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WIRELESS ENGINEER

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The Electromagnetic Momentum of Space

In a recent number of the *British Journal of Applied Physics** Dr. Searle states that in 1916 he sent an electromagnetic problem to Oliver Heaviside but that, so far as he knows, Heaviside never attacked it. The problem was this: a circular ring carries an electric charge, and a magnetic pole is moving along its axis, thus causing a change in the magnetic flux through the circle and inducing an electromotive force in it which, acting on the charge, produces a couple tending to rotate the charged ring. Since the pole experiences no couple, Dr. Searle states that *the reaction must be against the ether*, and that the force on the ether per unit volume is $d(V\mathbf{DB})/dt$ where V denotes the vector product. He says that, although this formula for the force occurs many times in Heaviside's treatment of the electromagnetic field, he did not examine its consequences. Dr. Searle wanted Heaviside to prove that these forces on the ether produced a couple equal to that on the charged ring, thus satisfying Newton's third law.

In the article referred to, Dr. Searle solves a similar problem, but one more amenable to mathematical treatment than the charged ring. He considers two concentric charged spheres with equal and opposite charges, with a magnetic pole moving towards the centre from an external point. He calculates the resultant couple exerted on the two spheres and then calculates the couple due to the force $d(V\mathbf{DB})/dt$ integrated over the space between the two spheres, and shows that the two are equal. He concludes with the statement, "Although the moving pole creates no resultant torque, it has the remarkable effect of urging the combined pair of spheres to turn in one direction and the medium between them to turn in the opposite direction." The two spheres tend to turn in opposite directions, but with unequal torques, so that if combined, that is, mechanically connected, they tend to turn in one direction. Dr. Searle sometimes refers to the ether and sometimes to the medium; it is open to anyone who objects to these terms to call it space, but it is not easy to picture space being urged "to turn in the opposite direction."

Although the case of the two spheres and the moving pole is an interesting mathematical exercise, the principles involved are brought out, perhaps even more clearly, by considering two concentric metal cylinders situated in a uniform axial magnetic field. We assume that the cylinders are so long compared with the distance between them that we can consider a length of 1 cm and neglect end effects. If the inner cylinder has a radius a and a charge $+q$ per unit length, and the outer cylinder a radius b and a charge $-q$ per unit length, at the inner cylinder $D_a=q/2\pi a$ and $E_a=2q/a$, and at the outer cylinder $D_b=q/2\pi b$ and $E_b=2q/b$. Since the mechanical tension $F=E^2/8\pi$ per cm^2, $F_a=q^2/2\pi a^2$ and $F_b=q^2/2\pi b^2$. The total outward pull on the inner cylinder is q^2/a and the total inward pull on the outer cylinder is q^2/b per cm of length. We discussed this apparent infringement of Newton's third law in the Editorial of last May, and showed that it was due to the neglect of the Maxwellian lateral pressure in the electric field. If one considers the two cylinders to be split along a diameter as shown in Fig. 1, the resultant outward force on each half of the inner cylinder is $2aF_a=q^2/\pi a$ and the resultant

*Vol. 1, pp. 268-269, October, 1950.

inward force on each half of the outer cylinder is $q^2/\pi b$. The lateral pressure in the field is $E^2/8\pi = q^2/2\pi x^2$ per cm² and on integrating this across mn and pq we obtain $2\int_a^b q^2 dx/2\pi x^2 = \frac{q^2}{\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$, which is exactly equal to the difference between the resultant forces on the two half cylinders. Hence, as we pointed out in May, in connection with concentric spheres, the reaction to the tension on the inner cylinder comes only partly on the outer cylinder and partly as compression on the medium between the two cylinders.

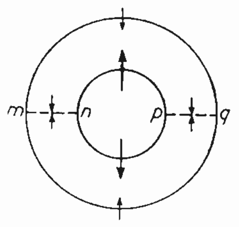

Fig. 1

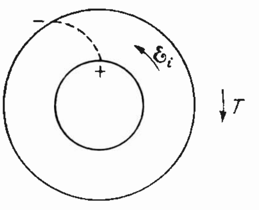

Fig. 2

We have not yet come to Dr. Searle's problem but have considered a purely electrostatic condition in order to show the nature of the demands made on the medium in such cases. We now go a step further by assuming the charged cylinders to be situated in an axial uniform magnetic field. This has no observable effect so long as the magnetic field is unchanging, although, according to Poynting's theorem, in an unchanging electromagnetic field there is a flow of energy perpendicular to both E and H, and in this case that would mean a circulation of energy around the space between the two cylinders. If, however, the axial magnetic field is increasing, electromotive forces will be induced, and at any point of radius x there will be a tangential component of electric force equal to $(dB/dt) \times x/2$. On the inner cylinder, for which $x=a$, this will cause a torque $T_a = q(dB/dt)a^2/2$ and on the outer cylinder a torque $T_b = q(dB/dt)b^2/2$. Hence the torque is greater on the outer cylinder, and the resultant torque on the combination is $T_b - T_a = q(dB/dt)(b^2 - a^2)/2$; this raises the question as to where the mechanical reaction to this torque is exerted, and Dr. Searle's answer is—on the medium. Since in the present case **D** and **B** are always at right-angles, $V = 1$ and the formula for the force on the medium per unit volume reduces to $D(dB/dt)$, which is equal to $(q/2\pi x)(dB/dt)$; for a ring of 1 cm² cross-section the torque will be $qx(dB/dt)$, and integrating this form a to b gives for the total torque experienced by the medium

$$q(dB/dt)\int_a^b x dx = q(dB/dt)(b^2 - a^2)/2$$

which is exactly equal to the resultant torque on the two charged cylinders.

If in Fig. 2 the magnetic field is away from us and increasing, the induced electric force will be in the direction shown, and since it increases with the radius, whereas the radial electric force decreases, the resultant electric field will be curved as indicated. Hence there is a tangential force tending to turn the inner cylinder left-handedly but a greater force and a still greater moment tending to turn the outer cylinder right-handedly. The curvature of the resultant line of electric force shows that there must be lateral forces acting on it and causing the resultant torque on the combination. Heaviside explains this by endowing the medium with a momentum $V(\mathbf{DB})$ per unit volume, and ascribing the force to the rate of change of this momentum; as we have seen, this gives the correct result. The curvature of the electric field does not affect the torque due to the change of momentum since, in the vector product, the tangential force depends only on the radial component of D. One can eliminate any question of currents being induced in the cylinders by assuming them to be divided axially into a number of segments.

We have referred to Poynting's theorem, but we must confess that we have doubts about the generalization of this theorem. In a d.c. transmission line E and H in the dielectric are due to the distribution and movement of the electrons in the conductors bounding the space, and the power transmitted can certainly be expressed in terms of E and H but when, as in the present case, the charges producing E are stationary, and H is produced by a separate source, we see no reason for associating the vector product of E and H with any transfer of energy. If one did apply Poynting's theorem one would obtain a transfer of energy left-handedly around the space between the cylinders, and it would increase with B, like Heaviside's momentum. This suggests some connection between them, but, as we have said, we consider the application of Poynting's theorem to this case to be unjustified.

G. W. O. H.

OPTIMUM SPACING OF BROADCAST TRANSMITTERS

By D. C. Espley, O.B.E., D.Eng., M.I.E.E.

(Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England)

SUMMARY.—It is known that the interference range of a radio transmitter extends, to some extent, beyond the limits of the effective service area. This note gives the unique solution of the geometrical problem in which it is desired to know the number of different stations necessary to cover an unlimited territory for a given ratio of service range to interference range. The shape and extent of a finite territory have some effect on this number.

The Problem

The service coverage of an area large compared with the service area of a single station cannot be solved in the general case by a distribution of stations working on the same wavelength, unless the boundaries of the service areas are contiguous and no interference fields extend into other service areas. One practical exception is found in common-wavelength sound broadcasting as the addition, at a receiver, of signals from more than one station produces substantially no distortion of the envelope of the resultant carrier. A television programme signal would show perceptible pattern or echo distortions except when the desired carrier level is at least 40 db above all interfering carriers having the same or different video modulations.

It is necessary to define the radius of the service area and to space the stations by at least twice this radius. If the range at which a significant interference signal is produced is longer than this radius, and this is invariably the case, then the spacing of common-wavelength stations must be increased. The gaps appearing in the pattern of the total service area must be covered by other stations working at different wavelengths so that freedom from interference is ensured by receiver selectivity. The problem is to determine the possible spacing between common-wavelength stations when a number of wavelengths is available and a service is to be provided over the whole territory.

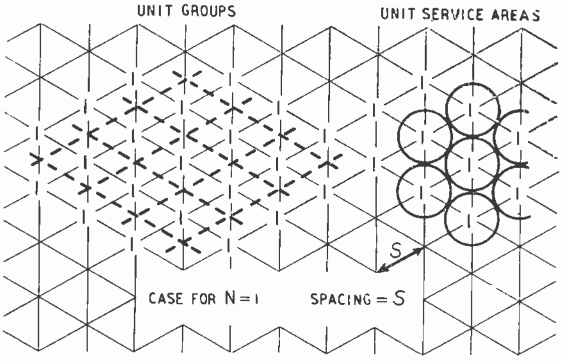

Fig. 1. *The primary arrangements of unit areas.*

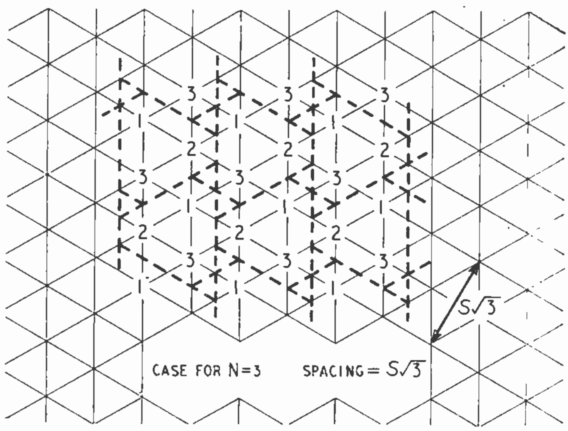

Fig. 2. *The keying of groups showing the small triangular packing areas.*

The propagation conditions over an actual territory are variable according to time and topography, with the result that, for given station powers, the service areas are variable in size and shape. The case treated here assumes circular field distributions and constant range and represents the mean condition, although some modifications may be required due to availability of station sites and the extent of anomalous propagation at the chosen wavelengths. However, the solution of the regular geometrical problem provides a very useful guide in an initial coverage plan.

The Numerical Solution

The simple case of a distribution of stations working on one wavelength is shown in Fig. 1, from which it will be seen that gaps appear between the service areas if no overlap is allowed. The stations fit into the familiar hexagonal

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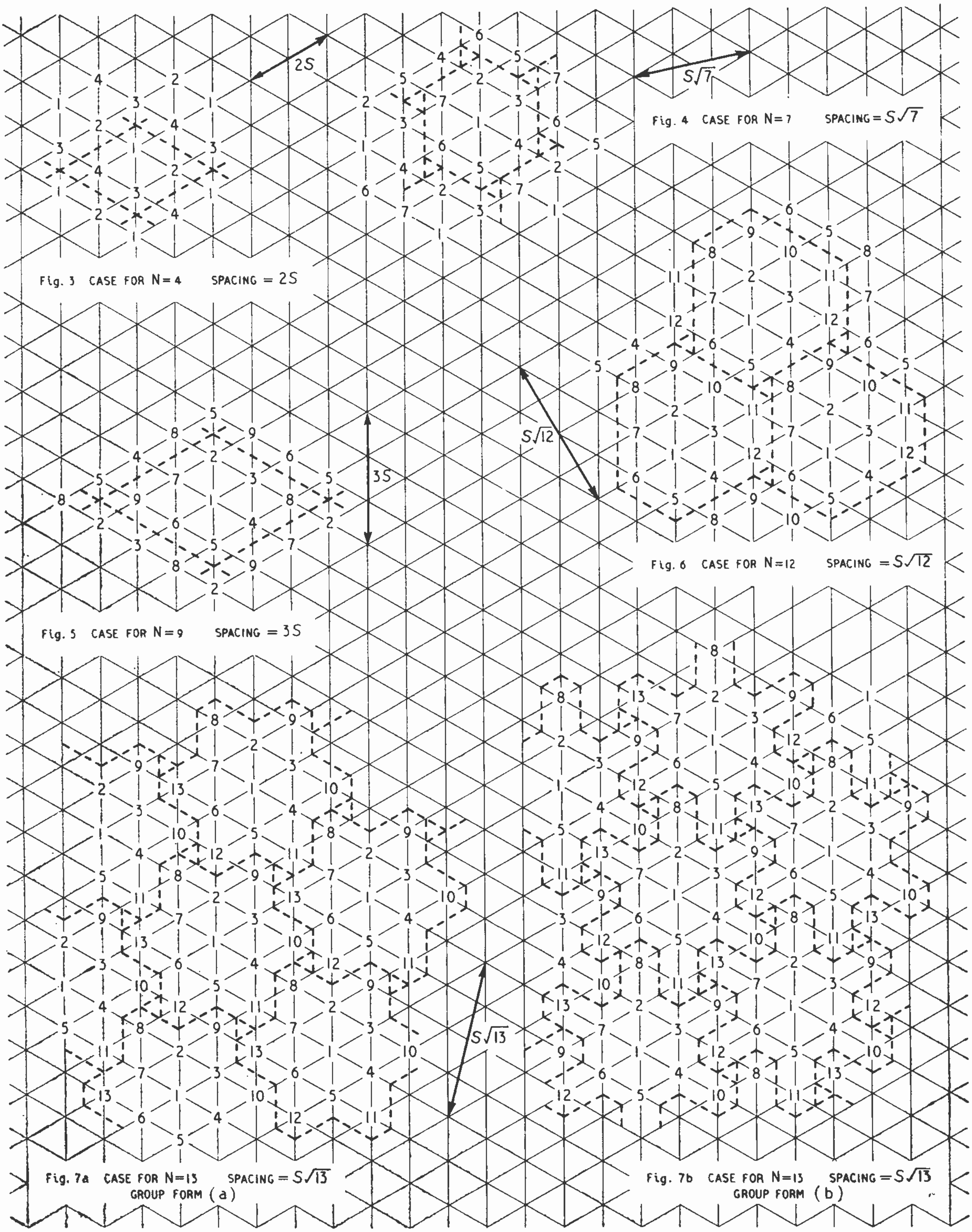

Figs. 3–7(*b*). *Keying of high-order groups ; values of N ranging from* 4 *to* 13.

pattern which permits the closest packing. If the service area is of radius R then the station spacing S is $2R$.

