temperature; for certain mixed sulphides of Zn and Cd the quenching is almost complete at a temperature of the order of 70°C and an electric field of the order of 20–40 kV/cm r.m.s. As the temperature rises, the phenomenon of momentary illumination is at first intensified, then passes through a maximum and becomes weaker. The dose of exciting radiation corresponding to the maximum of momentary illumination decreases steadily as the temperature rises. See also 110 of 1949 (Destriau).

535.37 **645**

Influence of the State of Oxidation of Luminescence Centres on the Luminescence Colour of Copper-Activated Zinc Sulphide.—E. Grillot & M. Bancie-Grillot. (*C. R. Acad. Sci., Paris*, 6th Nov. 1950, Vol. 231, No. 19, pp. 966–968.)

535.37 : 546.221 **646**

Theory of the Luminescence of Sulfide Phosphors.—S. Roberts & F. E. Williams. (*J. opt. Soc. Amer.*, Aug. 1950, Vol. 40, No. 8, pp. 516–520.)

535.37 : 546.47.284 **647**

On the Existence of 'Sub-Bands' in the Luminescence Emission Spectrum of Manganese-Activated Zinc Silicate.—C. C. Klick & J. H. Schulman. (*J. opt. Soc. Amer.*, Aug. 1950, Vol. 40, No. 8, pp. 509–516.)

535.37 : 546.472.21 **648**

Effect of Infra-Red on Emission and Trapping in ZnS:Cu Phosphors.—R. H. Bube. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 764–765.)

535.37 : 546.472.21 **649**

Luminescence and Trapping in Zinc Sulfide Phosphors with and without Copper Activator.—R. H. Bube. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 655–666.)

537.228.1 : 549.514.51 **650**

Piezoelectric Constants of Alpha- and Beta-Quartz at Various Temperatures.—R. K. Cook & P. G. Weissler. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 712–716.) The adiabatic piezoelectric constants d_{11} and d_{14} of α-quartz were measured at temperatures from room temperature up to 571·5°C, where d_{11} has a value about half that at room temperature, while d_{14} is nearly three times greater. At 573°C, where the transition to β-quartz occurs, d_{11} vanishes. The value of d_{14} for β-quartz is practically constant in the temperature range 584–626°C and differs by only a few per cent from the value at 570°C. The values of the constants were deduced from measurements by a *Q*-meter technique of the equivalent circuits of long thin bars driven at frequencies near resonance.

537.311.31 : 539.23 **651**

Experiments on the Electrical Conductivity at Ordinary Temperature of Very Thin Films of Silver subjected to Strong Electric Fields.—A. Blanc-Lapierre & M. Perrot. (*J. Phys. Radium*, Oct. 1950, Vol. 11, No. 10, pp. 563–569.) The equivalent thickness of the films investigated was < 10 mμ; the method of preparation is described. Field strengths ranged up to nearly 20 kV/cm; a decrease of resistance was observed with increase of applied field strength. The detector properties corresponding to the curved current/voltage characteristic are nearly independent of frequency between 50 c/s and 10 kc/s. See also 2242 of 1950.

538.221 **652**

Gyromagnetic Phenomena Occurring with Ferrites.—H. G. Beljers & J. L. Snoek. (*Philips tech. Rev.*, May 1950, Vol. 11, No. 11, pp. 313–322.) The material ferroxcube is characterized by very low eddy-current and hysteresis losses. In the range 0–10^5 c/s some after-effect is observed. Above a certain critical frequency, differing from one material to another, additional losses occur due to gyromagnetic resonances, the theory of which is explained by means of a mechanical model. Measurements are described which have been carried out with a material placed in a constant strong magnetic field polarizing the material in a direction perpendicular to the direction of observation. The gyromagnetic effect can be used to realize a 4-terminal network with new properties, a gyrator. See also 980 and 2745 of 1949 (Tellegen).

538.221 **653**

Thermomagnetic Investigation of Boroferrites.—R. Benoit. (*C. R. Acad. Sci., Paris*, 27th Nov. 1950, Vol. 231, No. 22, pp. 1216–1218.)

538.221 **654**

Coercive Field of Granular and Aggregated Ferromagnetic Materials.—L. Weil. (*C. R. Acad. Sci., Paris*, 23rd Oct. 1950, Vol. 231, No. 17, pp. 829–831.)

538.221 **655**

Magnetic Properties of Copper in Solid Solution in Cobalt and in Fe/Ni Alloy.—A. J. P. Meyer & P. Taglang. (*C. R. Acad. Sci., Paris*, 6th Nov. 1950, Vol. 231, No. 19, pp. 956–958.)

538.221 : 537.311.33 **656**

Electrical Conductivity of Ferromagnetic Compounds of Manganese with Perovskite Structure.—J. H. van Santen & G. H. Jonker. (*Physica, 's Grav.*, July/Aug. 1950, Vol. 16, Nos. 7/8, pp. 599–600. In English.) A preliminary account of conductivity measurements at 3 kc/s on polycrystalline ceramics prepared from mixed crystals of lanthanum hypomanganite and various manganites. Results for different compositions are shown as functions of temperature and are discussed briefly.

538.221.001.11 : 621.318.22 **657**

Theory of Magnetic Properties and Nucleation in Alnico V.—C. Kittel, E. A. Nesbitt & W. Shockley. (*Phys. Rev.*, 15th March 1950, Vol. 77, No. 6, pp. 839–840.) A possible explanation of the mechanism of nucleation in alnico V is suggested which could account for the observed magnetic properties of the material.

538.221.001.11 : 621.318.22 **658**

Theory of Magnetic Properties of Anisotropic Permanent-Magnet Alloys.—K. Hoselitz & M. McCaig. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 757–758.) Criticism of an explanation of the magnetic properties of alnico V proposed by Kittel, Nesbitt & Shockley (657 above). See also 2241 of 1950 (McCaig).

539.23 **659**

Continuous Observations with the Electron Microscope on the Formation of Evaporated Films of Silver, Gold, and Tin.—T. A. McLauchlan, R. S. Sennett & G. D. Scott. (*Canad. J. Res.*, Sept. 1950, Vol. 28, Sec. A, No. 5, pp. 530–534.) Micrographs are reproduced which illustrate the formation of the films. The results confirm the usually accepted assumptions regarding the formation of nuclei and the growth of aggregates.

546.289 **660**

Some Properties of High-Resistivity P-Type Germanium.—W. C. Dunlap. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, pp. 286–292.) Hall coefficient R, resistivity ρ, mobility figure μ ($10^8 R/\rho$) and rectification characteristics were measured as functions of temperature T and magnetic field H for homogeneous single crystals of high purity. Average values at H = 3 600 gauss and T = 298°K were:—ρ = 18·8 Ωcm; R = 5·14 × 10^{-4} V.cm/A.gauss; μ = 2 730 cm²/V.s. Resistance change was about 22% between H 3 600 and 13 750 gauss. Band separation was 0·82 eV from Hall-effect measurements and 0·75 eV from resistivity measurements. Mobility obeyed a $T^{-2.0}$ law in the temperature range 78°–400°K. The best rectification ratio obtained was about 6 at 5 V, using an Al whisker.

546.289 **661**

Magnetoresistance of Germanium Samples between 20° and 300° K.—I. Estermann & A. Foner. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, pp. 365–372.) The resistivity of pure samples and of samples with added impurities was measured at various temperatures with various magnetic field strengths H and orientations. The results were compared with those following from the theoretical investigation of a classical electron gas in combined electric and magnetic fields in an isotropic medium and in an anisotropic medium possessing cubic symmetry. For transverse orientation, the relative change in electrical conductivity Q was found proportional to H² for small values of H, but nearly proportional to H for larger values of H. Q was found to increase with the purity of the sample. For longitudinal orientation, Q was of the expected order of magnitude for *p*-type samples but much larger than the theoretical prediction for *n*-type samples. The angular dependence of Q was as predicted. Carrier mobilities calculated from magnetoresistance measurements agreed reasonably well with those calculated from Hall-effect and conductivity measurements.

546.289 **662**

Electronic Mobility in Germanium.—V. A. Johnson & K. Lark-Horovitz. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, pp. 409–410.) The resistivity ρ is made up of resistivities ρ_l due to lattice scattering and ρ_i due to impurity scattering. The mobility $|R|/r\rho_l$ (R is the Hall coefficient) is dependent on ρ_i/ρ through r. Using calculated values for r, the mobility is found to be 3 270 ± 700 cm²/V.s and is the same for single-crystal and polycrystalline samples, and also for high- and low-resistivity samples.

549.514.51 : 621.396.611.21.002.2 **663**

The Manufacture of Quartz Oscillator-Plates: Part 1.—W. Parrish. (*Philips tech. Rev.*, May 1950, Vol. 11, No. 11, pp. 323–332.) In cutting an oscillator plate out of a quartz crystal according to a low-temperature-coefficient cut, the angle tolerances for the orientation of the crystal are only about 10 minutes. For a rough adjustment of the angle of cut, double-refraction methods are used. The crystallographic orientation of a test cut is then determined very accurately by an X-ray diffraction measurement and the correction for the position of the saw-table is deduced. Twinning is also briefly discussed and the practical problems arising from its occurrence are considered.

549.514.51 : 621.396.611.21.002.2 **664**

The Manufacture of Quartz Oscillator-Plates: Part 2 — Control of the Cutting Angles by X-Ray Diffraction.—W. Parrish. (*Philips tech. Rev.*, June 1950, Vol. 11, No. 12, pp. 351–360.) An X-ray diffraction apparatus which uses a G-M counter tube for detection of the reflected beam is described. The angle between the reflecting lattice plane and the reference surface of the test crystal may be readily and quickly determined to within a few minutes of arc by relatively unskilled personnel. Examples of the use of the apparatus in checking AT, BT and YZ cuts are given. Part 1: 663 above.

621.315.592† : 546.289 : 621.385.3 **665**

The Transistor — Bibliographical Survey.—Gaulé. (See 778.)

621.315.61 **666**

Dielectric Properties of Liquid Insulating Substances with Polar Components.—P. Henninger. (*Frequenz*, Sept. 1950, Vol. 4, No. 9, pp. 233–245.) Debye's theory gives the frequency variation of permittivity and loss angle for a very dilute solution of a polar substance. Experiments on mixtures of paraffin oil and Clophen A50 (a mixture of various chlorinated diphenylenes) are described, and discrepancies between calculated and measured results are traced to neglect of the dispersion of relaxation times. A characteristic quantity Z is introduced which is a measure of the departure of a medium from nonpolarity; Z can be determined as the integral of the imaginary component of the permittivity over the logarithmic frequency band. To illustrate the theory the permittivity of a class of purely polar liquids is calculated.

621.315.61 **667**

The Dielectric Properties of Polyethylene Terephthalate (Terylene).—W. Reddish. (*Trans. Faraday Soc.*, June 1950, Vol. 46, No. 330, pp. 459-475.)

621.315.61 **668**

The Rheological Properties of Dielectric Polymers.—W. Lethersich. (*Brit. J. appl. Phys.*, Nov. 1950, Vol. 1, No. 11, pp. 294–301.)

621.315.61 : 537.226.2 **669**

Dielectric Constants of Non-Polar Fluids: Part 2—Analysis of Experimental Data.—W. F. Brown, Jr. (*J. chem. Phys.*, Sept. 1950, Vol. 18, No. 9, pp. 1200–1206.) Part 1: 609 above.

621.317.335.3.029.64† **670**

Microwave Techniques for the Measurement of the Dielectric Constant of Fibers and Films of High Polymers.—Shaw & Windle. (See 686.)

621.357.7 : 546.23 **671**

The Electroplating of Metallic Selenium.—A. von Hippel & M. C. Bloom. (*J. chem. Phys.*, Sept. 1950, Vol. 18, No. 9, pp. 1243–1251.) The fact that selenium is a nonmetal of peculiar properties has delayed accomplishment of a satisfactory method of electroplating it; such a method is described.

621.357.7 : 621.385.032.21 **672**

Making Small Metal Tubes by Electrodeposition on Nylon Fibers.—R. J. E. Gezelius. (*Rev. sci. Instrum.*, Oct. 1950, Vol. 21, No. 10, p. 886.) A brief account of a method for producing metal tubes with diameters from 1 mm down to 0·1 mm or less, as required, e.g., for indirectly heated cathodes.

621.396.622.6.029.64 : 621.385.2/.3 **673**

Crystal Detectors and their Use at Ultra-High Frequencies.—Engel; Welker; Mataré. (See 775.)

666.1.037.5 **674**

A Nickel-Chromium-Iron Alloy for Sealing to Glass.—J. E. Stanworth. (*J. sci. Instrum.*, Oct. 1950, Vol. 27, No. 10, pp. 282–284.) The development is described of an alloy containing 47% Ni and 5% Cr, and matching ordinary lead glass as used for lamps and valves. Stresses in seals made with these materials are low at all temperatures, even though there is a 60° difference between the alloy Curie temperature (about 340°C) and the glass transformation temperature (about 400°C).

778.3 : 621.317.755.087.5 **675**

Techniques of Photo-Recording.—H. P. Mansberg. (*Oscillographer*, April/June 1950, Vol. 12, No. 2, pp. 3–16.) Suitable methods for recording a wide range of stationary patterns and transients are outlined. The determination of the optimum exposure, and the selection of filters, type of c.r. tube screen and film are considered. Processing techniques, the avoidance of various forms of fog, and methods of trace calibration are also described.

MATHEMATICS

517.5 : 517.942.4 **676**

Eigenfunction Problems with Periodic Potentials.—E. C. Titchmarsh. (*Proc. roy. Soc. A*, 24th Oct. 1950, Vol. 203, No. 1075, pp. 501–514.) The expansion of an arbitrary function in terms of the solutions of the differential equation $\frac{d^2\phi}{dx^2} + \{\lambda - q(x)\}\ \phi = 0$ is obtained in the case where $q(x)$ is a periodic function of x.

517.941.4 : 517.522.5 **677**

The Remainder Theorem and its Application to Operational-Calculus Techniques.—A. S. Richardson, Jr. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1336–1339.) "The necessary procedure involved in the transition from the Laplace transformation to the solution of linear differential equations is summarized, and a particular form of partial-fraction expansion which may be advantageous in special cases is noted. The remainder theorem with regard to algebraic polynomials is restated, and it is shown how this theorem may be applied to the evaluation of high-degree polynomials for real and complex numbers. A numerical example is treated to illustrate application to a typical transfer function. Finally, the method is shown to be useful in the evaluation of the frequency response of such a transfer function."

519.21 : 621.396.812 **678**

Probability Distributions of the Resultants of Two or More Vibrations.—C. F. Kent & J. E. Boyd. (*Phys. Rev.*, 15th July 1950, Vol. 79, No. 2, p. 417.) Summary of American Physical Society paper. The method of 'random flights' outlined by Chandrasekhar (2866 of 1943) is used to derive probability distributions for the resultants of 2, 3, 4 or more vibrations of equal amplitude and random phases. When normalized relative to their mean intensities, the probability distribution curves for the resultants of relatively small numbers of vibrations (10 or more) of equal amplitude are closely similar to the Rayleigh distribution for an immense number of vibrations. Two random-phased components with a Gaussian distribution of amplitude give a probability curve which is almost identical with the Rayleigh curve. Experimental frequency distributions of microwave radio signal strength, obtained from measurements of propagation over land under changing atmospheric conditions, are found to be similar to the theoretical probability distributions for many vibrations.

519.283 : 621.39.001.11 **679**

Correlation Functions and their Application to Communication Problems.—Y. W. Lee & J. B. Wiesner. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Title only of Acoustical Society of America paper. See also 2262 of 1950.

681.142 : 621.385.832 **680**

A Storage System for Use with Binary-Digital Computing Machines.—F. C. Williams & T. Kilburn. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 453–454.) Discussion on 2258 of 1949.

MEASUREMENTS AND TEST GEAR

621.317 : 538.56.029.6 : 538.65 **681**

Ponderomotive Effects of Centimetre Waves and the

Possibility of their Application for Measurement Purposes.—H. A. Bomke & T. Schmidt. (*Arch. elekt. Übertragung*, Jan., March, June & Sept. 1950, Vol. 4, Nos. 1, 3, 6 & 9, pp. 33–35, 105–111, 219–222 & 377–381.)

621.317.088.4 : 621.314.12 **682**

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 III, Nov. 1950, Vol. 97, No. 50, pp. 461–462.) Summary only. See 152 of January.