If enough separate wavelengths are available, say N in number, it is clear that the common-wavelength stations can be spaced by more than $2R$. The increase of spacing for N greater than unity is not a continuous function of N and a cluster of N stations of different wavelengths must, in the most economic arrangement, lie within a group which can be repeated indefinitely over an infinite area substantially without gaps. This requirement is familiar in the printing of patterned fabrics where pattern groups must key in an area of a number of groups. The group of Fig. 1 contains only one unit, but the simple diamond shape is found in all cases in which $\sqrt{N}$ is an integer.

No increase in spacing can be achieved by the use of two wavelengths, as a station would be surrounded by six stations of the other wavelength and these would be subject to the minimum spacing $S=2R$. Fig. 2 shows the case for $N=3$ in which the spacing is increased to $S\sqrt{3}$. The group is substantially triangular in shape, but it will be seen that the keying of groups cannot be achieved without the inclusion of small triangular packing areas. These have no significance in terms of service coverage as the circular service areas pack as in Fig. 1.

The addition of one more wavelength gives a spacing of $2S$ for $N=4$ which is shown in Fig. 3.

The next extension requires an increase of stations to $N=7$ when the spacing is $S\sqrt{7}$ as in Fig. 4.

Figs. 5, 6, 7 and 8 show the cases for $N=9$, 12, 13 and 21 respectively.

The case for $N=13$ is interesting as two forms of the group are possible. It is thought that sufficient illustrations have been given to indicate the nature of the problem, but it can be stated that $N=19$ requires a group of regular hexagonal shape and the $N=16$ and $N=25$ groups are of a simple diamond shape. In the figures the numbers are placed on the station sites, and stations with the same number operate on the same wavelength. Different numbers indicate different wavelengths. It will be noticed that in most of the groups the numbers can be rearranged, but other combinations yield only redundant solutions.

It has been shown by E. V. Newbery and J. W. Ryde that permissible values of N are given by a solution of the equation $N=p^2+pq+q^2$ in which p and q are any integers, including zero. Such values of N up to 109 are given in the Table.

Any other values of N within the range of the Table would be wasteful, as the effective value of S would correspond with the next lower entered value of N. For example, 6 wavelengths give no improvement over the case for $N=4$.

TABLE

1	31	73
3	36	75
4	37	76
7	39	79
9	43	81
12	48	84
13	49	91
16	52	93
19	57	97
21	61	100
25	63	103
27	64	108
28	67	109

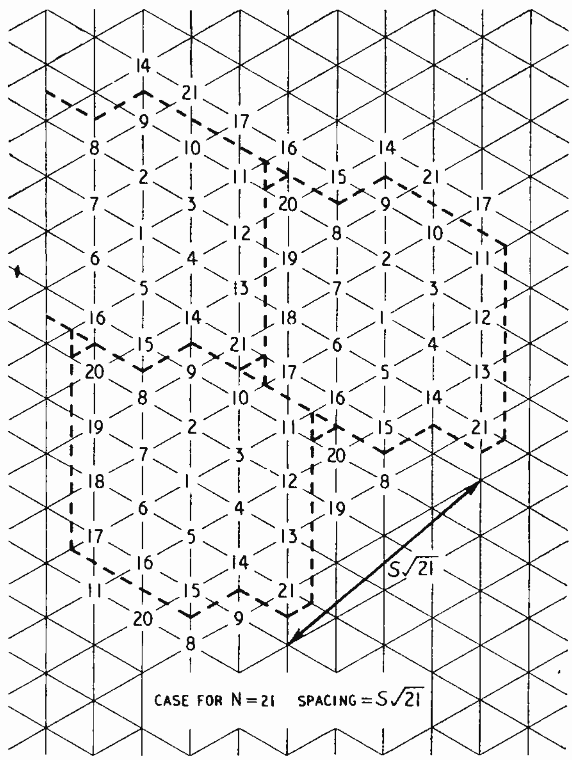

Fig. 8. *Keying for group of N= 21.*

Cases arise in which the territory to be covered is in the form of a long strip (e.g., United Kingdom) where the width may be of the order of one or a few times S. All strip cases permit further values of N and the corresponding values of the common-wavelength station spacings are equal to, or greater than, the cases for an infinite territory. In the simplest case of a strip equal in width to S then it can be seen clearly that the common-wavelength station spacing is equal to N.

FLICKER IN TELEVISION PICTURES

By J. Haantjes and F. W. de Vrijer

(Philips Research Laboratories, Eindhoven, Netherlands)

Introduction

IN television, just as in motion picture projection, a limited number of pictures per second is used to create the impression of continuity of motion. The number of pictures per second (24) used to-day in most films is quite adequate for this, but it is not enough to avoid flicker under normal viewing conditions. In normal practice to avoid flicker each picture is projected twice, thus doubling the frequency of projection. In television the same result is accomplished by interlaced scanning. The number of complete pictures per second used in television is 25 in Europe and 30 in the United States. This corresponds to frame frequencies of 50 and 60 respectively, using two-fold interlacing. The question has arisen whether 50 c/s is high enough to avoid flicker in television pictures. Some work has been done in this field by E. W. Engstrom[1] and by O. H. Schade[2]. In order to investigate this question more thoroughly the present work was undertaken. As an introduction a survey is given of the results of earlier experiments on flicker phenomena.

Rotating Sector-disc Experiments

If a screen is illuminated intermittently an observer looking at that screen will either see an apparently constant illumination or he will perceive flicker. It is known that the apparent brightness as seen by the observer is the average brightness over a whole number of periods, according to Talbot's law (1834). This law has been checked very accurately by Hyde[3] for the case where no flicker or only slight flicker occurs. At low frequencies (10–18 sec^{-1}) when flicker is very annoying a kind of resonance effect may occur, causing the apparent brightness to be greater than the mean brightness of the screen. If the apparent brightness of the screen is kept constant, but the frequency of illumination is varied, there appears to be a critical frequency f_c above which flicker is not perceptible but below which it is perceptible. The lower the frequency is below f_c the more annoying the flicker will be. The critical frequency f_c depends on the apparent brightness of the screen, rising with increasing apparent brightness. From this it follows that when the frequency is kept constant and the brightness varied there is a critical brightness B_c above which flicker occurs, but below which there is no flicker. The higher the frequency the higher is B_c.

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Measurements of the critical frequency f_c with various brightnesses B were taken long ago with rotating sector discs between the light source and the illuminated screen. This case is analogous to the normal situation in motion-picture projection. From the results obtained the so-called Ferry-Porter law was formulated :

$$f_c = a \log B + b.$$

In the case of equal duration of light and dark periods at brightness levels above 0·1 cd/m² a is found to lie between 10 and 20. This means that when B is increased 10 times f_c is increased by an amount between 10 and 20 c/s. This Ferry-Porter law is only an approximation and the constants are dependent upon various factors. In particular, the ratio of light to dark periods or, more generally, the way in which the brightness B varies with the time t, has a marked effect on the values of the constants a and b (Cf. Bartley[4]). Also the distance from the illuminated screen to the observer is of importance. The colour of the light used has no great influence on the flicker phenomena provided the brightness is not too low (not below 5×10^{-2} cd/m²). A more detailed review of these results and also many recent data can be found in a book written by Hecht[5].

When discussing flicker data it has to be borne in mind that flicker is a subjective phenomenon. Rather large deviations are found between different observers. Even the same observer may find different results at different times. Eye strain, drugs and certain diseases have a pronounced effect and it is reported that even accompanying sounds or odours may influence flicker susceptibility[6]. Differences between the left and the right eye of an observer are also quite common. Further, different parts of the retina behave in different ways. The periphery is much more susceptible to large area flicker, with which we are concerned here, than the central part of the retina. Therefore a screen which is not seen to flicker when the eyes are fixed on its centre, appears to start flickering as soon as the eyes are turned aside.

Flicker in Television Pictures

Turning now to the case of television, it must first be stressed that the situation is different from that in sector-disc experiments or motion-picture projection. In the television case the screen brightness is not a result of illuminating the screen as a whole by a source of light, for the screen is scanned line by line by a cathode ray. When the decay time of the fluorescent material used is not too short a horizontal bar of light, consisting of a number of lines, moves from top to bottom across the screen periodically with the frame* frequency. The brightness has its highest value at the bottom end of the bar and diminishes gradually upwards according to the decay characteristic of the phosphor. When the decay time is of the same order as, or shorter than, the scanning time for one line the situation is even more involved. If the scanning frequency is high enough the persistence of vision causes one to see this scanned area again as an area of constant brightness. When the frame frequency is not high enough flicker occurs. This flicker has the same appearance as the flicker of an area illuminated periodically as a whole, as in sector-disc experiments and in motion-picture projection. The general laws mentioned above also apply to this case. Of the various factors influencing the critical brightness the most important are :

(1) distance from picture to observer, relative to picture dimensions,
(2) frame frequency,
(3) decay characteristic of the phosphor used in the fluorescent screen.

An experimental study has been made into the influence of these three factors. About 10 different observers were used to get reliable average values.

Before a measurement was taken the observer was given a few minutes for adaptation. The critical brightness was defined as the mean value of the brightness at which flicker was just perceptible and the brightness at which flicker had just disappeared. All measurements were carried out with the observer looking at the centre of the screen. The ambient illumination had little influence on the observed values of critical brightness.

Distance from Picture to Observer

It is a well-known fact that the size of the image on the retina has a great influence on critical brightness. When a fixed frequency is used, the critical brightness decreases as the size of the image on the retina is increased. To investigate this phenomenon measurements were carried out with a normal sulphide tube with a blank raster and at distances from screen to observer between 4 and 20 times the picture height. It is obvious that the distance measured in picture heights determines the size of the image on the retina. The results are summarized in Fig. 1. The curve given is an average for a large number of observers. None of them observed a critical brightness more than 30% below the mean value. A few observers were very insensitive to flicker and observed critical brightnesses about 3 times higher than normal.

When instead of a blank raster a normal television picture is used and the critical high-light brightness for flicker is determined, one finds values about 5 times as high as the critical brightness in the case of a blank raster. This again is an average value for various pictures and different observers. The factor 5 is about the same as mentioned by Schade[2] and by Masterson and Kellog[7]. It is perhaps significant that this factor 5 is often considered to be equal to the ratio of high-light brightness to average brightness in a normal picture. The values found for critical high-light brightness in this way can also be read from Fig. 1.

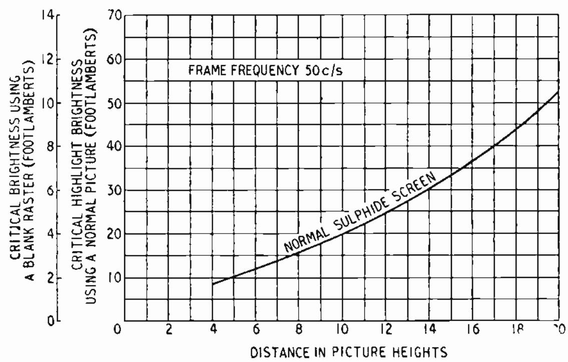

Fig. 1. *This curve shows (a) the values of critical brightness when using a blank raster and (b) the values of critical high-light brightness when using a normal picture (both in foot-lamberts) at various distances from picture to observer when a normal sulphide screen and a frame frequency of 50 c/s are used.*

Frame Frequency

Next the critical brightnesses at frame frequencies of 50 and 60 c/s were compared. At 60 c/s the critical high-light brightness was on the average 4·2 times higher than at 50 c/s. The variation among different observers was between 3·5 and 4·7. These measurements were carried out with a normal sulphide screen. The distance from picture to observer had little influence on the ratio. When a silicate screen having a longer decay time was used the gain factor in passing from 50 to 60 c/s frame frequency was somewhat larger than 4·2 ; viz. 5·5. This is in accordance with the fact found by Engstrom[1] that increasing the ratio of light to dark periods diminishes the constant *a* of the Ferry-Porter law.

Decay Time

Besides frame frequency and distance from picture to observer, the third factor influencing

* In the U.S.A., 'field'.

critical high-light brightness is the decay characteristic of the phosphor used. The longer the decay time the higher the critical brightness. Decay time is defined as the time in which brightness falls to $1/e = 37\%$ of the initial brightness after excitation ceases. A normal sulphide screen has a decay time shorter than 0·1 msec. Other phosphors used in our measurements were zinc-beryllium-silicate having a decay time of 5 msec and willemite having a decay time of 13 msec. The results of the measurements at 50 c/s are given in Fig. 2. From this it is clear that by choosing an appropriate phosphor it is possible to get very high critical brightness values even at 50 c/s. The decay time should not be too long, otherwise moving objects will have 'trails'. Even willemite, where after one picture time the brightness has fallen to 6% of the initial value, proved to be not objectionable in this respect. The only drawback of willemite for use in a television tube is the green colour of its fluorescence. Other phosphors have to be added to get white light. Various mixtures were used. In each case the blue component was a short-persistence phosphor for no blue phosphor having a longer decay time was available. Nevertheless the best tubes showed a critical brightness value at 50 c/s of 4·5 times the critical brightness of a normal sulphide tube. Thus this gain is of the same order as that obtained by raising the frame frequency from 50 to 60 c/s when using an ordinary tube. With a blue com-

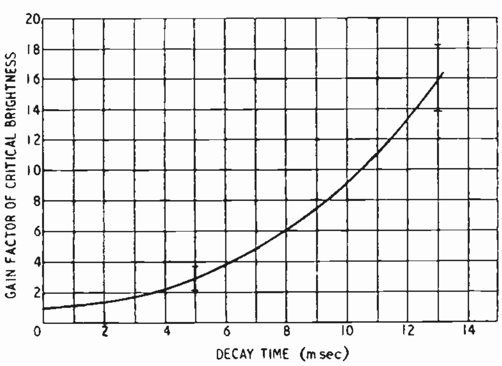

Fig. 2. *Gain factor of critical brightness over a normal sulphide screen as a function of decay time of the phosphor used. The curve gives the average value from a number of observers. The variation of the results for different observers is also indicated in the diagram.*

ponent of slower decay even better results can be expected. The difference in decay time of the components of the phosphor mixture may also cause colour fringing in moving objects. This effect could be detected in some cases but, in general, it was not perceptible. In Fig. 3 the critical high-light brightness is plotted against distance from picture to observer for the new mixture with the corresponding curve for a normal sulphide screen added for comparison. The curve for a silicate mixture, such as is often used for projection tubes, lies in between.

When instead of the critical brightness one determines the brightnesses at which flicker is very well perceptible but not yet annoying, the gain factors mentioned in this article increase. From 50 to 60 c/s we measured about 6 instead of 4·2, and for the new phosphor mixture 7 instead of 4·5.

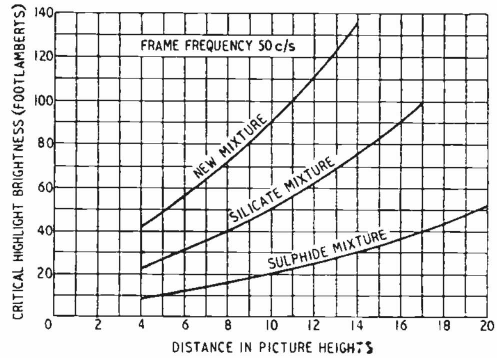

Fig. 3. *Critical high-light brightness is plotted against distance from picture to observer for three types of white fluorescent phosphor mixtures, the frame frequency being 50 c/s. The lowest curve relates to a sulphide mixture as normally used in direct-vision television tubes. The uppermost curve relates to the new mixture, which is very favourable in regard to flicker. In between lies the curve for a normal silicate mixture as frequently used for projection tubes.*

Conclusion

In conclusion it can be stated that with this new phosphor mixture the critical high-light brightness at 50 c/s frame frequency observed from six times the picture height is about 55 foot-lamberts, while flicker is not yet very annoying at about 100 foot-lamberts. This proves that 50 c/s is quite adequate for flicker-free pictures; under most circumstances a high-light brightness of, say, 20 foot-lamberts will be enough. The only reason for very high brightness is lack of contrast under ambient illumination, but in that case some absorbent layer can be introduced in the tube face, resulting in better contrast without using very high brightness. This results in a good picture not causing eye strain, as a very bright picture does.

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IONOSPHERIC STORMS AND RADIO CIRCUIT DISTURBANCES

Possibilities of Forecasting

By C. M. Minnis, M.Sc., F.Inst.P.

(Communication from the National Physical Laboratory)

SUMMARY.—The importance of distinguishing between forecasts of radio-circuit disturbances and ionospheric or magnetic storms is emphasized. Varying amounts of advance warning are given by different precursors of storms and the consequent logical division of storm warnings into the long and short range and immediate warning categories is explained.

The more important storm precursors are discussed, but it is concluded that none of them alone can be used as a reliable basis for making forecasts. The problem of forecasting reduces to a statistical one which cannot immediately be solved because the necessary data do not exist. Empirical methods must therefore be used ; these would become more reliable if more were known of the physical processes in the sun responsible for the emission of storm-causing radiation and of the subsequent development of the storm effects both in time and over the earth's surface.

1. Introduction

BEFORE 1939 the modern methods for forecasting the maximum usable frequencies on long-distance radio circuits existed only in a very primitive form. This was because only a small number of ionospheric recording stations were in operation ; consequently there was very little information on the way in which ionization density, particularly that of F_2-region, varied with time and season and with latitude and longitude. During the war years, recorders were set up for the first time in many new places and the eventual result was an increase in the accuracy with which numerous ionospheric parameters could be forecast.

At the present time it is possible to make forecasts of the monthly mean critical frequency, even for F_2-region, several months in advance and with a high degree of accuracy For F_2-region a day-to-day fluctuation of 10-15% about the mean value is quite normal, but in addition to this it is often found that for a period of a few days the observed critical frequencies fall far below the expected values. During these periods the height of the F_2-region is frequently much higher than the normal value and there may also be an increase in the turbulence of the region. Such disturbed conditions are usually referred to as 'ionospheric storms' and, since they are frequently accompanied by severe dislocations of long-distance radio circuits, they are of more than purely scientific interest.

The nature of these circuit disturbances and the measures which may be taken to minimize their effect depends on the severity of the storm and the type of modulation in use. From the commercial users' point of view, it would clearly be advantageous if some means could be found of giving advance warning of the incidence of these interruptions to his carefully planned traffic schedules and frequency allocations : hence the demand which has sprung up for a 'storm-warning system.'

MS accepted by the Editor, April 1950

2. Definitions and Statement of Problem

Before discussing in any detail the practicability of a storm-warning system, it is important to have a perspective view of the problem as a whole, and to be clear about the meanings of the different types of storms and disturbances to which reference is frequently made.

An ionospheric storm may be defined qualitatively as a period when the critical frequency of F_2-region is abnormally low ; this condition is often associated with an increase in the turbulence and height of the region and with increased absorption on long-distance circuits. Any more precise definition must be made either from the point of view of the commercial operator who wishes to correlate ionospheric and circuit disturbances, or in order to assist in the classification of the changes which take place in the ionosphere itself. No quantitative definition of either kind has yet been formulated on which general agreement has been reached.

Magnetic storms are periods during which the normal quiet-day changes in the components of the earth's magnetic field are superposed on large and often very irregular disturbances. Several indices are in use for describing the changes in field strength such as the international character-figure C, which describes the general level of magnetic activity over the earth's surface during a 24-hour period, and the K-figure which is a measure of activity at one station during a 3-hour period.

Circuit disturbances obviously refer to radio conditions which prevent the normal transmission of usable signals from one point to another, but beyond this no definition exists. It is usual for operators to classify the quality of a circuit according to some subjective scale of values, but these are far from satisfactory for use in any scientific analysis. In order to make progress in such analyses, a more precise definition of the different ways in which circuits may be disturbed is essential. The definitions would obviously vary according to the type of modulation used and should take account of the effects of field strength, fading, multi-path transmission, and possibly other effects.

All three of these different types of disturbance —ionospheric, magnetic, and radio circuit—are quite closely connected, although the nature of the inter-relationships is not yet fully understood. It is, however, universally agreed that they all have their common origin in the arrival at the earth's outer atmosphere of solar radiation which is unusual in kind or intensity or both.

This abnormal radiation may be either electromagnetic or corpuscular. Maris and Hulbert[1] have shown how ultra-violet radiation might generate electrons near the equator and how these could be guided by the earth's magnetic field into the auroral belts. Chapman and Ferraro[2] have assumed that the radiation takes the form of a beam of positive ions and electrons; when it reaches the earth, the electrons are guided towards the auroral belts, or they may form a ring current outside the ionosphere according to the Birkeland-Størmer theory.[3] Both hypotheses lead to storm theories which contain many defects but the consensus of opinion, in Britain at least, is in favour of the corpuscular theory.

Whether electromagnetic or corpuscular radiation is responsible for magnetic and ionospheric storms, a step towards the making of storm forecasts could be made if it were possible to identify the sources on the sun's surface from which the radiation is emitted. Some progress has been made in this direction in recent years and this has made possible the issue of tentative forecasts of disturbed conditions a day or so ahead. To increase the range of the forecasts the only hope appears to lie in being able to identify the positions on the sun of active areas in the early stages of their formation.

The events culminating in a storm, and on which a storm-warning system must be based, are then as follows :—

(i) Long-range Warning (weeks).
  Identification of early indications of solar activity likely to be followed later by emission of radiation.

(ii) Short-range Warning (days).
  Identification of emitting areas.

(iii) Immediate Warning (hours)
  Detection of first signs of arrival of radiation in earth's atmosphere; i.e., initial disturbances of :—
  (*a*) magnetic field,
  (*b*) ionosphere, especially F_2-region,
  (*c*) radio circuits.

Some success has been achieved in forecasting magnetic and ionospheric disturbances, but it is important to bear in mind that the ultimate aim is the forecasting of radio-circuit disturbances. Even if magnetic and ionospheric disturbance forecasting technique were perfect, it would not at present be directly applicable to the forecasting of circuit disturbances.

3. Forecasts and Immediate Warnings

As seen from the earth, the sun appears to rotate about its axis in about 27 days. Consequently any active area which causes a storm on D-day may give rise to further storms on D+27, D+54 and so on, provided the activity lasts long enough. Although storms do recur in this way at certain parts of the solar cycle, a great many storms are caused by newly formed active areas for whose development a constant watch must be kept.

Surface features on the sun's disc can only be investigated properly for about 11 days centred on the day of central meridian passage (c.m.p.); for the remaining 16 days of one rotation, they are either near one of the limbs, and consequently very foreshortened, or on the hemisphere remote from the earth and hence invisible. Consequently an active area which becomes invisible near the W limb may, if it lives long enough, reappear near the E limb 16 days later. Such observations could provide the basis for forecasts 16 days or more in advance; the exact length of warning would depend on the position of the active area on the disc most favourable for causing storms.

Not all solar features are confined to the surface: the corona and prominences extend to great heights above the photosphere. As a result, they can be seen on the E and W limbs when surface features beneath them are invisible. If active areas could be identified with such a phenomenon, then on its appearance at the E limb, several days warning of possible storms could be given. In the same way, a high-altitude phenomenon observed at the W limb might reappear 14 days later at the E limb but it is worth noting that during this 14-day period, no information whatever can be gained about conditions in the area concerned because it is on the hemisphere remote from the earth.

These considerations provide a convenient means of dividing storm forecasts into long- and short-range categories: forecasts based on observations made on the W limb, or on the disc west of the central meridian (long-range forecasts), necessarily refer to a period at least 14 days but more usually 18 days ahead ; forecasts based on features observed near the E limb (short-range forecasts), as will be seen later, will usually be applicable not more than 4 or 5 days ahead. No forecast of intermediate length is conceivable while the area of the sun's surface concerned is on the reverse side of the disc.

Finally if, as a result of the study of the connection between magnetic, ionospheric, and circuit disturbances, it is discovered that disturbances of one of these precede disturbances in the others, then forecasts of the immediate-warning type may be possible a few hours ahead. In the last resort it may even be possible to detect features which are characteristic of the early stages of a circuit disturbance and which may be used to forecast the time of the most severe part of the disturbance.

4. 27-Day Solar Cycle

The most convenient means of studying the 27-day recurrence tendency in magnetic storms is the Bartels diagram.[4] On such a diagram, symbols representing the magnetic character figures for each day are arranged in chessboard fashion in such a way that the horizontal rows correspond to consecutive days, while the vertical columns represent days 27 days apart. Thus if the day at the top of a column is D-day, the days below it are D+27, D+54, D+81, and so on. On such a diagram, any tendency for magnetic disturbances to recur at intervals of 27 days shows up as a block of high-activity symbols ; on the other hand non-recurrent activity is represented only by isolated symbols.

Examination of a Bartels diagram covering a long period shows that for the years near sunspot minimum, the 27-day cycle is very pronounced, while near the maximum of the solar cycle it is hardly noticeable. Even during the years when the recurrence tendency is pronounced, it is found that storms may occur which are neither preceded nor followed by other storms. It is reasonable to conclude that near sunspot minimum the 27-day cycle may be used to forecast magnetic storms 27 days ahead. Unfortunately the existence of isolated storms implies that such forecasts can never cover all the storms which occur, and also that forecasts of disturbances may sometimes result only in false alarms.

Some means of differentiating between those storms which recur and those which do not would be valuable. In this connection it has been found that only the disturbances which have progressive commencements are likely to recur ; those characterized by sudden commencements (s.c.) do not. This is shown clearly in a superposed epoch analysis made by Thellier[5] covering 688 magnetic storms in the period 1884-1947. From the storm-forecasting standpoint it is unfortunate that the great storms, which are most likely to cause severe dislocation of radio circuits, are usually s.c. storms and, therefore, non-recurrent. In Thellier's list of storms the two strongest progressive storms are only 24th and 38th in order of magnitude.

The magnetic storms which recur at 27-day intervals are presumed to have their origin in certain active areas on the sun's surface. Bartels refers to these hypothetical areas as M-regions and it is presumed that they emit radiation which can reach the earth and cause storms only when they are in some position on the sun's disc which has not yet been identified. Evidently then, the possibility exists that M-regions may display certain characteristic features by which they might be identified. This has led, especially during the past decade, to an intensive search for correlations between certain visible features of the sun's surface already well known to astronomers, and magnetic and radio disturbances.

This problem resolves itself into two parts : it is first of all necessary to identify surface features which are indicative of solar activity and the possibility of terrestrial effects ; it is also highly desirable that the occurrence of a disturbance on the earth should be associated with the passage of the solar feature across some fiduciary line on the sun's disc. If both these requirements can be met, it will be possible not only to forecast a disturbance but also to say when it is most likely to occur.

A considerable number of characteristic solar features have been examined from this point of view and in the following paragraphs they will be discussed briefly.

5. Solar Flares

Solar flares are apparent as small areas on the sun's surface which exhibit certain spectrum lines in emission and not, as is usually the case, in absorption. They are usually associated with sunspot groups in the active stage of their lives. The visible part of their radiation reaches a maximum in a few minutes and subsides in about an hour to a low level.

Since about 1936, it has been known that the immediate result of a flare is to cause a Dellinger fade-out on radio circuits crossing the sunlit hemisphere of the earth. These fade-outs are brought about by an increase in the ionization in D-region caused by the absorption of the radiation falling on it from the flare. Because the D-region, in contrast to the upper regions, lies at a height at which the atmospheric pressure is comparatively high, the absorption of radio waves passing through it is also high and this causes abnormally large attenuation of radio signals which would ordinarily be received by propagation via E- or F-regions. Nothing short of an impossibly large increase in transmitted power would enable communications to be maintained during a Dellinger fade-out ; they are in any case of short duration and consequently there is little incentive towards trying to forecast their occurrence.

It is usual to classify flares according to their visual intensity : Classes 1, 2 and 3 denote successive increases in intensity. Hale[6] first drew attention to the fact that very intense flares are often followed about a day later by a severe magnetic storm. This observation has been followed up by Newton[7] who has made a detailed analysis of 37 exceptionally intense flares which occurred between 1859 and 1942. He has designated these as Class 3+ to distinguish them from the comparatively frequent flares in Classes 2 and 3 which he has tabulated for the period 1934-1942.