621.317.3.001.4 : 621.396.615.142.2 **683**

Test Methods and Apparatus for the Development of 3-cm Low-Voltage Klystrons.—R. Musson-Genon, J. Chantereau & R. Métivier. (*Onde élect.*, Oct. 1950, Vol. 30, No. 283, pp. 425–432.) Illustrated description of manufacturers' tests on reflex klystrons for the frequency range 8·5–9·6 kMc/s. Measurement of the Q factor of the cavity alone is based on Slater's method: to facilitate measurement of the voltage s.w.r. a waveguide transmission line is used to lengthen the coaxial output line from the valve; two series of measurements are made at frequencies close to the resonance frequency of the cavity; Q at resonance may be calculated without a knowledge of the impedance characteristics of the coupling line. The Q value on load is measured similarly. A study is made of the output line regarded as a transformer and the conditions for optimum Q value are discussed. See also 1680 of 1948 (Musson-Genon) and 1720 of 1950 (Musson-Genon & Brissonneau).

621.317.333.029.6 **684**

A Resonance Method of Impedance Measurement at Ultra-Short Wavelengths.—A Haug. (*Z. angew. Phys.*, 15th Aug. 1950, Vol. 2, No. 8, pp. 330–331.) The impedance to be measured is connected across one end of a Lecher-wire system, which is loosely coupled to a constant-voltage source and is short-circuited at the other end. A capacitively coupled instrument at a constant distance from the short-circuiting link measures the voltage V. The position of the link is adjusted first to obtain resonance at a voltage V_0 and then to obtain a voltage of $V_0/\sqrt{2}$. The real and imaginary components of the unknown impedance are derived from the lengths of the line in the two cases.

621.317.335 : 534.442.2 **685**

The Analysis of Oscillations by the Search-Tone Method.—Meyer-Eppler. (See 532.)

621.317.335.3.029.64† **686**

Microwave Techniques for the Measurement of the Dielectric Constant of Fibers and Films of High Polymers.—T. M. Shaw & J. J. Windle. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 956–961.) A resonant-cavity method is described and results obtained for wool, nylon and cellophane at 3 kMc/s are given.

621.317.7 **687**

A Novel R.M.S.-Value Rectifier [meter] **with Reduced Waveform Error.**—H. Boucke. (*Arch. elekt. Übertragung*, July 1950, Vol. 4, No. 7, pp. 267–270.) Description of circuit and operation of an a.c. moving-coil rectifier-type meter in which the time constants for the charge and discharge of a capacitor in the rectifier circuit are so related that the r.m.s. indication is largely free from waveform error. A square wave is investigated as a particular example. Results indicating the accuracy in practice are given.

621.317.725 : 621.3.018.78† **688**

A New Distortion Meter.—H. Boucke. (*Funk u. Ton*, Sept. 1950, Vol. 4, No. 9, pp. 451–457.) Circuit and description of an instrument based on the Küpfmüller bridge. Range is 0·5 to 4·5 V for frequencies from 30 c/s to 10 kc/s.

621.317.725.083.6 **689**

An Electronic A.C. Differential Voltmeter.—L. A. Rosenthal & H. S. Zablocki. (*Rev. sci. Instrum.*, Sept. 1950, Vol. 21, No. 9, pp. 799–801.) An instrument giving a direct reading of percentage changes of voltage in the range ±10%, for voltages from 1·5 to 150 V and frequencies from 20 c/s to 200 kc/s.

621.317.73 : 621.385 **690**

Impedance-Testing Set for Valves at High Frequencies.—(*Engineering, Lond.*, 21st July 1950, Vol. 170, No. 4408, p. 56.) A short description of equipment intended primarily for research or development purposes in connection with valves operating in the range 10–150 Mc/s. The basic principles are similar to those of Q meters. Measurements of input impedance are made by connecting the valve cathode and control grid to the terminals of a parallel resonant circuit and noting the change in tuning capacitance and dynamic resistance of the circuit. A calibrated piston attenuator, together with tuning capacitors with micrometer adjustment, enable high accuracy of measurement to be obtained.

621.317.733.089.6+621.3.011.2 (083.74) **691**

H.F. Resistance Standards and their Use in the Calibration of an Admittance Bridge up to 60 Mc/s.—W. H. Ward, M. H. Oliver & S. J. Fray. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 438–446.) Transfer standards are described for the calibration of an admittance bridge covering the ranges 0–100 millimhos and −150 pF to +150 pF.

621.385.012 : 621.317.79 **692**

Apparatus for the Determination of [valve] **Characteristics.**—W. Graffunder & H. Schultes. (*Frequenz*, Sept. 1950, Vol. 4, No. 9, pp. 229–233.) An arrangement is described which enables an accurate quantitative assessment to be made by simultaneously displaying the characteristic and a pair of co-ordinate axes on the screen of a c.r.o. The method is applicable when the valve is to be tested under positive-grid or overload conditions, when pulse methods have to be used.

621.396.615 : 534.321.7 **693**

A Bridge-Stabilized Generator for Tuning Musical Instruments.—R. Gauger & J. Sommer. (*Funk u. Ton*, Nov. 1950, Vol. 4, No. 11, pp. 554–558.)

621.396.615.015.7† **694**

Narrow-Pulse Generator.—C. S. Fowler. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, pp. 265–269.) The generator produces pulses of known amplitude either singly or at repetition rates between 5 and 5 000 per sec. The shape of the pulses is such as to give an energy spectrum which is substantially flat up to 40 Mc/s. The pulse amplitude is expressed in terms of the equivalent sine-wave voltage per unit bandwidth of the circuit in which the voltage is developed.

621.397.335.001.4 (083.74) **695**

Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950.—(See 750.)

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.717.1 **696**

A Thickness Gauge for Ceramic Coatings.—C. C. Gordon & J. C. Richmond. (*J. Amer. ceram. Soc.*, 1st

Oct, 1950, Vol. 33, No. 10, pp. 295–300.) The gauge is designed to measure coatings with a maximum thickness of about 0·09 in., and operates by an electromagnetic method based on the dependence of the inductance of a coil on the proximity of the nonmagnetic metal surface carrying the coating.

551.508.11 : 621.396.9 **697**

International Radiosonde Trials.—H. E. Painter. (*Weather, Lond.*, Sept. 1950, Vol. 5, No. 9, pp. 307–310.) Short account of the trials held at Payerne, Switzerland, in May 1950, with descriptions of the different types of equipment used.

621.314.634 : 621.384.6.027.85 **698**

A 500-Kilovolt Linear Accelerator using Selenium Rectifiers.—Arnold. (See 745.)

621.384.611.1/.2† **699**

Field Measurements on Model Betatron and Synchrotron Magnets.—E. A. Finlay, J. F. Fowler & J. F. Smee. (*J. sci. Instrum.*, Oct. 1950, Vol. 27, No. 10, pp. 264–270.)

621.384.611.2† **700**

The Birmingham Proton Synchrotron.—L. U. Hibbard. (*Nucleonics*, Oct. 1950, Vol. 7, No. 4, pp. 30–43.) Details of design and construction. Maximum proton energy is 1 300 MeV.

621.385.833 **701**

A Method for the Detection and Measurement of Elliptical Astigmatism.—R. Castaing. (*C. R. Acad. Sci., Paris*, 23rd Oct. 1950, Vol. 231, No. 17, pp. 835–837.) A study is made of a particular form of image distortion which constitutes a sensitive test for astigmatism in electron lenses. See also 702 below.

621.385.833 **702**

Detection and Direct Measurement of the Elliptical Astigmatism of an Electron Lens.—R. Castaing. (*C. R. Acad. Sci., Paris*, 30th Oct. 1950, Vol. 231, No. 18, pp. 894–896.) Description of a method based on observation of the distortion suffered by the image of a wire in the shadow microscope. See also 701 above.

621.385.833 **703**

Calculation of the Optical Constants of Powerful Magnetic Electron Lenses.—W. Glaser. (*Ann. Phys., Lpz.*, 20th May 1950, Vol. 7, No. 5, pp. 213–227.) Formulae are derived for the focal length, the positions of foci, the projection magnification, the chromatic aberration and the aperture error of the powerful magnetic lenses of the ultramicroscope, as functions of lens strength (coil excitation), accelerating voltage and pole-shoe parameter.

621.385.833 **704**

Velocity and Two-Directional Focusing of Charged Particles in Crossed Electric and Magnetic Fields: Part 1.—N. Svartholm. (*Ark. Fys.*, 11th Oct. 1950, Vol. 2, No. 3, pp. 195–207. In English.) A mathematical analysis of the aberrations of cylindrically symmetrical magnetic and electric fields with particular application to mass-spectrometer problems. The radial, axial, astigmatic, double-directional and velocity-focusing field functions are given and a system of fields is found which possesses both first-order velocity focusing and second-order two-directional focusing.

621.385.833 **705**

Calculation of Optical Parameters of Magnetic Electron Lenses with Extended Bell-Shaped Field.—F. Lenz. (*Z. angew. Phys.*, 15th Aug. 1950, Vol. 2, No. 8, pp. 337–340.)

621.385.833 **706**

Determination of the Resolving Power of the Electron Microscope by means of Fresnel Diffraction.—L. Wegmann. (*Helv. phys. Acta*, 20th June 1950, Vol. 23, No. 4, pp. 437–452. In German.)

621.385.833 : 621.316.721 **707**

A Mains Unit for Generating Highly Constant Magnetization Currents for Electron Lenses.—Kinder & Schleich. (See 746.)

621.386.1.027.89 : 621.396.611.4 **708**

A Million-Volt Resonant-Cavity X-Ray Tube.—B. Y. Mills. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 425–434. Discussion, pp. 434–437.) Description of a very compact X-ray tube in which the accelerating voltage is developed in a resonant cavity excited by a high-power magnetron operating on a wavelength of 25 cm. A mean beam current of 70 μA has been obtained at a peak voltage of 1·1 MV.

621.387† **709**

The Properties of Proportional Tubes and Ion Chambers with Glass Envelopes and External Graphite Electrodes.—A. L. Cockroft & J. M. Valentine. (*J. sci. Instrum.*, Oct. 1950, Vol. 27, No. 10, pp. 262–263.)

621.387.4† **710**

The Propagation of the Discharge in Geiger-Müller Counters with External Cathode.—M. Schérer & E. Vieille. (*C. R. Acad. Sci., Paris*, 6th Nov. 1950, Vol. 231, No. 19, pp. 964–966.)

621.387.4† : 621.3.015.7 **711**

Differential Method of Counting in Pulse-Amplitude Selectors.—Valladas & Thénard. (See 577.)

621.387.4† : 621.3.015.7 **712**

A Simple Differential Pulse-Height Analyzer.—Roulston. (See 578.)

621.387.422† **713**

Calibration of Proportional Counters by the Excitation of Fluorescence Radiation with Radioactive Sources.—G. M. Insch. (*Phil. Mag.*, Sept. 1950, Vol. 41, No. 320, pp. 857–862.)

621.387.424† **714**

Temperature Effect in Geiger-Müller Counters.—M. Kimura. (*Phys. Rev.*, 15th Nov. 1950, Vol. 80, No. 4, pp. 761–762.) Measurements of the variation of the rate of spurious discharges in G-M counters when heated and cooled at constant rates are described and discussed.

621.387.424† **715**

An Improved Resolving-Time Measuring Device.—B. W. Roberts, Jr, K. E. Perry & R. G. Fluharty. (*Rev. sci. Instrum.*, Sept. 1950, Vol. 21, No. 9, pp. 790–796.) A circuit for measuring the resolving time of counters is described; this is based on Curran & Rae's scheme (1708 of 1948) but uses a delayed pulse of variable width. Any random event initiates a delayed pulse which is fed in coincidence with subsequent pulses, causing a sharp increase in the coincidence rate at a delay time close to the resolving time. Theory is given which accounts for observed curve shapes, and data for several counters illustrate the operation for different counting rates and overvoltages.

621.365.54/.55† **716**

Industrial High-Frequency Electric Power. [Book Review]—E. May. Publishers: J. Wiley & Sons, New York, 355 pp., $5.00. (*Elect. World, N.Y.*, 9th Oct. 1950, Vol. 134, No. 15, p. 196.) Deals with circuits and design details for induction furnaces and dielectric-heating apparatus.

PROPAGATION OF WAVES

538.56 : 537.525.6 **717**

Electrical Waves in Moving Plasma.—W. O. Schumann. (*Z. angew. Phys.*, Oct. 1950, Vol. 2, No. 10, pp. 393–399.) Previous work by Hahn, Bailey, the author and others is reviewed; e.m. waves can be built up in plasma if an electron stream is present together with either (*a*) another stream of moving particles, or (*b*) a static magnetic field, or (*c*) a sufficiently large thermal motion of the electrons. Propagation along moving plasma ayers is investigated, making use of relativistic trans-ormations and neglecting oscillations of the positive ions; the plasma boundaries may be conducting or insulating (e.g. atmosphere), and the theory is worked out for both absence and presence of magnetic field. The frequency ranges and phase velocities of the wave modes possible in the various sets of conditions are determined.

538.566 **718**

'Internal' Reflection in a Stratified Medium: Particular Application to the Troposphere.—G. Eckart & T. Kahan. (*J. Phys. Radium*, Oct. 1950, Vol. 11, No. 10, pp. 569–576.) 'External' reflection in a stratified medium is caused by discontinuity in the values of dielectric constant ϵ or permeability μ or their differentials, while 'internal' reflection is caused by continuous gradation of ϵ and μ. The problem is analogous to that of a line with graded inductance and capacitance per unit length. To eliminate the internal reflection it is necessary and sufficient that the ratio of ϵ and μ shall be constant. Two methods are presented for calculating the internal reflection, one based on classical cable theory and the other more general. Vertical propagation in the troposphere is considered and the practical impossibility of observing internal reflection is demonstrated. See also 977 of 1950.

538.566 : 517.544.2 **719**

Green's Function for Electromagnetic Waves in a Half-Space with a Plane Discontinuity.—T. Kahan & G. Eckart. (*J. Phys. Radium*, Nov. 1949, Vol. 10, No. 11, pp. 333–341.) Mathematical treatment of the problem of propagation in an atmospheric duct bounded below by a plane perfectly conducting earth and above by the plane of a discontinuity in the dielectric constant. See also 1446 and 1467 of 1949 and 1480 of 1950.

538.566 : 551.510.535 **720**

Computation of Propagation in the Ionosphere.—J. C. W. Scott. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, pp. 267–269.) By using hyperbolic functions of a complex variable, the Appleton-Hartree equations of radio-wave propagation in the ionosphere are given a simple form suitable for computation. The indices of refraction and absorption and the polarization may be easily computed without using approximations.

538.566 : 551.510.535 **721**

The Origin of Harmonics in the Ionosphere at Points of Zero Dielectric Constant.—K. Försterling & H. O. Wuster. (*C. R. Acad. Sci., Paris*, 23rd Oct. 1950, Vol. 231, No. 17, pp. 831–832.) Further consideration of the propagation of a plane wave in a stratified ionosphere [see 3518 of 1949 (Försterling)]. Where the dielectric constant ϵ is zero, there is a strong local variation of the field. Hence when ϵ is calculated from the fundamental equation of motion of the electrons the value of the field obtained from Maxwell's equations is inapplicable, and the actual value as a function of the instantaneous position of the electron must be substituted; harmonics of the radiated wave are thus introduced. The energy in the harmonics is drawn from the fundamental, which thus undergoes absorption.

621.396.11+621.397.8 **722**

Long-Range Television.—T. W. Bennington & R. Morris. (*Wireless World*, Nov. 1950, Vol. 56, No. 11, pp. 407–408.) Analysis of results obtained between 13th March 1949 and 31st July 1950. The 41·5-Mc/s sound-channel signals from the Alexandra Palace transmitter were received frequently at the S.A.B.C. station, Johannesburg, during the late-winter/early-spring and late-autumn/early-winter periods, occasionally during mid-winter, and not at all in the summer. Peak reception during the late-winter/early-spring period of 1950 was less frequent than during both peak-reception periods of 1949. These seasonal and annual variations of signal strength agree with those of predicted m.u.f. values, although the actual frequencies for the path tend to be higher than predicted.