The results of Newton's work are particularly interesting because they afford a means of distinguishing between those flares which are likely to be followed by magnetic storms and others. It is found that a Class 3 or 3+ flare anywhere on the disc almost invariably causes a Dellinger fade-out. In the case of Class 3+ flares which occur within 45° of the centre of the disc, 82% of these are followed by a magnetic storm about 25 hours later ; of these storms, 70% are in the 'great' category and are likely to be accompanied by abnormal ionospheric disturbances.

The implications of these figures in terms of storm forecasting are worth noting. If it were possible to maintain a continuous watch on the sun, then, on the appearance of a Class 3+ flare in the central zone of the disc at time H, it could be said that the probability of a storm occurring between H+20 and H+30 hours was 0·8 ; it could further be said that the chance of its being a 'great' storm was 0·7. Unfortunately a great many storms occur which are not due to intense flares of this kind. Consequently, although the probabilities quoted are high, this criterion would permit the successful forecasting of only a small percentage of the storms which actually occur. In any case, continuous observation of the sun is not practicable and, even if it were, the distribution of the information with adequate speed would present difficulties.

It might be thought that Dellinger fade-outs themselves could be used to indicate intense flares. This is not possible at present because such fade-outs are caused not only by Class 3+ central-zone flares, but also by outer-zone Class 3+ flares and even by Class 3 flares anywhere on the disc ; in neither of these circumstances is the likelihood of a subsequent storm high enough to be of value in a forecasting system. In fact, the probability of a storm following a Dellinger fade-out is less than 0·5 and the chance of its being 'great' only 0·25.

Newton's results also show that Class 3 and Class 2 flares are followed by magnetic storms only on 30% and 20% of occasions respectively. Since neither of these values is significantly greater than that which would be expected by chance, it appears that the less intense flares by themselves are of little importance in making storm forecasts. Another difficulty which arises in connection with the storms which follow the less intense flares is that the time which elapses between the beginning of the flare and that of the storm is very variable ; indeed there is room for doubt as to whether the correlation is real at all.

A slightly different line of attack has been adopted by Allen[8] who, before attempting to draw any conclusions about the origins of magnetic storms, divides them into a number of different categories depending on their position relative to M-regions on a Bartels diagram. Disturbances occurring at the beginning, middle and end of an M-region are designated B, M, and E disturbances; isolated storm days not associated with any M-region are referred to as T disturbances. Allen then shows that T disturbances are frequently preceded by a solar flare about three days earlier. As a result of Allen's and Newton's work it seems reasonable to conclude that while central-zone Class 3+ flares cause 'great' magnetic storms, outer zone Class 3+ flares or Class 3 flares on any part of the disc are followed by T disturbances as defined by Allen.

It is not known how important the ionospheric or radio disturbances associated with T disturbances may be and it is therefore difficult to say whether much effort should be spent on attempting to forecast them.

6. Solar Corona

A great deal of attention is often paid to the presence or absence of sunspots on the disc as an indicator of possible magnetic or ionospheric disturbances. Provided due attention is paid to the area and position on the disc, and also to the age and activity of the spots, they often provide a useful means of giving a few days warning of possible disturbances. A useful set of curves has been given by Newton[9] showing how the rise in magnetic character figure is related to c.m.p. of spot groups having different areas and degrees of activity.

It is well known that M-regions may persist for several months or even years near sunspot minimum, often in the absence of any sunspots.

Evidently then, sunspots are not the sole criterion of active areas and some other means of deducing their presence is required.

Allen has suggested that the M-regions may in fact be the coronal equatorial streamers which can of course only be observed at the sun's limbs but whose subsequent position on the disc can be calculated. It is worth noting also that these streamers are particularly well defined during the sunspot minimum years when M-regions are most highly developed. Evidence quoted by Allen relating the c.m.p. of sunspot groups to magnetic disturbances tends to support this hypothesis.

This suggestion of Allen's has a bearing on observations made by Waldmeier[10] on what he has called C-regions in the corona. These are regions in which one of the coronal-emission lines (5303A) is radiated with abnormally high intensity. Waldmeier asserts that on many occasions the c.m.p. of a C-region was followed about a day later by high magnetic activity, and he concludes that C-regions and M-regions may be identical.

More recently, Shapley and Roberts[11] have made an extended series of observations on the relation between C-regions and magnetic activity but their results are not in agreement with those of Waldmeier. Shapley and Roberts were interested in forecasting radio circuit disturbances but, in the absence of any suitable circuit interruption or ionospheric disturbance index, they studied instead the relation between the appearance at the E limb of a C-region (e.l.p.) and the subsequent increase in a magnetic character figure C_A based on observations made at a group of observatories.

Their broad conclusion is that there is a significant rise in C_A soon after the e.l.p. of a C-region. As C-regions often extend over a considerable range of longitude, the superposed epoch curves show a broad peak in magnetic activity which makes it difficult to decide on the time lag between the e.l.p. of a C-region and the rise in C_A. Shapley and Roberts then went on to investigate the rise in C_A which followed the e.l.p. of those C-regions immediately following a period of low coronal activity. This procedure should enable a more accurate estimate to be made of the time lag and in fact a sharp rise in C_A is found to occur on the third day after e.l.p. A similar analysis of the change in magnetic activity following the e.l.p. of abnormally intense C-regions shows a peak in C_A three to four days after e.l.p. These relations are, of course, statistical, but a comparison of the successive reappearances of a long-lived M-region in 1943 with the e.l.p. of C-regions shows that the leading edge of the M-region was in most cases preceded by the e.l.p. of a C-region three days earlier.

It would probably be unwise to place too much weight on the value of coronal observations until more is known of their applicability to different phases of the sunspot cycle. The discrepancy between Waldmeier's observations and those of Shapley and Roberts may arise from the fact that they were made several years apart.

7. Calcium Faculæ and Prominences

At present the main disadvantage of using coronal data lies in the difficulty of making the observations. Only a small number of coronagraphs are in existence and conditions are not always favourable to their use. It would, therefore, be very convenient if some other and more easily observed feature of the sun could be used instead.

Shapley[12] has made a few observations on the connection between Ca faculæ and the character figure C_A which was used in the coronal work. He finds that C_A is high during the five days preceding the c.m.p. of persistent faculæ. It should be noted here that this result relates a series of low-latitude faculæ which occurred during the last two years of the solar cycle which ended in 1944. At that time only a few of the high-latitude faculæ belonging to the new cycle had been observed and insufficient evidence was available to allow their behaviour to be studied.

Waldmeier[13] has investigated the possibility that M-regions are related to solar prominences because these are known to be relatively closely correlated with geomagnetic activity. The index used was the area of the profiles of stationary prominences seen on the limbs. The areas of the prominences seen on the E limb seven days earlier, and those on the W limb 7 days later than given any day were averaged to obtain the prominence index for that day. For the year 1930, in which two prominent M-regions occurred, a Bartels diagram showing the prominence indices reproduced the M-region pattern very closely with a lag in the magnetic activity amounting to six days in this particular case. Other M-regions studied by Waldmeier show that the time lags vary considerably; the shortest of them may be comparable with the longer time lags, of say two days, between intense solar flares and magnetic storms.

As the prominences can be seen on the E limb, that is about six days before c.m.p., and since the M-region disturbance begins from two to six days after c.m.p., it appears that a prominence index might often give eight to twelve days warning of an increase in magnetic activity. The uncertainty of the magnitude of the time lag for any particular set of prominences is a defect unless some means can be developed for estimating the velocity of the particles emitted.

8. Early Indications of the Onset of a Storm

All the phenomena which have been discussed so far are those more likely to give a warning of the order of days or weeks in advance of a storm day. It frequently happens, however, that no solar features are observed which would justify the issue of a warning before the onset of the storm itself. Under these circumstances the only course remaining is to keep a close watch for the first signs of the beginning of a disturbance in the hope that some time, of which good use might be made, may elapse before the most severe phase is reached.

It is known that when the storm-causing radiation enters the earth's atmosphere, disturbances are observed on radio circuits, in the properties of the ionosphere, and in the earth's magnetic field ; these are often accompanied by auroral displays, solar-noise bursts, abnormal changes in earth currents and a few other effects. Although all these diverse effects have a common cause, very little is known about how they are connected with each other and how, in particular, radio-circuit interruptions may be inferred from the other disturbances. Before the best use can be made of observations of such effects, it will be necessary to understand much more fully than is possible at present the chronological and geographical development of the different types of storm in which we are interested. In the meantime, the best that can be done is to try to correlate the changes in one phenomenon with those in another in the hope that some useful relation may be uncovered.

9. Geomagnetic Field

The result of the interaction of a stream of charged particles with the geomagnetic field is the setting up of a system of currents in the outer atmosphere different from those which normally exist. These currents are assumed to be responsible for the erratic and often violent changes in the magnetic components which constitute a magnetic storm. It is doubtful whether or not they should precede or occur simultaneously with ionospheric disturbances. This depends on the height at which the currents flow and on whether the existence of the currents necessarily implies a measurable change in the distribution or magnitude of the ionization of any of the normally observed regions of the ionosphere.

At the Radio Research Station, Slough, it has often been observed that small fluctuations in magnetic declination occur some hours before any deterioration in radio circuits becomes evident. Unfortunately these changes are not very characteristic and the certain identification of those likely to be followed by ionospheric changes is very difficult. This does not of course apply to sudden-commencement storms whose first indication consists of a characteristic discontinuity in one or more of the magnetic elements.

For a short period during the war,[11] some evidence was obtained on a suspected connection between the horizontal intensity and the initial stages of ionospheric storms but there is not sufficient reliable information on this effect to allow it to be used.

It has also been suggested that magnetic disturbances travel from the auroral zones towards the equator. If this were so, the possibility of using information from high-latitude magnetic observatories would be attractive but a very limited investigation of this did not produce any evidence for its existence. An additional difficulty is that as the auroral belts are approached, magnetic disturbances become more and more frequent and intense but only a few of them are reproduced in lower latitudes.

10. Radio-circuit Disturbances and the Ionosphere

The immediate causes of the interruptions to radio circuits are the disturbances which take place in the ionosphere on the arrival of the abnormal solar radiation. Although no evidence has yet been produced to show how various types of circuit disturbance can be related to the observed changes in the ionosphere, it is not difficult to deduce how these may come about.

One of the most spectacular changes in the ionosphere during a storm is the fall in critical frequency which is often accompanied by a rise in height of the F_2-region. Both these effects imply a reduction in the maximum-usable frequency for oblique-incidence transmission. Consequently, circuits which are operated by reflection from F_2-region, and particularly those working near m.u.f., are likely to break down completely during this phase of the disturbance. These ionospheric changes are usually too rapid to be of much value as warnings of worse conditions to follow ; furthermore, the initial part of the drop in critical frequency may not be distinguishable from the fluctuations which occur normally and which are not followed by ionospheric storms.

It is sometimes found that this fall in ionization density is preceded by a small rise ; this, however, is not invariably reliable because of the normally observed, but insignificant, changes mentioned in the preceding paragraph.

Although, in theory, a new but lower operating frequency may be found to enable communications to be maintained during an ionospheric storm, this is not always possible in practice. During ionospheric storms, an absorbing region may be formed below E-region, and at times echoes from this region can be seen on vertical-incidence records. Whether this region can be identified with the normal D-region is not important here, but it must inevitably cause high attenuation on the frequencies commonly used on long-distance circuits. Systematic vertical-incidence measurements of absorption in D-region are not often made and no evidence is available as to whether any increase in absorption is detectable in the early stages of storms.

Both a fall in m.u.f. and a rise in absorption can result in the complete disappearance of signals. Even when this does not happen it may be found that, during ionospheric storms, circuits become unworkable because of a high degree of distortion. One of the characteristic features of certain phases of ionospheric storms is the breakdown of the normal vertical gradient of ionization density and the formation of a mass of small clouds of high ionization density. These clouds act as scattering centres and may cause a single incident pulse of radiation to emerge from the ionosphere as a group of pulses. Although this may not be serious in the case of hand-operated Morse stations, it is likely to cause certain types of high-speed circuit or telephony channels to break down completely.

Vertical-incidence ionospheric records made during storm conditions show the development of this cloud structure. It seems to provide a possible explanation for the flutter fading observed by Bennington[15] in the early stages of circuit disturbances. At night, and especially during winter nights in temperate latitudes, such scattering is common even during quiet ionospheric conditions and this makes its interpretation as a precursor of storm conditions inconclusive.

Another characteristic of ionospheric disturbances is the very rapid change in virtual height of F-region with change of frequency. The implication of this is that propagation conditions for a number of adjacent frequencies may be quite different and may in extreme cases result in a carrier and its associated sidebands arriving at a distant point but having a phase and amplitude distribution very unlike that transmitted. The result is the type of distortion known as selective fading but here again the effect is not confined entirely to storm conditions and does not seem likely to be of any assistance in following the progress of a storm.

11. Miscellaneous Effects

Several other possible precursors of disturbed ionospheric conditions are worth mentioning in passing. It has been found that in the early stages of some storms, the direction of arrival of the waves from certain stations changes appreciably.[16] The reasons for this deviation from the usual direction are not known with certainty but it could be accounted for in terms of tilts in the reflecting layer, or off-path transmission due to scattering from ionization clouds. It appears to be most prevalent along paths where the great circle passes near or through the auroral belts.

Solar flares are known to be accompanied by large bursts of radiation on radio frequencies, but similar bursts are sometimes observed during the passage of active areas across the sun's disc even in the absence of a major flare.[17] Whether such radiation can supply any information on solar activity which cannot already be gained by visual means is not certain. It would have the advantage that solar observations would not be interrupted by cloudy weather.

One advantage of observing the sun by radio rather than by light waves is that continuous automatic recording is possible. The main applications of this technique at present are the recording of enhancements in long-wave atmospheric reception as developed by Bureau,[18] and the observation of sudden phase anomalies on signals received from long-wave stations first recorded by Budden, Ratcliffe and Wilkes.[19] Both these phenomena, and especially the phase anomalies, provide an easy way of detecting the occurrence of solar flares in all weathers.

12. Statistical Method of Forecasting

From what has been said up to now it will be obvious that there is no one-to-one correspondence between ionospheric storms or circuit disturbances and any of the solar or terrestrial phenomena which have been investigated so far. Instead, we are confronted with numerous observable effects whose occurrence on any particular day is correlated, sometimes not very closely, with the beginning of a terrestrial disturbance at some future time.