621.396.11 **723**

Circle Diagrams for the Reflection Coefficient of Electromagnetic Waves Reflected at a Zero- or First-Order Discontinuity of the Dielectric Constant.—G. Eckart. (*Z. angew. Phys.*, 15th Aug. 1950, Vol. 2, No. 8, pp. 334–337.) The dependence of reflection coefficient (r) on frequency, angle of incidence and polarization is studied in the two cases of discontinuity of (*a*) the permittivity ϵ, (*b*) the permittivity gradient. In case (*b*) r is frequency-dependent; longer waves are favoured. The Brewster angle is 45°, the limiting value for case (*a*) as the values of ϵ on either side of the discontinuity approach equality. For grazing incidence $r = -1$; the change from this value with increasing angle of incidence is greater the shorter the wavelength. See also 3135 of 1950.

621.396.11 : 551.510.535 **724**

Note on the D-Layer at Very Low Frequencies.—R. E. Burgess. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, p. 350.) Discussion on 723 of 1950 (Pfister).

621.396.11 (083.72) **725**

Standards on Wave Propagation: Definitions of Terms, 1950.—(*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1264–1268.) Copies of this Standard, 50IRE24.S1, may be obtained while available from the Institute of Radio Engineers at $0.60 per copy.

621.396.11.029.55 **726**

Round-the-World Radio Signals.—A. H. de Voogt. (*Onde élect.*, Oct. 1950, Vol. 30, No. 283, pp. 433–437.) Transit time T and details of trajectory are calculated using hypothetical ionization curves and assuming maximum electron density to be between 5×10^5 and 6×10^5 electrons/cm³ and at a height of 200–300 km. Tabulated values of T for frequencies of 10 and 20 Mc/s are between 136 and 145·5 ms, according to the ionization curve and radiation angle considered. Measurements of T made during the winter of 1949/1950 at Kootwijk and Horstermeer, Holland, using frequencies of 10–22 Mc/s and square pulses of duration 100–1 000 μs, gave values between 137 and 139 ms. Reception of the first signal is usually preceded by 'scatter'; sometimes even the third round-the-world signal is received with little distortion. Further experimental results are to be published.

621.396.11.029.64 **727**

Outline of a Theory of Radio Scattering in the Troposphere.—H. G. Booker & W. E. Gordon. (*J. geophys. Res.*, Sept. 1950, Vol. 55, No. 3, pp. 241–246.) See 1757 of 1950.

621.396.812 **728**

Variability of Sky-Wave Radio Signals under Conditions of Ionospheric Absorption.—G. McK. Allcock.

(*Nature, Lond.*, 25th Nov. 1950, Vol. 166, No. 4230, pp. 902–903.) The instantaneous value of signal strength of a 9·15-Mc/s radio wave was recorded once a minute at a distance of 788 km from the transmitter. The Rayleigh distribution of amplitudes was found to give a poor fit to the observed distribution at times around local noon, when ionospheric absorption is considerable. A good fit was, however, obtained with a lognormal curve, an example of which is given covering the period June 14–30, 1949. The lognormal curve also affords a more accurate means of predicting the value of signal strength which is exceeded for 90% and 95% of the time. The 95% value calculated from the Rayleigh distribution would lead to a transmitter power more than twice that actually required to maintain good communication.

621.396.812 : 519.21 **729**

Probability Distributions of the Resultants of Two or More Vibrations.—Kent & Boyd. (See 678.)

RECEPTION

519.272.15 : 621.39.001.11 **730**

Application of Correlation Analysis to the Detection of Periodic Signals in Noise.—Y. W. Lee, T. P. Cheatham, Jr, & J. B. Wiesner. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1165–1171.) The theory of correlation analysis is briefly reviewed and then applied to the detection of periodic signals in random noise. An electronic correlator, capable of performing the mathematical processes necessary to obtain the required correlation functions, is described and experimental results obtained with it are presented in support of the theoretical conclusions.

621.396.621 **731**

A Frequency-Modulation Receiver for Use on the 88–108-Mc/s Band.—P. M. Miller. (*A.W.A. tech. Rev.*, Dec. 1949, Vol. 8, No. 3, pp. 203–215.) The broadcast receiver described is a 13-valve superheterodyne, with controls for tuning and volume only, and visual tuning indication. Critically coupled transformers are used. The discriminator is of Foster-Seeley type, linear over a band of ± 200 kc/s. The push-pull output stage is capable of delivering 3 W with $< 3\%$ distortion over the range 30 c/s–15 kc/s. Test results are reported.

621.396.621 **732**

Signal-to-Noise Improvement through Integration in a Storage Tube.—J. V. Harrington & T. F. Rogers. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1197–1203.) The theory of the ideal (linear) and the nonideal integrator is developed, relating improvement in signal/noise ratio to certain tube parameters and the number of integration cycles. The expected improvements have been verified experimentally, using a storage tube as the integrating device. Where the number of integrations is small and the output signal/noise ratio need not exceed 10 to 15, the Type STE-A barrier-grid storage tube has practical value as an integrator for repetitive signals.

621.396.621 : 621.396.662 **733**

Variable-Filter Tuning.—A. B. Shone. (*Wireless World*, Oct. & Nov. 1950, Vol. 56, Nos. 10 & 11, pp. 355–358 & 393–398.) General design data are given of variable-frequency filters for r.f. and i.f. stages. Details are included of typical filters constructed from commercially available components to give stipulated frequency/response characteristics. Photographs and diagrams show the practical layout of a filter-tuned receiver and its overall a.f. response for different settings of its variable i.f. filter.

621.396.81 : 621.396.932 **734**

A Test of 450-Mc/s Urban Area Transmission to a Mobile Receiver.—A. J. Aikens & L. Y. Lacy. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1317–1319.) 1949 I.R.E. National Convention paper noted in 1757 of 1949. Transmissions at 456 Mc/s and at 152 Mc/s were compared, using identical speech modulation. Average speech/noise ratio is plotted against received-signal amplitude. Ignition noise is the limiting factor for both frequencies. For equal speech/noise ratios, the required r.f. signal voltage input to the receiver was about 10 db lower at 450 Mc/s than at 150 Mc/s.

621.396.621.5 **735**

Super-regenerative Receivers. [Book Review]—J. R. Whitehead. Publishers: Cambridge University Press, London, 169 pp., 21s. (*Wireless World*, Nov. 1950, Vol. 56, No. 11, p. 392.) "The treatment is perfectly general, and the influence of particular conditions and modes of operation are only brought in when the more general results have been fully established . . . the author has arranged his work admirably and has expressed the results clearly in words and in formulae that can be directly applied in design."

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 **736**

The Design of Periodic Radio Systems.—M. Leifer & N. Marchand. (*Sylvania Technologist*, Oct. 1950, Vol. 3, No. 4, pp. 18–21.) "The design of radio systems which utilize a periodic signal for the transmission is examined in the light of the modern theory of communication. Conventional practice requires signal detection and a human observer at the receiver to accomplish recognition of the signal. Such design has persisted despite the decrease in signal-to-noise ratio caused by detection and the fluctuations of signal threshold and inefficiencies of an observer. The statistical approach utilizing the auto- and cross-correlation functions is developed. It is noted that signal recognition may be achieved by the latter without requiring an observer. The method requires a correlation of the received signal with a replica of the transmitted signal, suitably phased and noise-free. Inasmuch as all of the characteristics of the signal are utilized, the efficiency of the recognition process may be considerably increased. The theory provides a basis for the choice of the fundamental parameters of transmitted power, signal bandwidth and receiver bandwidth, and shows the fundamental distinction between the last two."

621.39.001.11 **737**

The Information-Theory Point of View in Speech Communication.—R. M. Fano. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Title only of Acoustical Society of America paper.

621.39.001.11 : 519.283 **738**

Correlation Functions and their Application to Communication Problems.—Y. W. Lee & J. B. Wiesner. (*J. acoust. Soc. Amer.*, Sept. 1950, Vol. 22, No. 5, p. 677.) Title only of Acoustical Society of America paper. See also 2262 of 1950.

621.395.44 **739**

A 48-Channel Carrier Telephone System: Part 1—the Method of Modulation.—G. H. Bast, D. Goedhart & J. F. Schouten. (*Commun. News*, May 1950, Vol. 11, No. 1, pp. 22–32.) Reprint. See 2356 of 1948.

621.396.619.16 **740**

Crosstalk Considerations in Time-Division Multiplex Systems.—S. Moskowitz, L. Diven & L. Feit. (*Proc.*

Inst. Radio Engrs, Nov. 1950, Vol. 38, No. 11, pp. 1330–1336.) 1949 I.R.E. National Convention paper noted in 1785 of 1949. "An experimental study was made of the effects on interchannel crosstalk of the bandwidth characteristics of the transmission medium in pulse-time multiplex systems. Pulse-amplitude modulation and pulse-position modulation systems are considered. The effects of various types of high- and low-frequency response are discussed from both experimental and theoretical points of view."

621.396.932 **741**
A Six-System Urban Mobile Telephone Installation with 60-kc/s Spacing.—R. C. Shaw, P. V. Dimock, W. Strack, Jr, & W. C. Hunter. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1320–1323.) 1949 I.R.E. National Convention paper noted in 1785 of 1949. The commercial operation of six channels in the 160-Mc/s band in Chicago with half the normal channel spacing, and the measures necessary to prevent mutual interference, are described. No major equipment changes are necessary.

621.396.93.029.6 **742**
Radio Communication at Ultra-High Frequency. [Book Review]—J. Thomson. Publishers: Methuen, London, 203 pp., 21s. (*J. sci. Instrum.*, Nov. 1950, Vol. 27, No. 11, p. 318.) Seven chapters cover u.h.f. circuit elements, valves, transmitters, receivers, modulation techniques, methods of frequency control, and the communication system as a whole.

SUBSIDIARY APPARATUS

621-526 **743**
Theory of Relay Servomechanisms.—J. R. Dutilh. (*Onde élect.*, Oct. 1950, Vol. 30, No. 283, pp. 438–445.)

621.314.634 **744**
Capacitance Measurements on Selenium Rectifiers: Evidence of Anomalous Dispersion.—R. Cooper. (*Proc. phys. Soc.*, 1st March 1950, Vol. 63, No. 363B, pp. 176–179.) Contrary to the generally accepted view, the a.f. capacitance of a Se rectifier may vary with frequency. The magnitude of the variation depends on the metal used as counter-electrode; little variation occurs with Sb or Bi, but with Cd there is considerable decrease over the frequency range 300–2 000 c/s. Related work by Breckenridge indicates that the effect may be due to relative motion in the Se lattice of the negatively charged impurity centres and positive ions which diffuse into the Se from the counter-electrode.

621.314.634 : 621.384.6.027.85† **745**
A 500-Kilovolt Linear Accelerator using Selenium Rectifiers.—W. R. Arnold. (*Rev. sci. Instrum.*, Sept. 1950, Vol. 21, No. 9, pp. 796–799.) Description of equipment designed for use in a linear accelerator. A cascade arrangement of Se rectifiers and 1-μF capacitors in 22 voltage-doubler stages is used, fed from a 750-cycle 10-kVA alternator.

621.385.833 : 621.316.721 **746**
A Mains Unit for Generating Highly Constant Magnetization Currents for Electron Lenses.—E. Kinder & F. Schleich. (*Z. angew. Phys.*, 15th Aug. 1950, Vol. 2, No. 8, pp. 332–334.) In the electron microscope separate rectifiers supply the condenser, objective and projection lenses. The control circuit for the two latter is described. This uses two pentodes, V_1 and V_2. The lens coil is in the cathode circuit of V_2 and the voltage drop across a cathode resistor is applied to the grid of V_1, which is battery biased. The anode of V_1 is connected to the control of grid V_2. Refinements and the operation of the circuit are discussed.

778.36 **747**
A 100 000 000 Frame-per-Second Camera. — M. Sultanoff. (*J. Soc. Mot. Pict. Televis. Engrs*, Aug. 1950, Vol. 55, No. 2, pp. 158–166.) See 3178 of 1950.

621.352 **748**
Primary Batteries. [Book Review]—G. W. Vinal. Publishers: J. Wiley & Sons, New York, 336 pp., $5.00. (*Elect. World, N.Y.*, 9th Oct. 1950, Vol. 134, No. 15, p. 196.) Historical résumé with survey of properties and performance of present-day types.

TELEVISION AND PHOTOTELEGRAPHY

621.397.335 **749**
A Television Synchronizing-Signal Generator.—J. E. Benson, H. J. Oyston & B. R. Johnson. (*J. Brit. Instn Radio Engrs*, Nov. 1950, Vol. 10, No. 11, pp. 348–361; *A.W.A. tech. Rev.*, Dec. 1949, Vol. 8, No. 3, pp. 231–261.) Reprint. See 760 of 1950.

621.397.335.001.4 (083.74) **750**
Standards on Television: Methods of Measurement of Time of Rise, Pulse Width, and Pulse Timing of Video Pulses in Television, 1950.—(*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1258–1263.) Copies of this Standard, 50IRE23.S2, may be obtained while available from the Institute of Radio Engineers at $0.75 per copy.

621.397.5 **751**
Quality Rating of Television Images.—P. Mertz, A. D. Fowler & H. N. Christopher. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1269–1283.) 1950 I.R.E. National Convention paper noted in 1534 of 1950 (No. 104). The impairment of the image is measured by two subjective methods: (*a*) an extension of Baldwin's method (1425 of 1941) in which observers state their preference for a television image or an optically projected one; (*b*) the impairment is rated by observers in terms of a list of comments to which values are assigned. Results thus obtained for the impairment caused by several types of interference are discussed.

621.397.5 **752**
Television Outside Broadcasts.—T. H. Bridgewater. (*B.B.C. Quart.*, Autumn 1950, Vol. 5, No. 3, pp. 179–192.) Supplements Birkinshaw's paper on B.B.C. television studio technique (3284 of 1949). In television outside broadcasts, extreme values of illumination and of ratio of highest to lowest light intensity are encountered. Problems of gamma, colour response, focusing and perspective are discussed.

621.397.5 : 621.396.712.3 **753**
The Lime Grove Television Studios.—M. J. L. Pulling. (*B.B.C. Quart.*, Autumn 1950, Vol. 5, No. 3, pp. 173–178.) Illustrated description of the converted film studios at Shepherds Bush, London, serving as temporary television studio headquarters for the B.B.C.

621.397.61 **754**
A Rooter for Video Signals.—B. M. Oliver. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1301–1305.) A nonlinear impedance (triode) is used to give an output whose amplitude varies as the *n*th root of the input. The device is inserted after the linear camera of a television system and linearizes the overall transfer characteristic of such a system using normal viewing tubes.

621.397.61 **755**
The Design of a Television Camera Channel for Use with the C.P.S. Emitron.—E. L. C. White & M. G.

Harker. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 393–408. Discussion, pp. 408–413.) The characteristics of the pickup tube and mechanical considerations affect the design of equipment suitable for use in a van fitted up as a mobile control room. A general description is given of the camera group and rack group of units and of their electrical features, with additional details of circuits of particular interest, including the signal-amplifier chain, head amplifier, contrast-law control in the main amplifier, camera control unit, line-scan generator and camera-cable circuits. Methods of testing the overall performance as regards sensitivity, resolution, hum pickup, geometrical distortions and r.f. interference are described.

621.397.611.2 **756**
A Review of Some Television Pick-Up Tubes.—J. D. McGee. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 377–392. Discussion, pp. 408–413.) The performance characteristics of the emitron, super-emitron and orthicon tubes are compared and an attempt is made to draw up a specification for an ideal pickup tube. The cathode-potential-stabilized emitron is described. The advantages of the methods of focusing and e.m. deflection used are explained and the method of eliminating spurious signals (caused by gas ions) by the use of a mesh trap is outlined. Processes in the manufacture of the tube and the technique of forming the target mosaic by means of a stencil mesh are described. Performance characteristics for sensitivity, image movement and stability are discussed with reference to the specification of the ideal tube.

621.397.62 **757**
Tone Rendition in Television.—B. M. Oliver. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1288–1300.) The relations between scene and image brightness and signal strength (brightness characteristics) are studied. Families of curves corresponding to various transmitter and receiver brightness characteristics are given.

621.397.62 : 77 **758**
Tone Rendition in Photography.—W. T. Wintringham. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, pp. 1284–1287.) General discussion. Possible application to television is considered briefly.

621.397.645 : 621.392.53 **759**
The Orthogam Amplifier.—C. L. Townsend & E. D. Goodale. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 399–410.) Gradient correction for a television film transmission system is discussed and correction amplifiers giving adjustable nonlinear compensation for the light-grey and the white components of the picture signal are described, full circuit details being given for Model 'B'.