The combination of the observations so as to enable a forecast of the intensity of disturbance expected for a given future day is therefore a problem in multiple correlation. It would first of all be necessary to determine the correlation coefficients for a number of storm precursors with circuit or ionospheric disturbances for a series of time intervals. These could then be used to form a regression equation which would permit the expected value of the disturbance index to be evaluated for any required day in the future. As none of the correlation coefficients is likely to be very high, any such equation would presumably require to have a considerable number of terms. The amount of labour required would be very great and it is doubtful in any case whether the required observational data are available: while most of the solar and magnetic data go back many years, suitable ionospheric measurements are available for little more than through one loop for unit current in the other. According to circumstances the mutual inductance may be larger or smaller than the self-inductance of the common lead. To obtain an idea of the difference consider a numerical example (Fig. 2). The length of the lead AB is 2 cm, the diameter of the wire of the loops is 0·05 cm. The self-inductance of the lead AB, obtained from the formula given below, is 16×10^{-9} henry, but the mutual inductance between the loops I and II is only $12{\cdot}3\times10^{-9}$ henry when the loops are infinitely long and only $9{\cdot}7\times10^{-9}$ henry when the length of the loops is 1 cm.

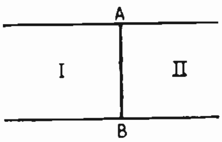


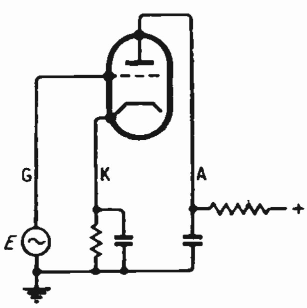
Fig. 2. *The coupling between two circuits depends on the mutual inductance between them, not merely on the self-inductance of AB.*

The above considerations are of importance when we measure the input conductance of amplifier valves and wish to separate the effects due to transit time and due to cathode feedback. In Fig. 3 the leads G, K and A are the connections from the electrodes to the valve socket. The earthing capacitors in the cathode and anode leads (which act as inductances at the frequencies concerned) may be considered as parts of the leads. The input conductance caused by feedback depends on the e.m.fs induced by the anode current in the loops GK and GA ; i.e., on the mutual inductances AK-GK and AK-GA. The loops formed by the electrodes themselves are small and may be disregarded. As to the remainder of the loops, the sources of the e.m.fs are essentially in the connecting leads. We, therefore, use the well-known formulae for the mutual inductance between two parallel wires, in addition to that for the self-inductance of a single wire. These are

$$L = 4{\cdot}6l\,(\log_{10}\frac{2l}{r} - 0{\cdot}434)10^{-9}\text{ henry},$$

where l is the length and r the radius of the wire in cm, and

$$M = 4{\cdot}6l\,(\log_{10}\frac{2l}{d} - 0{\cdot}434)10^{-9}\text{ henry},$$



where l is the length and d the distance apart of the two wires in cm. In both cases the magnetic field inside the wires is supposed to be zero.

Fig. 3. *Basic circuit used for calculation.*

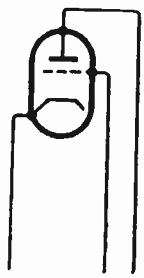
We assume, as a reasonable simplification, that the anode current in Fig. 3 is Eg_m, then the contribution to the input conductance due to feedback is

$$g_m\omega^2[C_{gk}(L_K - M_{KG} - M_{AK} + M_{AG}) - C_{ga}(L_A - M_{AG} + M_{KG} - M_{KA})].$$

Naturally the values for C_{gk} and C_{ga} are those of the 'hot' capacitances.

For an experimental proof of the above the Acorn triode HA1 was mounted so that leads of varying lengths and spacings could be inserted between the valve and the valve socket. Input admittances were measured at about 30 Mc/s ; in particular, changes in input conductance were observed for different positions of the grid lead. One example from various measurements is given.

The length of the leads inserted was 4 cm, the diameter of the leads 0·45 mm, the grid lead lay between the cathode and the anode leads (Fig. 4); the distance between the latter was 13 mm. The grid lead was moved so that (a) the distance from the cathode lead was 2 mm and from the anode lead 11 mm, (b) the distance from the cathode lead was 11 mm and from the anode lead 2 mm.



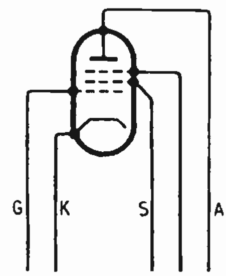


Fig. 4. (left) *Arrangement of leads for measurement on a triode.*

Fig. 5. (right) *Lead arrangement for a pentode.*

In (a) the input conductance was 7·6 μmhos while in (b) it was 16·4 μmhos. The calculation, taking into account the distributed capacitance between the leads gives a difference of 10 μmhos for the two positions. Without additional leads the input conductance was 10·8 μmhos. This shows that it is possible to neutralize the input conductance from cathode coupling by a correct run of the leads, even if the length of the cathode lead is of the order of 5 cm.

The result suggests that in a pentode the positive input conductance due to the grid–cathode capacitance C_{gk} might be neutralized by the negative conductance due to the grid–screen-grid capacitance, without the insertion of an additional inductance in the screen-grid lead. Such neutralization should be particularly easy in a single-ended pentode, for obvious reasons. In Fig. 5 the significant data are : C_{gk}, C_{g-sc},

di_a/dV_g, di_{sc}/dV_g, L_K, L_S, M_{KG}, M_{KS}, M_{AK}, M_{SG}, M_{AG} and M_{AS}. The calculation, though more cumbersome, is essentially the same as with a triode.

For an experimental verification the single-ended pentode 6SJ7 was mounted in the same way as the HA1. Additional leads of varying length could be inserted between the valve base and the valve socket. The differences in input conductance between the conducting and non-conducting state were measured, (a) without additional leads, (b) when leads of 4 cm length and 0·45 mm diameter were inserted. In the latter case the positions of the various leads were changed and the effect on the input conductance observed. Fig. 6 gives a cross-section of the leads in their usual arrangement, as determined by the valve base. The position of the grid lead was the most important. This is easy to understand. When G is near K, the e.m.f. induced in the loop GK from the anode and screen currents is small. On the other hand the e.m.f. in the loop GS is relatively large. The former causes positive and the latter negative input conductance, so that on moving the grid lead both effects tend to change the input conductance in the same direction. This is not the case when the leads A or S are moved towards the cathode.

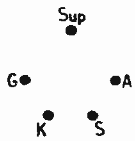


Fig. 6. *Base-pin layout for a 6SJ7 pentode.*

The table shows the input conductance at 32 Mc/s for different distances of the grid lead from the cathode lead. In each case the grid lead lay to the left of the cathode lead, approximately in the direction SK (Fig. 6). The working conditions were $i_a = 3{\cdot}9$mA, $i_{sc} = 1{\cdot}3$mA, $g_m = 1{\cdot}8$ mA/V

	Input conductance
No additional leads	29 μmhos
With additional leads,	
distance GK = 2 mm	28 μmhos
distance GK = 5 mm	33 μmhos
distance GK = 20 mm	40 μmhos

As was the case with the triode HA1 there is a slight decrease in input conductance due to the leads inserted when the distance between the grid and cathode leads is only 2 mm. This shows that the negative input conductance due to the grid–screen–grid capacitance just exceeds the positive conductance due to the grid-cathode capacitance. The increase in input capacitance was in this case 0·4 pF.

The results obtained enable us to draw conclusions as to the effect of the leads inside the valve. The connections from the grid and the cathode to the pins inside the valve are metal strips about 1 cm long, 0·12 mm thick and 0·4 mm wide. The distance between the two strips is 5 mm. The valve pins outside the valve are short and thick and the overall length of the cathode lead from the electrode to the chassis was in the experiment 5 cm, mostly of very thick wire. From this it may safely be assumed that without additional leads the input conductance due to feedback is of the order of 3 μmhos. This shows that by far the largest part of the input conductance of the 6SJ7 is due to transit time.

Applying the formula $\omega^2 L_k C_{gk} di_k/dV_g$ for the input conductance from feedback gives a value of about 11 μmhos (C_{gk} 'hot' was 3·6 pF, the self-inductance of the cathode lead, calculated from its dimensions, was approximately 31×10^{-9} henry). Even if we take into account the influence of the grid–screen–grid capacitance, assuming the inductance of the screen-grid lead to be equal to that of the cathode lead and glibly using the formula $G = \omega^2 L_{sc} C_{g-sc} di_{sc}/dV_g$, we arrive at a total input conductance from feedback of 9·8 μmhos ($C_{g-sc} = 1{\cdot}6$ pF, $di_{sc}/dV_g = 0{\cdot}6$ mA/V) which is about three times the correct value. Hence it is apparent that the usual formula cannot be considered even approximately true, since it gives values which may be in error by a factor of two or three.

While this paper was being prepared my attention was drawn to the fact that the influence of the mutual inductance between leads is mentioned in a paper published in 1938*. In this paper the authors deal with valves in which the grid lead comes out at the top and consider it permissible to neglect the influence of mutual inductance. They also say that, possibly, conditions might be different with single-ended pentodes. Hence, although the fundamental idea of this paper is not novel it appears that its implications have not been sufficiently stressed. In trying to arrive at the value of input conductance caused by feedback one should measure the mutual inductances between the various loops concerned, but not the self-inductance of the cathode lead.

* M. J. O. Strutt and A. van der Ziel, "The Causes for the Increase of the Admittances of Modern High-Frequency Amplifier Tubes on Short Waves," *Proc. Inst. Radio Engrs.*, Vol. 26, p. 1011, August, 1938.

REPORT OF BROADCASTING COMMITTEE

V.H.F. and Television Aspects

THE Committee was appointed by the Lord President of the Council and the Postmaster-General "To consider the constitution, control, finance and other general aspects of the sound and television broadcasting services of the United Kingdom . . . and to advise on the conditions under which these services and wire broadcasting should be conducted after 31st December, 1951." It has now produced its report. It is in two volumes : "Report of the Broadcasting Committee 1949," pp. 327+vii, including Appendixes A-G, price 6s. 6d. and Appendix H, "Memoranda Submitted to the Committee," pp. 583+viii, price 10s. 6d.

In general, the Committee takes the view that broadcasting should continue on much the same lines as hitherto and, although it makes many recommendations on points of detail, it does not suggest any sweeping changes. In particular, it is opposed to 'sponsored' broadcasting.

The report contains very little of direct engineering and technical interest, but there are quite a few recommendations which are of indirect interest through their possible repercussions. It is said that the development of v.h.f. broadcasting should be regarded as important and urgent and that the terms of reference of the Television Advisory Committee should be enlarged to include it as well as television. These are recommendations made to H.M. Government for action as is also the following :—"Where this course appears preferable to establishment of a local station by the Corporation, the Government should be prepared after consultation with the Corporation to license an approved public authority or voluntary organization to establish a local station."

Among the recommendations for action by the B.B.C. there appears the development of v.h.f. broadcasting with the double aim of securing better coverage for the present programmes and for increasing the diversity of programmes. In addition, it is said that the B.B.C.'s present plan for v.h.f. development should be revised to include a number of local stations in selected areas as experiments.

It is, presumably, to guard against the failure of the B.B.C. to provide adequate local services that the recommendation for the licensing of public authorities or voluntary organizations has been made.

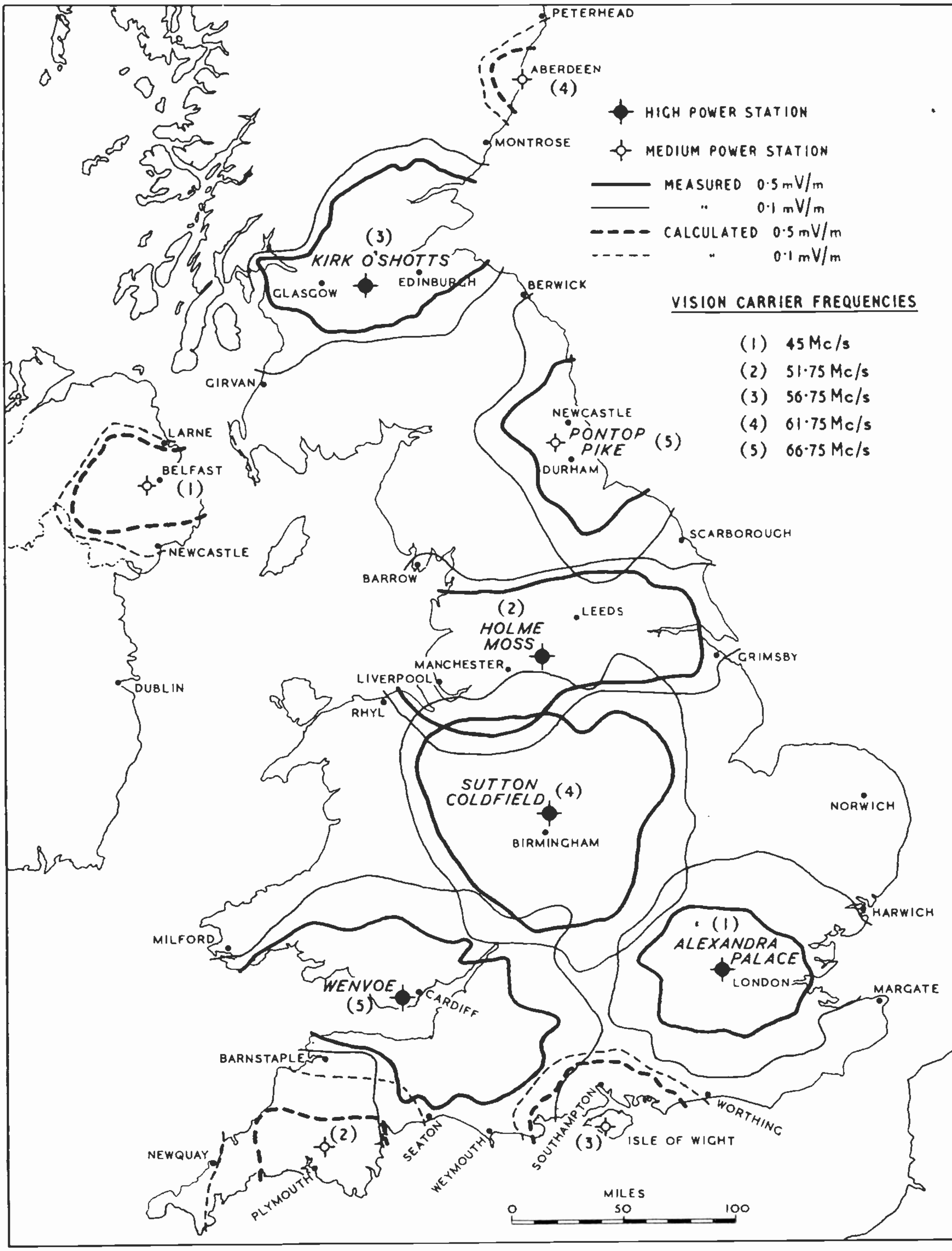
The importance is stressed of giving the public long notice of any change which would affect the type of receiver they must have. No recommendation is made about whether amplitude or frequency modulation should be used. Advice on this matter is presumably outside the terms of reference of the Committee but, in any case, a decision must await the conclusion of the B.B.C.'s Wrotham experiments.