621.397.8+621.396.11 **760**
Long-Range Television.—Bennington & Morris. (See 722.)

621.397.823 : 621.396.619.16 **761**
Interference Effects in Pulse-Width Modulation.—W. E. Ingham. (*Wireless Engr*, Oct./Nov. 1950, Vol. 27, Nos. 325/326, pp. 241–256.) The effects of ignition interference on a width-modulated synchronizing-pulse method of transmitting television sound is described. The tests simulated the practical conditions as closely as possible in so far as the source of interference and the subjective method of measurement were concerned. The investigation showed how the noise output for a given interference level is affected by changes in the synchronizing-pulse demodulator, and provided data for a comparison with a.m. and f.m. systems.

621.397 **762**
Practical Television Servicing and Trouble-Shooting Manual. [Book Review]—Coyne Electrical and Radio-Television School. Publishers: Greenberg Publishers, New York, 1949, 392 pp., $4.25. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, p. 1360.) Fairly complete and clearly written. No mathematics is used.

TRANSMISSION

621.396.61/.62 : 629.13 **763**
A V.H.F. Transceiver for Small Aircraft.—J. B. Rudd. (*A. W. A. tech. Rev.*, Dec. 1949, Vol. 8, No. 3, pp. 195–201.) The transceiver provides a.m. transmission with a 200-mW carrier on two crystal-controlled frequencies, reception with manual tuning of signals $> 10\,\mu$V within the range 112–122 Mc/s, means for establishing a common send/receive frequency, and intercommunication within the aircraft. It is contained in a case about 4 in. × 4 in. × 4 in., and weighs $3\frac{1}{2}$ lb. A separate power unit, 4 in. × 4 in. × 7 in., weighs $6\frac{1}{4}$ lb.

621.396.61 : 621.396.619.13 **764**
High-Power F.M. Broadcasting Transmitters.—L. Rohde, H. Nitsche & A. Pfefferl. (*Frequenz*, Sept. 1950, Vol. 4, No. 9, pp. 217–228.) Problems of efficiency and cost are discussed generally; apart from special considerations, the economically optimum transmitter power is about 1 kW. Limitations imposed by 100-Mc/s operation on choice of valves are explained; tetrodes are useful for outputs up to 2–3 kW, but triodes are more suitable for wideband applications (television and radio-telephony); air cooling is almost universal. Inductance rather than capacitance is varied for tuning; tuning-circuit Q must be limited to keep down distortion factor. Power stages are grounded-grid circuits up to about 10 kW and grounded-anode circuits for higher outputs. A brief description is given of a complete 10-kW transmitter. Aerial feed arrangements are considered and a coaxial-line filter device is described which enables a common aerial to be used for two transmitters.

621.396.61 : 621.396.662 **765**
Automatic Tuning of Large Transmitters by means of an Electrically Controlled Tuning Mechanism.—A. G. Robeer & W. L. Vervest. (*Commun. News*, July 1950, Vol. 11, No. 2, pp. 56–64.) The mechanism described is capable of tuning the final stage, or any other large tuning element, of a high-power transmitter to one of six preset frequencies within a few seconds, in response to a resetting of the frequency-selector switch. In special cases, e.g. when ice forms on feeders and aerial, the tuning can be corrected continuously.

621.396.61 : 621.396.97 **766**
Co-ordinated Design of A.M. Broadcast Transmitters for a Range of Power Output.—P. R. Hellyar. (*A.W.A. tech. Rev.*, Dec. 1949, Vol. 8, No. 3, pp. 217–229.) Reprint. See 775 of 1950.

621.396.61.029.55 : 629.13 **767**
The Application of Impulse-Governed Oscillators (I.G.O.) in Aircraft Transmitters.—E. H. Hugenholtz. (*Commun. News*, May 1950, Vol. 11, No. 1, pp. 13–21.) An account of the SVZ101 transmitter, which covers the frequency range 2·8–24 Mc/s with great setting accuracy and stability, using a single piezoelectric crystal of resonance frequency 100 kc/s and a highly stable oscillator tunable from 200 to 300 kc/s. The circuit is based on one described by Boosman & Hugenholtz (2070 of 1949). Aerial power is about 100 W. The click gear described by Vervest (2941 of 1949) is used for selecting one of 12 frequencies.

VALVES AND THERMIONICS

535.215.2+535.215.6 **768**

The Surface Photoelectric Effect.—Buckingham. (See 607.)

621.383.42 **769**

Investigation of the Spectral Sensitivity of Selenium Photocells.—H. G. Sanner. (*Ann. Phys., Lpz.*, 20th July 1950, Vol. 7, Nos. 7/8, pp. 416–419.)

621.385 : 537.291 **770**

Graphical Representation of Particle Trajectories in a Moving Reference System.—M. Garbuny. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 1054–1056.) "A graphical method is derived for the analysis of microwave electron tubes, ion accelerators, etc., which refers particle positions and velocities to a moving reference system. If the forces are dependent on time only, the trajectories are transformed into straight lines. For inhomogeneous fields an approximation procedure applies. To demonstrate the capabilities of this method a brief treatment of the transit-time phenomena in cavity triodes is outlined."

621.385.012 : 621.317.79 **771**

Apparatus for the Determination of [valve] **Characteristics.**—Graffunder & Schultes. (See 692.)

621.385.029.64/.65 : 621.392.5 **772**

Delay Lines of Comb or Interdigital Type and their Equivalent Circuit.—R. Warnecke, O. Doehler & P. Guénard. (*C. R. Acad. Sci., Paris*, 27th Nov. 1950, Vol. 231, No. 22, pp. 1220–1221.) Substitution of such lines for the more commonly used types in travelling-wave valves reduces the energy stored per unit length and hence increases interaction between beam and wave. The nature of the couplings is examined for both types of line, and curves are presented giving the variation of wave retardation with wavelength for two modified forms of the comb-type line and for the interdigital type. Using the latter, travelling-wave valves may be designed having a wide pass band and outputs of the order of a kilowatt for continuous operation and of a megawatt for pulsed operation at $\lambda = 10$–20 cm. See also 2064 of 1950 (Warnecke et al.).

621.385.032.216 **773**

A New Thermionic Cathode for Heavy Loads.—H. J. Lemmens, M. J. Jansen & R. Loosjes. (*Philips tech. Rev.*, June 1950, Vol. 11, No. 12, pp. 341–350.) The 'L' cathode consists of a mixture of barium and strontium oxides contained behind a wall of porous tungsten. When heated, the oxides are reduced and Ba, Sr and BaO escape through the pores of the wall to form on the surface a monatomic layer of Ba and Sr with some oxygen between. This layer reduces the work function to 1·62–2·0 V. The maximum useful emission amounts to some hundreds of amperes per cm². Other properties claimed for the cathode are great mechanical strength, ability to withstand electron bombardment, and rapid recovery after gas poisoning.

621.385.032.216 **774**

Thermionic Processes in Thoria Cathodes.—G. Mesnard. (*C. R. Acad. Sci., Paris*, 23rd Oct. 1950, Vol. 231, No. 17, pp. 833–835.) Continuation of study noted in 504 of February. The observed results suggest that for every operating temperature there is a corresponding emission value giving dynamic equilibrium. This emission value is reached the more rapidly the higher the temperature and the thinner the thoria layer. With increase of temperature in the range 1 400–2 800°K, A and ϕ both decrease up to about 2 150°, increase from 2 150° to about 2 600°, and then decrease again slightly, as does also the emission. An interpretation is given involving the availability of free thorium and the layer thickness.

621.385.2/.3]: 621.396.622.6.029.64 **775**

Crystal Detectors and their Use at Ultra-High Frequencies.—A. Engel; H. Welker; H. F. Mataré. (*Bull. Soc. franç. Élect.*, Aug. 1950, Vol. 10, No. 107, pp. 379–396.) After an introduction (Engel), the atomic structure and mechanism of semiconductors are discussed, barrier layer conditions are considered quantitatively and transistor action is analysed (Welker). The characteristics and operation of crystal diodes and transistors are then dealt with (Mataré). Values of conductivity, conversion loss, sensitivity, etc., for different crystal diodes are compared and equivalent circuits, based on observed behaviour at different frequencies, are derived. Formulae for amplification, slope of power characteristic, etc., of a transistor, based on quadripole theory, are given and conflicting theories on interaction current and surface states are discussed. See also 2976 of 1949; 855 and 1505 of 1950 (Mataré).

621.385.2 : 621.3.011.2.029.5 **776**

High-Frequency Impedance of Low-Pressure Gaseous Diodes.—Chai Yeh & E. L. Chaffee. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 981–986.) A simple theory of the lagging effect of the positive ions in neutralizing the space charge near the cathode of a gaseous diode is developed. The theory is confirmed by measurements of the h.f. impedance of diodes. Constants such as the transit time and the lifetime of a positive ion can be deduced from the theoretical and experimental results.

621.385.2.011 **777**

Theory of the Parallel Plane Diode.—A. H. Taub & N. Wax. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp.974–980.) General solutions of the fundamental equations for transient and steady-state conditions are applied to analysis of the space-charge-limited diode. Power consumption is discussed; the notion of complex impedance is insufficient alone to account for all the power consumed by the diode.

621.385.3 : 621.315.592† : 546.289 **778**

The Transistor — Bibliographical Survey.—G. Gaulé. (*Fernmeldetech. Z.*, Oct. 1950, Vol. 3, No. 10, pp. 390–400.) Review of transistor theory and applications, in the form of abstracts and summaries of over 40 published papers, to which references are given.

621.385.3 : 621.315.592† : 621.396.822 **779**

Background Noise in Transistors.—H. C. Montgomery. (*Bell Lab. Rec.*, Sept. 1950, Vol. 28, No. 9, pp. 400–403.) A brief nonmathematical account. Illustrations show the variation of transistor noise power per cycle with frequency, an oscillogram of transistor noise over the band 30–1 500 c/s compared with one of thermal noise, and variation of noise output with collector bias for a fixed emitter bias. A definition of 'noise figure' is given. Causes of transistor noise are still under investigation.

621.385.3.029.64 **780**

Low-Level Triode Amplifier for Microwaves.—G. Diemer & K. S. Knol. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 153–154.) Advantages and performance obtainable using an 'L-type' cathode (see 773 above) are summarized. Overall noise level in a receiver circuit was found to be 7 db at 3 kMc/s.

621.385.38 **781**

Pulse Measuring of Deionization Time.—H. H. Wittenberg. (*Elect. Engng, N.Y.*, Sept. 1950, Vol. 69, No. 9, pp. 823–827.) Description of a flexible method, using repeated probing pulses, for measuring deionization time of thyratrons.

621.385.38 **782**

Hot-Cathode Thyratrons: Practical Studies of Characteristics.—H. de B. Knight. (*Proc. Instn elect. Engrs*, Part III, Nov. 1950, Vol. 97, No. 50, pp. 455–458.) Discussion on 504 of 1950.

621.385.5 : 621.318.572 **783**

Construction of Cold-Cathode Counting or Stepping Tubes.—M. A. Townsend. (*Elect. Engng, N.Y.*, Sept. 1950, Vol. 69, No. 9, pp. 810–813.) A.I.E.E. Winter General Meeting paper, 1950. An electronic digital counter capable of operating at high speed is described in which the position of a glow discharge is made to step along a row of cathodes, under the control of input pulses. A large number of elements may be accommodated in one envelope and with a small driving power sufficient output is obtained to operate electromechanical devices.

621.385.5 : 621.318.572 **784**

Multicathode Gas-Tube Counters.—G. H. Hough & D. S. Ridler. (*Elect. Commun.*, Sept. 1950, Vol. 27, No. 3, pp. 214–226.) A new principle of priming is described which makes possible the transfer, from one cathode to another in a multicathode gas-filled tube, of the discharge to a common anode. Various types of counter tube resulting from different electrode combinations are discussed. A more detailed account is given of a practical decade unidirectional counter which is triggered by a pulse of width 16 μs and amplitude 120 V; the maximum operating frequency at present is about 25 kc/s. Other operational details are given, together with typical circuits, including a 27-point distributor using three of the valves in series. See also 266 (Lamb & Brustman) and 2066 (Bacon & Pollard) of 1950.

621.385.83 : 537.291 **785**

Some Crossover Properties in the Electron Immersion Objective.—L. Jacob. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 966–970.) Analysis of electron motion in e.s. fields. Correct solution of the trajectory equation shows that the simple theory [183 of 1949 (Einstein & Jacob)] gives an adequate approximation for c.r. tube design purposes.

621.385.832 **786**

Charge-Storage Picture Tubes with Storage Grids.—M. Knoll & J. Randmer. (*Arch. elekt. Übertragung*, July 1950, Vol. 4, No. 7, pp. 238–246.) Various ways of operating charge-storage picture tubes are discussed; the potential levels corresponding to the different steps of the 'writing' and 'reading' processes are illustrated graphically and tabulated. The use as storage electrode of a separate grid, exercising point-to-point control over the 'reading' beam, has the advantage over the capacitive signal-plate assembly that the signal can be read without removal of charge; hence more repetitions of the same signal can be obtained without loss of detail. An experimental demountable tube is described.

621.385.832 **787**

Storage of Small Signals on a Dielectric Surface.—J. V. Harrington. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 1048–1053.) "A mathematical analysis is presented which is believed to be applicable to a general class of storage tubes where signal storage is accomplished by depositing through secondary emission a charge pattern on a dielectric surface. The assumptions made to linearize and simplify the problem are outlined and plots are given of the predicted output signals for writing, reading, and cancellation operations when the input signal is a step function. Experimental evidence is presented to substantiate the analytical results."

621.385.832 : 621.3.087 **788**

The Recording Storage Tube.—R. C. Hergenrother & B. C. Gardner. (*Proc. Inst. Radio Engrs*, Nov. 1950, Vol. 38, No. 11, p. 1287.) Correction to paper abstracted in 2942 of 1950.

621.396.615.141.2 **789**

Some Observations on the Back Heating of Magnetron Cathodes.—R. T. Young, Jr, L. W. Holmboe & W. E. Waters, Jr. (*J. appl. Phys.*, Oct. 1950, Vol. 21, No. 10, pp. 1066–1067.) Discussion of effects observed in various types of magnetron. It appears that a state of oscillation is involved which is primarily a function of the space-charge conditions in the interaction space. No satisfactory explanation is available at present.

621.396.615.142 **790**

Pendular Secondary-Electron Multiplication in High-Frequency Fields.—K. Krebs. (*Z. angew. Phys.*, Oct. 1950, Vol. 2, No. 10, pp. 400–411.) The operation of v.m. valves is discussed generally, and a method of calculating the h.f. power from the field dimensions is developed. From discrepancies between theoretical and measured results it is established that within certain voltage-amplitude ranges a pendular secondary-electron multiplication system is set up, of the type first described by Farnsworth; the energy abstracted from the h.f. system by the rapidly increasing secondary-electron current is the cause of the power loss. The pendular multiplication process is studied, taking into account electron emission velocities corresponding to 5–10 eV; calculated values of critical voltage-amplitude range agree well with observed values. Methods of eliminating the effect by choice of materials and dimensions are indicated.

621.396.615.142.2 : 621.317.3.001.4 **791**

Test Methods and Apparatus for the Development of 3-cm Low-Voltage Klystrons.—Musson-Genon, Chantereau & Métivier. (See 683.)

621.383 **792**

Photoelectric Cells in Industry. [Book Review]—R. C. Walker. Publishers: Pitman Publishing Corp., New York, 1948, 510 pp., $8.50. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 134, 138.) "The object of this British book is . . . to present a representative selection of the industrial uses of light-sensitive cells of the emission and rectifier types . . . adequate information is supplied for design and construction of even the most elaborate installations."

MISCELLANEOUS

5+6] : 621.317.2 **793**

The Bell Telephone Laboratories—an Example of an Institute of Creative Technology.—M. J. Kelly. (*Proc. roy. Soc. A*, 10th Oct. 1950, Vol. 203, No. 1074, pp. 287–301.) Text of a lecture describing the structure and scope of the organization.

621.396 **794**

The Radio Manual. [Book Review]—G. E. Sterling & R. B. Monroe. Publishers: D. Van Nostrand Co., New York, 4th edn 1950, 890 pp., $12.00. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 142, 146.) ". . . a comprehensive study of the entire field of radio communication . . . a completely rewritten and reworked version . . . a ready reference for the engineer and/or operator who needs a quick answer to routine or special questions and problems."