On the television side, the B.B.C. is recommended to have a greater administrative distinction between sound broadcasting and television than between other parts of the broadcasting organization and to consider the possibility of establishing supplementary television studios outside London.

In its evidence to the Committee, the B.B.C. put forward its television plans. These comprise the erection of five main and five subsidiary stations at sites shown in the map reproduced opposite. Each main station will have a separate channel in the 40-70 Mc/s band and each subsidiary station will share the channel of a remotely situated main station. Although a subsidiary station will presumably often act as a relay station, it is emphasized that it will be capable of operation with a different programme from that of the main station with which it shares a channel. The map shows the expected field strength based in some cases on calculation and in others on measurements with low-power transmitters. It can be seen that the greater part of the country will be well provided with television if the present plan reaches completion.

The question of television for cinemas was also considered and the Committee recommends that the Postmaster-General should be prepared to license responsible organizations to use a television system for public showing. This is subject to the provisos that "wavelengths not needed for home television or other prior purposes" can be used for such television, that the pictures are made available to the B.B.C. and others on financial terms approved by the Postmaster-General, and that conditions are imposed to prevent commercially-controlled television from being indirectly introduced into the home.

The report covers a very wide ground and shows that the Committee has given very careful consideration to the conflicting views of those who have given evidence before it.



This map shows the location of the television transmitters which it is proposed to erect in the future with the existing London and Birmingham area stations. The field strengths are computed for a height of 30 ft above ground level and in many cases are derived from site tests. The 0·5-mV/m and 0·1-mV/m contours represent the expected limits of first- and second-class service areas.

TRIODE TRANSMISSION NETWORKS

Under Linear Negative-Grid Conditions

By A. W. Keen, A.M.I.E.E., M.I.R.E.

(*E.M.I. Research Laboratories, Ltd.*)

SUMMARY.—The small-amplitude alternating-current signal behaviour of the negatively-biased triode valve is represented by a π configuration in which the grid-anode element is allowed to assume negative values in its real component in order to avoid the use of fictitious voltage or current generators. The value of the grid-anode impedance is computed for the six possible orientations of the valve in three types of circuit configuration and the validity of the representation checked by computing the driving-point impedance and voltage gain for all eighteen cases. An appendix gives the matric expressions corresponding to the transmission equivalents of three basic networks.

1. Introduction

In electronic systems thermionic valves and their coupling networks generally occur alternately to form chains through which a signal is transmitted, usually for control or communications purposes. As the art has developed, and particularly as a result of the increasing complexity of the signals handled, circuit engineers have resorted more and more to the classical theory of four-terminal transmission-type networks (quadripoles) in the synthesis of the coupling circuits. In view of the extent to which this theory has been developed it would appear to be advantageous to treat the thermionic valve in a similar manner; moreover, pedagogic and aesthetic motives lead one to seek a corresponding approach so that the entire system may be treated as a continuous and uniform structure.

The special treatment generally accorded to amplifier-type thermionic valves arises from their active properties since active devices are excluded from the class of passive elements used in the synthesis of the equivalent networks of conventional linear-network theory. Hitherto this active property has been accounted for by the use of fictitious idealized generators of voltage or current. In the first approximation a generator is associated with a two-terminal passive impedance (cf. Thévenin's Theorem) on the basis of the equivalent anode circuit 'theorem.' Although a π configuration of capacitors was superimposed by H. W. Nichols[1] to account for the internal inter-electrode capacitances the resultant network remained essentially a two-terminal structure, the capacitances being of secondary importance. Later, E. L. Chaffee[2] treated the case of the conductive grid by the addition of a second fictitious generator-impedance pair in analogy with the equivalent anode circuit.* Finally, F. B. Llewellyn[3] using a π network, showed by a mesh current artifice that one of Chaffee's two generators could be dispensed with. The present paper may be regarded as a sequel to Llewellyn's work in that the remaining generator is eliminated in favour of a negative-impedance element. In fact, the work arose *ab initio* in the course of a graphical study of negative volt-ampere characteristics which forms the subject of a complementary paper.[4]

In view of the dissipative character of ordinary resistance the property of negative resistance has been ascribed to sources of electrical energy so that, in seeking as an alternative to the imaginary generator an active element more directly related to the idealized passive elements (viz. resistance, inductance and capacitance), it is natural to make use of the negative-resistance concept. It is characteristic of the thermionic valve arranged as an amplifier that signal energy appears in its output circuit only when a signal voltage is applied to the input terminals even though the input impedance be substantially infinite. In this respect the required negative element must behave similarly to passive elements, which develop an e.m.f. only upon application of current but otherwise remain non-dissipative. The e.m.f. developed by the negative element must, however, be forward- rather than backward-acting. The relationship between the required element and the conventional passive elements is, therefore, as shown vectorially in Fig. 1 where the vector representing the e.m.f. developed across a negative resistor forms with the three corresponding back-e.m.f. vectors associated with resistance, inductance and capacitance, a complete symmetrical set of vectors. Expressed alternatively, the properties possessed by the points (1,0), (0,j) and (0,$-j$), representing the unit elements of R, L and C respectively in the complex impedance plane, are possessed also by (-1,0). This may therefore be used to define the unit negative resistor and to justify its use with the passive elements to form a group

* This possibility had been mentioned by Nichols, loc cit.

MS accepted by the Editor, December 1949

capable of representing networks containing both active and passive devices.

In using negative elements in equivalent valve networks conductive coupling to all available terminal-pairs must be provided so that however the signal may be applied to the valve the negative element is supplied with signal current and enabled to generate a forward-acting e.m.f. The networks to be presented are all of π form and based on the arrangement shown in Fig. 1(d).

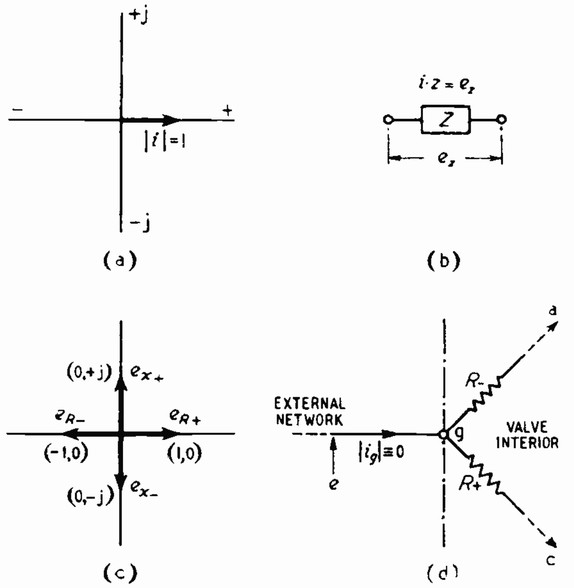


Fig. 1. *The application of unit current; (a) to a two-terminal impedance, (b) develops a p.d. which measures the value of the impedance. The p.d. vectors for four special cases are shown at (c); (d) basis chosen for derivation of stable triode networks incorporating negative-impedance elements.*

The portion of the space current attributable to the attractive influence of the grid, but which the latter fails to collect, is accounted for by the connection of a negative element in the grid-anode path and of a corresponding positive element in the cathode-grid path. In the case of negative-grid operation the negative element automatically assumes a magnitude relative to that of the positive element such that the resultant grid current is zero; an additional element may be placed in parallel with the existing cathode-grid element to account for grid current due to positive-bias operation.

This basic arrangement leads to what will be recognized as resistive analogues of Boucherot networks.[5]

2. Derivation of Basic Network

The functional dependence of the grid and anode currents of the triode on the potentials applied to those electrodes with respect to the cathode potential may be expressed in conventional differential notation thus :—

$$di_1 = \frac{di_1}{de_{01}}\,de_{01} + \frac{di_1}{de_{02}}\,de_{02}$$
$$di_2 = \frac{di_2}{de_{01}}\,de_{01} + \frac{di_2}{de_{02}}\,de_{02} \qquad \ldots \quad (2.1)$$

where the numeral subscripts 0, 1, 2 denote cathode, grid and anode respectively. It is more convenient to write these relations in matrix form, as follows :—

$$\begin{Vmatrix} di_1 \\ di_2 \end{Vmatrix} = \begin{Vmatrix} \gamma_{01} & \gamma_{21} \\ \gamma_{12} & \gamma_{02} \end{Vmatrix} \cdot \begin{Vmatrix} de_{01} \\ de_{02} \end{Vmatrix} \qquad \ldots \quad (2.2)$$

in which the γ_{ij} are admittance coefficients corresponding to the partial derivatives of (2.1). The admittance matrix represents the internal mechanism of the valve and when operated upon by the voltage matrix post-multiplier yields the current matrix. In the present paper only the linear case will be considered so that the γ_{ij} will be pure numerics.

The existence of the array of admittance coefficients in (2.2) implies the possibility of current flow between the electrodes concerned and requires the existence of corresponding conducting paths. A graph of the valve considered as a network may therefore be constructed by plotting three nodal points, one for each available electrode, and joining them by four branches, one for each admittance, as shown in Fig. 2(a).

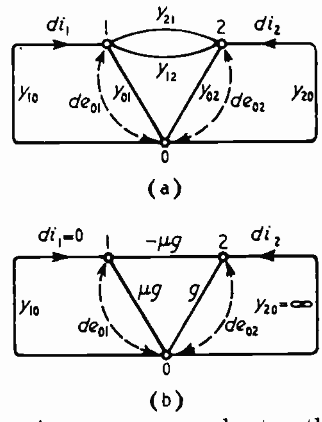


Fig. 2. *Derivation of the equivalent transmission network of the triode; (a) graphical representation of the matrix equation, (b) reduction of (a) for low-frequency negative-grid operation with infinite load admittance.*

As an approach to the inter-relationships between the γ_{ij} two special cases may be considered. Thus with the node-pair 0,2 externally short-circuited γ_{21}, γ_{02} effectively vanish and from the node-pair 0,1 the network appears as a two-terminal impedance consisting of γ_{01}, γ_{12} in parallel. With the further restriction of zero current in the grid lead 10 the admittances γ_{01}, γ_{12} must be of equal magnitude and opposite sign ; the reduced network may therefore be regarded as the resistive analogue of the parallel *LC* anti-resonant tuned circuit.

Alternatively 0,1 may be short-circuited in which case γ_{01}, γ_{12} effectively vanish. If grid current is precluded γ_{21} will also vanish, thereby removing the need to postulate that $\gamma_{10} = \infty$ in eliminating γ_{01}, γ_{12}. The valve then appears as a single element γ_{02} directly in parallel with 0,2. Since γ_{12} in the first case, and γ_{21} in the second, are both determined by the restriction of grid current to zero it is convenient to treat the two admittances as a single bilateral (i.e., $\gamma_{12} \neq \gamma_{21}$) branch whose admittance automatically assumes such a value, depending on the external circuit conditions, that i_{10} remains identically zero. Since i_{20} is not so restricted the entire network is asymmetrical.

It is convenient to express γ_{01} in terms of γ_{02}, thus :—

$$\gamma_{01} = \mu . \gamma_{02} \qquad (2.3)$$

In general the factor μ relating the two admittances is complex but with slowly varying applied voltages will be a pure numeric. It measures the relative efficacy of the grid and the anode in drawing space current from the cathode and it has been shown to be very nearly equal to the ratio of the cathode-grid and cathode-anode interelectrode capacitances ; i.e.,

$$\mu = C_{01}/C_{02} \qquad (2.4)$$

It may be identified with the familiar voltage amplification factor :—

$$\mu = g_m r_a \qquad (2.5)$$

which may be written

$$\mu = \gamma_{01}/\gamma_{02} \qquad (2.6)$$

in conformity with the notation adopted in the foregoing.[6, 7]

Since the above development is independent of the time rate of change of the applied voltages, and the present paper will not deal with high-frequency conditions, the γ_{ij} terms may be replaced by corresponding conductances g_{ij} ; moreover, by making use of the factor μ all three conductances may be expressed in terms of the cathode-anode conductance g, thereby allowing the numeral subscripts to be dropped. The resultant network, which represents the simplest case of Fig. 2(a), is shown at (b).

In so far as Fig. 2(b) has been developed from a consideration of two special cases involving short-circuited terminations, it is representative only of the valve itself. In practical cases the terminating impedances must be non-zero in order to produce an output voltage so that the forward value of the grid-anode conductance g_{12} will assume a different value from $-g_{01}$ in preserving zero grid current. The deviation from the value obtained in the unloaded reference condition will be termed the reflected component of g_{12} since it will depend on the external network faced by the valve, and will be denoted by a star superscript. Moreover, where the latter includes reactive as well as resistive elements the reflected component will be complex, thus :—

$$^*\gamma_{12} = -g_{01} + \gamma_{12} \qquad (2.7)$$

The appearance of the reflected component in the equivalent transmission network is characteristic of the use of negative impedances in accounting for the generation of forward-acting electromotive force. Even so, this feature may be regarded as a disadvantage of the present method of representation ; on the other hand, it has the merit, not shared by other methods, of illustrating graphically the beneficial effect of external elements in stabilizing the internal valve impedances, the latter being generally considerably less stable than those comprising the coupling networks.

Despite the importance of the distinction between the two components $-g_{01}$, γ_{12}^* their sum may be computed more directly than the reflected component (except in simple cases where the latter may often be written by inspection ; see Section 4). As a preliminary to the evaluation of this quantity it is desirable to consider the permissible forms of the entire network, and the possible modes of transmission through it, in a comprehensive manner so as to derive a suitable basis for the tabulation.

3. Transmission Forms of Triode Network

In practical circuits the differential voltages de_{01}, de_{02} are rarely independent ; usually de_{01} is the applied voltage change (the signal) and de_{02} arises as a result of the insertion of a suitable impedance in the external branch 20. The valve then forms a transmission network between the source of the input voltage de_{01} and the load across which the output voltage de_{02} is developed. In the transmission process the signal is generally altered in form and magnitude and may suffer time delay (phase shift), although in an amplifier, for example, it is desired merely to achieve scalar multiplication of it. The availability of three connections for the external network allows a transmission arrangement having distinct input and output terminal pairs, but with one terminal common to each, to be taken in six ways in all, as follows :—

1. Grid-anode
2. Grid-cathode
3. Cathode-anode

} Forward transmission

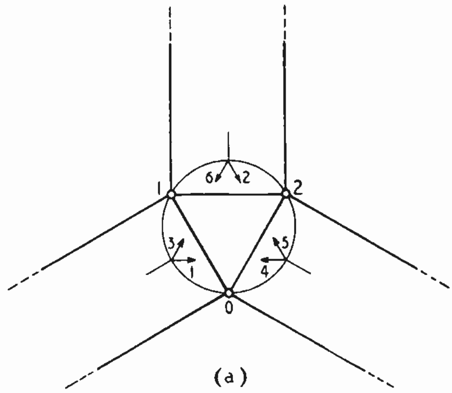
4. Anode-grid
5. Cathode-grid
6. Anode-cathode

} Backward transmission

The common terminal is often earthed and the mode of transmission in cases 1-3 are accordingly denoted in U.S.A., as 'grounded-cathode,' 'grounded-plate,' and 'grounded-grid' operation respectively. The six transmission paths enumerated are shown schematically in Fig. 3(a).

In considering the relative importance and properties of these various paths it must be remembered that in practice both forward and backward transmission must be considered (the one desired, the other spurious) in any particular arrangement so that since cases 1-3 are all employed for forward transmission the remainder are also of practical significance. Moreover, it is common practice to improve the transmission characteristics of the valve by the addition of controlled negative feedback in which case the paths 4-6 become as important as the forward paths 1-3.

The application of feedback involves coupling the input and output branches of the valve network. In cases 3-6 the branch of the π network in series with the transmission path is bilateral so that coupling between input and output already exists, but in cases 1-2 the unilateral property assigned to the grid-anode impedance requires an additional coupling element and two possibilities arise according as the additional path acts in series or in shunt with the transmission path, as shown in Fig. 3(c) and (d).



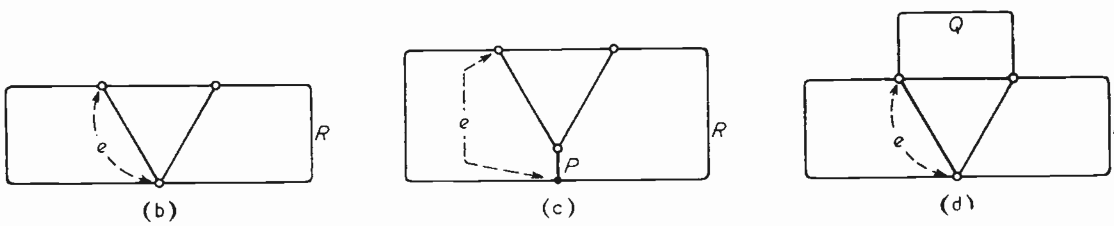


Fig. 3. *(a) Transmission paths associated with the triode ; (b) basic network configuration ; (c) addition of coupling element P in shunt with transmission path ; (d) addition of coupling element Q in series with transmission path.*

The three basic configurations of Fig. 3 (b) to (d) are of significance in all six paths enumerated above ; accordingly the value of the reflected component of the grid-anode impedance will be computed in all 18 cases to allow the gain and impedances to be derived.

It should be mentioned that difficulties arise as a result of distinguishing transmission paths in valve networks when feedback is appreciable.[8] The network should therefore be treated as a complete entity and a feature of the methods presented here is the derivation of results without regard to the presence of feedback paths. Moreover, the boundary between the valve and its external network may be ignored, as when applying transformations.

4. Evaluation of Grid-Anode Impedance*

In some cases the value of the grid-anode impedance required to satisfy the condition of zero grid current flow may be written by inspection ; an example is provided by the grid-anode amplifier, whose equivalent transmission network is given at Fig. 4 (a), where†

$$\rho = - \left\{ \frac{r}{\mu} + (r, R) \right\} \quad .. \quad .. \quad (4.1)$$

Occasionally the grid lead forms the diagonal of a bridge configuration having the driving voltage in its other diagonal so that when the external impedances are known, the grid-anode impedance may be evaluated by the familiar balance equation. Thus with grid-anode transmission over the basic configuration shown in Fig. 3 (d) the latter relationship yields directly :—

$$\rho = rQ/\mu R \quad .. \quad .. \quad .. \quad .. \quad (4.2)$$

Fig. 3 (d) has been redrawn as a bridge for the purpose of illustration in Fig 4 (b).

It is often possible to make use of the star-delta transformation in determining ρ. The

* Although it is generally more convenient to work in terms of admittance, in this and following parts, which deal with the analysis of specific networks, the results will be expressed as impedances in deference to the known preference of engineers for this form. In addition the subscripts 0, 1, 2, will be dropped for their more significant literal equivalents c, g, a, and the grid-anode impedance will be denoted ρ.

† The notation (r, R) denotes parallel connection of r, R.

impedance star comprising r/μ, r, and P formed about the cathode node of the cathode-loaded grid-anode amplifier, whose equivalent transmission network appears in Fig. 4 (c), transforms to a delta containing :

$$\begin{aligned} Z_{c'g} &= r'/\mu \\ Z_{ga} &= rr'/\mu P \\ Z_{ac'} &= r' \end{aligned} \quad \ldots \quad \ldots \quad \ldots \quad (4.3)$$

where $r' = \{r + (\mu + 1) P\}$ .. .. (4.4)

The value of ρ and Z_{ga} combined in parallel can then be written by inspection, as in the first example above, and ρ separated out as :—

$$\rho = -\left\{\frac{r}{\mu} + [r, (P + R)]\right\} \quad \ldots \quad (4.5)$$

Although this result could have been written by inspection this development is significant not only as an example of the possibility of the use of such a transformation, and without regard to the boundary between the valve and its associated network, but also for the derivation of an equivalent valve having an unloaded cathode [c.f. (a) and (c) of Fig. 4]. The insertion of the cathode load is equivalent to modification of the anode impedance r and its related impedances by the factor r'/r. This result facilitates treatment of configurations containing both impedances P and Q of Fig. 3 (c) and (d).

It is interesting to obtain confirmation of this result by applying the inverse (i.e., delta-star) transformation to the same circuit. The delta configuration formed by r, P, R transforms to the star comprising :—

$$\begin{aligned} Z_{oa} &= rR/r'' \\ Z_{oc} &= rP/r'' \\ Z_{oc'} &= PR/r'', \end{aligned} \quad \ldots \quad \ldots \quad \ldots \quad (4.6)$$

where $r'' = r + P + R$, ... (4.7)

as shown in Fig. 4 (d). For zero grid current the branch currents gco, gao must sum to zero (i.e., the loop impedance gcop must total zero), thus allowing ρ to be written down as :—

$$\rho = -\left\{\frac{r}{\mu} + [r, (P + R)]\right\} \quad \ldots \quad (4.8)$$

which agrees with the previous result (4.5). The lower equivalent network in Fig. 4 (d) will be found useful in Section 6 where it facilitates evaluation of both grid-cathode and grid-anode gain factors.

In general, it is necessary to evaluate ρ by direct analysis and, provided meshes are chosen to set up two equal and opposite currents in the grid lead, this method is preferable to the nodal

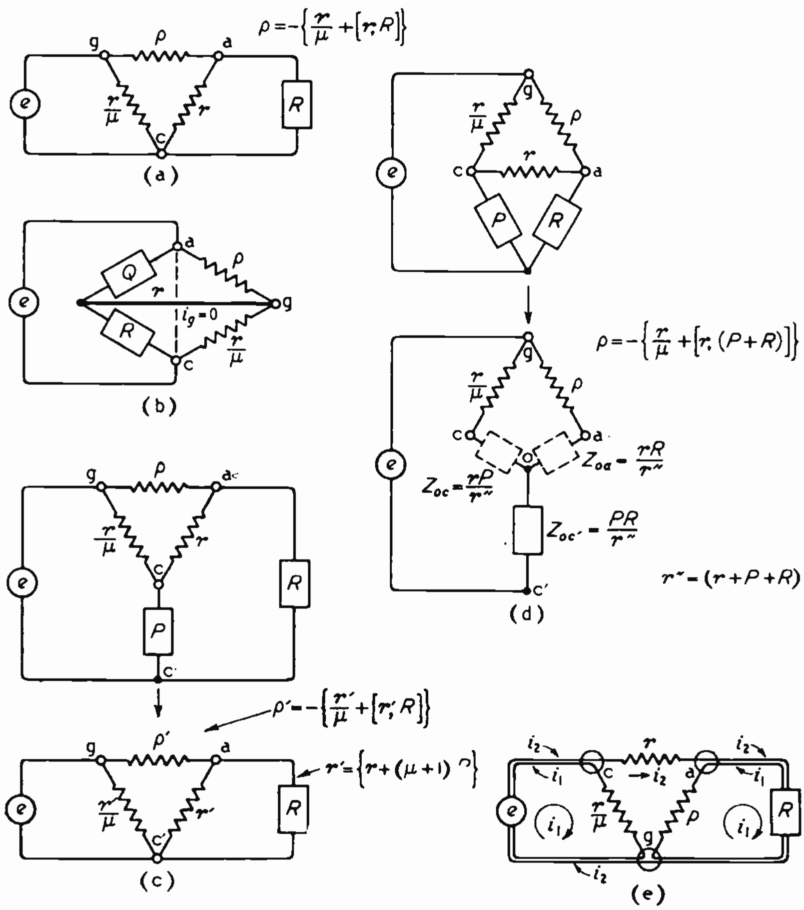


Fig. 4. *Evaluation of ρ; (a) by inspection for grid-anode transmission; (b) by bridge method where grid lead and driving voltage branch occur as diagonals; (c) for cathode-loaded grid-anode amplifier, using star-delta transformation; (d) for cathode-loaded grid-anode amplifier, using delta-star transformation; (e) for cathode-anode transmission by mesh analysis, i_1 and i_2 are mesh currents. Input and output branch currents are both (i_1+i_2) since current in (negative) grid lead (i_1-i_1) is zero. (Lines joining elements represent mesh currents rather than actual conductors).*

treatment. Taking the cathode-input amplifier as an example and resolving the equivalent transmission network into the system of meshes shown in Fig. 4 (e) the corresponding equations may be obtained as :—

$$\left(R - \frac{r}{\mu}\right)i_1 + \left(R + r\right)i_2 = 0$$

$$(R + \rho)i_1 + Ri_2 = 0.$$

Eliminating i_1 and i_2,

$$\left(R - \rho\right)\left(R + r\right) = \left(R - \frac{r}{\mu}\right)R$$

so that $\rho = -(\mu + 1)\, rR/\mu\,(r + R)$ .. (4.9)

By one or other of the foregoing methods* the value of ρ has been computed for all of the eighteen cases set out in Section 3. It may be expressed as the sum of $-r/\mu$ and a series reflected component or as a product which may be resolved into $-r/\mu$ and a parallel reflected component; the former expression is simpler and its reflected component has been set out in Table 1.

In the next two parts it is proposed to confirm the validity of the development given in the foregoing sections by demonstrating that both the driving-point impedance and the voltage-gain factor of particular networks may be obtained by direct analysis of the equivalent transmission network taking the appropriate values of ρ from Table 1.

5. Evaluation of Driving-point Impedance

In the synthesis of transmission systems consideration must be given to the input and output impedances of the constituent sections and in certain cases it may be necessary to insert sections solely for the purpose of removing mismatches or for buffering a section having a high output impedance from a succeeding section whose input impedance is considerably lower. The present method is particularly suitable for evaluating these impedances once ρ has been determined (Table 1), since the valve, being free of current or voltage generators and represented entirely by impedance elements, requires only reduction (together with its associated impedances) from a generally complex series-parallel combination to a single resultant impedance. Only the input or driving-point impedance need be computed for the six transmission paths associated with the triode, and this has been done for all three configurations illustrated in Section 3, the results being set out in Table 2.

As an example the cathode-input amplifier will be taken again. Inspection of Fig. 4 (e) shows that the driving-point impedance may, with the notational convention defined in Section 4, be written :—

$$Z_i = \left[\frac{r}{\mu}, r + (\rho, R)\right]$$

Substituting the value of ρ obtained in (4.9) this expression reduces to :—

$$Z_i = (r + R)/(\mu + 1) \qquad .. \quad .. \qquad (5.1)$$

Apart from its directness this method is, in certain cases, of considerable instructional value as, for example, in showing clearly the impedance-multiplying property of a valve having anode-

* See also Appendix 2.

TABLE 1 Values of Reflected Component of Grid-Anode Impedance*

Transmission Path	Configuration Fig. 3(b)	Fig. 3(c)	Fig. 3(d)
Grid-Anode	$-\dfrac{r.R}{r+R}$	$-\dfrac{r(P+R)}{r+P+R}$	$-\dfrac{rR(\mu Q - r)}{\mu(rQ + QR + Rr)}$
Grid-Cathode	$-\dfrac{r.R}{r+R}$	$-\dfrac{r(P+R)}{r+P+R}$	$-\dfrac{rR(\mu Q + r)}{\mu Q(r+R)}$
Cathode-Anode ..	$-\dfrac{r(\mu R - r)}{\mu(r+R)}$	$-\dfrac{r(\mu R - r)}{\mu(r+R)}$	$-\dfrac{rQ(\mu R - r)}{\mu(rQ + QR + Rr)}$
Anode-Grid	∞	$-\dfrac{r(\mu P + r)}{\mu P}$	$+\dfrac{r(Q+R)}{\mu R}$
Cathode-Grid	$+\dfrac{r}{\mu}$	$-\dfrac{r(\mu P - r)}{\mu(P+r)}$	$+\dfrac{r(Q+R)}{\mu Q}$
Anode-Cathode ..	$-\dfrac{r(\mu R + r)}{\mu R}$	$-\dfrac{r(\mu R + r)}{\mu R}$	$-\dfrac{rQ(\mu R + r)}{\mu R(Q + r)}$

* Note : Total grid-anode impedance $(\rho) = -r/\mu +$ (reflected component).

grid feedback over a capacitor to a resistive grid-cathode load.[9] This arrangement [see Fig. 5 (a)] will be recognized as an example of the configuration shown in Fig. 4 (b) so that ρ may be written as $rQ/\mu R$, using the bridge-balance relationship. Thus for R resistive the multiplier

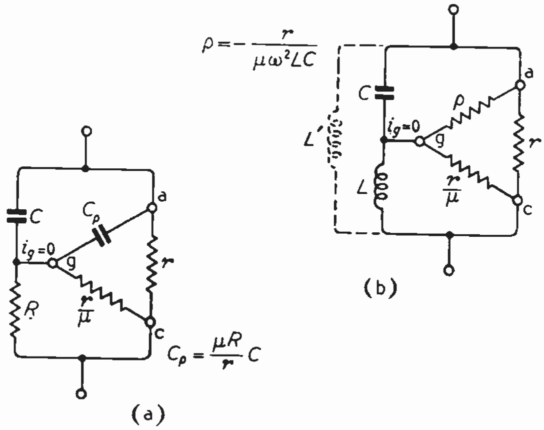


Fig. 5. (a) *Use of CR anode-grid feedback network to produce magnified internal grid-anode capacitance ; (b) use of LC anode-grid feedback network to produce frequency dependent negative resistance in the internal grid-anode branch.*

$r/\mu R$ is a pure numeric and by setting $r = R$ may be made equal to $1/\mu$; since Q is inversely proportional to C the latter is reflected as a capacitance μC in the internal grid-anode impedance. The driving-point impedance may be written as :—

$$Z_i = \left[r, \left(\frac{r}{\mu}, R\right) + 1/j\omega C \left(1 + \frac{\mu R}{r}\right)\right]$$

$$= r\left(R + \frac{1}{j\omega C}\right) \Big/ \left[r + (\mu + 1)R + \frac{1}{j\omega C}\right]$$

$$\approx \frac{1}{\mu}\left(r + \frac{1}{j\omega C}\right) \text{ when } r \approx R \text{ and } \mu \gg 1 \quad .. (5.2)$$

Systematic examination of the configuration of Fig. 4 (b) with elements of other kinds in the anode-grid coupling potentiometer reveals the possibility of constructing a frequency dependent impedance having a negative real component. For if R is replaced by an inductor L the internal grid-anode impedance becomes :—

$$\rho = -\, r/\mu\omega^2 LC \quad .. \quad .. \quad .. \quad (5.3)$$

which combines with r and r/μ [See Fig. 5 (b)] to form the resultant :—

$$r_i = \left[r, \left(\rho + \frac{r}{\mu}\right)\right] = r\left(\omega^2 LC - 1\right) \Big/ \left\{(\mu + 1)\,\omega^2 LC - 1\right\}$$

which is negative at frequencies below

$$f_o = 1/2\pi\,(LC)^{+\frac{1}{2}}.$$

The parallel reactance due to the feedback potentiometer may be tuned out at any desired frequency by adding a parallel inductor to form an anti-resonant circuit. The resultant network will be recognized as the Hartley Oscillator and the development suggests the possibility of applying the present method of treatment to such circuits.

6. Evaluation of Voltage Gain

It has been mentioned from time to time in the literature of transmission networks that the insertion of a negative resistor in series or in

TABLE 2 Values of Driving-point Impedance

Transmission Path	Configuration		
	Fig. 3(b)	Fig. 3(c)	Fig. 3(d)
Grid-Anode	∞	∞	$\dfrac{rQ + QR - Rr}{r + (\mu + 1)R}$
Grid-Cathode	∞	∞	$\dfrac{rQ + (\mu + 1)QR + Rr}{r + R}$
Cathode-Anode ..	$\dfrac{r + R}{\mu + 1}$	$\dfrac{r + R}{\mu + 1}$	$\dfrac{rQ + QR + Rr}{r + (\mu + 1)Q}$
Anode-Grid	r	$r + (\mu + 1)P$	$\dfrac{r(Q + R)}{r + Q + (\mu + 1)R}$
Cathode-Grid	$\dfrac{r}{\mu + 1}$	$\dfrac{r + P}{\mu + 1}$	$\dfrac{r(Q + R)}{r + R + (\mu + 1)Q}$
Anode-Cathode ..	$r + (\mu + 1)R$	$r + (\mu + 1)R$	$\dfrac{rQ + (\mu + 1)QR + Rr}{r + Q}$

shunt with a transmission line sets up regenerative reflection currents which provide an insertion gain if the magnitude of the negative resistor is suitably chosen in relation to the characteristic impedance of the line.[10,11] The triode having been shown to be representable by a π section composed of two positive and one negative (in most cases) resistors it will be of interest to compute its voltage gain factor (G) for different orientations of the valve in relation to the transmission net-

Simple examples are :—

(i) Grid-anode transmission (normal amplifier).

$$G\ (\mathrm{g},\ \mathrm{a}) = \frac{(r,\ R)}{\rho + (r,\ R)} = -\frac{\mu R}{r + R} \quad .. \quad (6.1)$$

(ii) Grid-cathode transmission (Cathode-follower).

$$G\ (\mathrm{g},\ \mathrm{c}) = \frac{(r,\ R)}{r/\mu + (r,\ R)} = +\frac{\mu R}{r+(\mu+1)R} \quad (6.2)$$

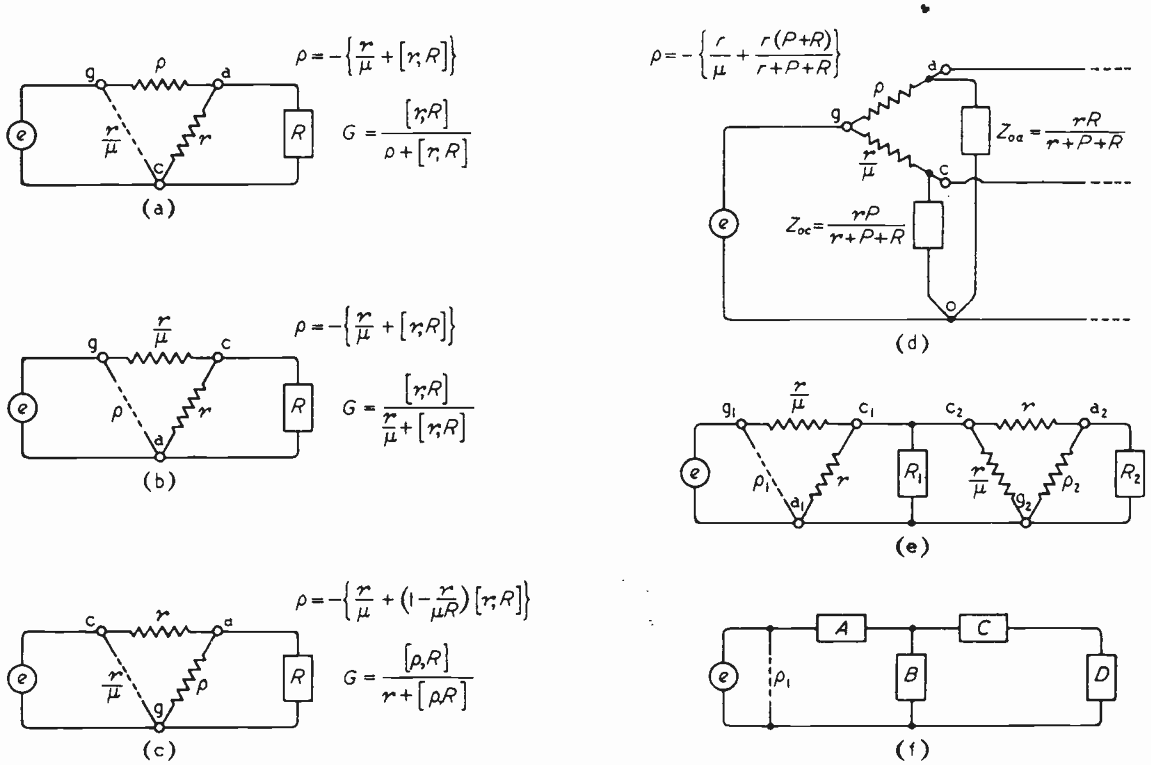


Fig. 6. *Equivalent gain potentiometers of three basic amplifier circuits ; (a) normal amplifier, (b) cathode follower, (c) cathode-input amplifier, (d) equivalent transmission network for computation of grid-anode and grid-cathode voltage gain of the normal amplifier having an anode load R and a cathode load P, (e) equivalent transmission network and configurational form, (f) equivalent transmission network of the double-triode amplifier.*

work formed with the external circuit. This has been done for all eighteen cases derived in Section 3 and the results set out in Table 3. In all cases one element of the π section representing the valve occurs in parallel with the input voltage and may therefore be ignored in the gain computation, while the other two elements form a potentiometer with the load impedance. Accordingly, ρ being known (Table 1), the gain may be written down directly in the form $Z_s/(Z_s + Z_p)$ where Z_s, Z_p are the resultant series and shunt arms of the potentiometer, and it is unnecessary to solve equations involving currents and potential differences.

(iii) Cathode-anode transmission (Cathode-input amplifier).

$$G\ (\mathrm{c},\ \mathrm{a}) = \frac{(\rho,\ R)}{r + (\rho,\ R)} = +\frac{(\mu+1)R}{r + R} \quad .. \quad (6.3)$$

Comparison of the three cases [see Fig. 6 (a-c)] shows that the negative grid-anode resistance must form part of the gain potentiometer for a gain greater than unity to be obtained. When in the series arm, the negative resistor causes reversal of signal polarity (G negative) and when in the shunt arm of the potentiometer it provides gain without polarity reversal (G positive).

In computing the grid-anode and grid-cathode gain factors of the cathode-loaded grid-anode amplifier, as an example of configuration Fig. 3 (c), use may be made of the delta-star transformation shown at Fig. 4 (d). Since ρ assumes such a value that the mesh currents in Z_{oc}' sum to zero the network reduces from the gain point of view to two gain potentiometers in tandem, as shown in Fig. 6 (d), thereby allowing the gain factors to be written by inspection, as :—

(i) Grid-anode gain.

$$G'\ (\text{g, a}) = \frac{Z_{oa}}{\rho + Z_{oa}} = -\frac{\mu R}{\{r+(\mu+1)P+R\}} \quad \ldots \quad \ldots \quad \ldots \quad (6.4)$$

(ii) Grid-cathode gain.

$$G'\ (\text{g, c}) = \frac{Z_{oc}}{r/\mu + Z_{oc}} = +\frac{\mu P}{\{r+(\mu+1)P+R\}} \quad \ldots \quad \ldots \quad \ldots \quad (6.5)$$

In the evaluation of the formal expressions ρ is taken from Table 1.

As examples of networks having an impedance bridging input and output terminals [configuration Fig. 3 (d)] the normal amplifier with anode-grid feedback and the grid-cathode loaded cathode follower will be taken. The gain factors are (See alternative forms in Table 3) :—

(i) Grid-anode.

$$G''\ (\text{g, a}) = \frac{(r,\ R)}{(\rho,\ Q)+(r,\ R)} = -\frac{\mu}{r}\left\{\frac{Q-(r/\mu)}{Q+(r,\ R)}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (6.6)$$

(ii) Grid-cathode.

$$G''\ (\text{g, c}) = \frac{(r,\ R)}{(r/\mu, Q)+(r.R)} = 1\Big/\left\{1+\frac{(r+R)Q}{(r+\mu Q)R}\right\} \quad \ldots \quad \ldots \quad \ldots \quad (6.7)$$

The double-triode cathode-coupled amplifier is typical of two different type sections connected in cascade. Its equivalent transmission network [See Fig. 6 (e)] has the form shown at Fig. 6 (f), for which the voltage gain is :—

$$G = BD/(AB + AC + AD + BC + BD) \quad \ldots \quad (6.8)$$

Substituting the actual impedance values, assuming identical characteristics in the two triodes, as follows :—

$$A = r/\mu$$
$$B = rR_1/\{r + (\mu + 1)\ R_1\}$$
$$C = r$$
$$D = -(\mu + 1)\ rR_2/(\mu R_2 - r)$$

yields, after some reduction :—

$$G\ (\text{g}_1, \text{a}_2) = \mu\,(\mu + 1)R_2\Big/\left\{\left(\frac{r}{R_1}+\mu+1\right)(r+R_2)+(\mu+1)\,r\right\} \quad \ldots \quad \ldots \quad \ldots \quad (6.9)$$

as has been derived by other methods elsewhere in the literature.[12-15]

The gain factors for all eighteen cases of Section 3 are given for reference in Table 3.

TABLE 3 Values of Voltage Gain Factor

Transmission Path	Configuration		
	Fig. 3(b)	Fig. 3(c)	Fig. 3(d)
Grid-Anode	$-\dfrac{\mu R}{r+R}$	$-\dfrac{\mu R}{r+(\mu+1)P+R}$	$-\dfrac{\mu R[1-(r/\mu Q)]}{r+R+(rR/Q)}$
Grid-Cathode	$+\dfrac{\mu R}{r+(\mu+1)R}$	$+\dfrac{\mu R}{r+(\mu+1)P+R}$	$+\dfrac{\mu R[1+(r/\mu Q)]}{r+(\mu+1)R+(rR/Q)}$
Cathode-Anode ..	$+\dfrac{(\mu+1)R}{r+R}$	$+\dfrac{(\mu+1)R}{r+R}$	$+\dfrac{(\mu+1)R\{1+[r/(\mu+1)Q]\}}{r+R+(rR/Q)}$
Anode-Grid	0	0	$-\dfrac{R}{Q+R}$
Cathode-Grid	0	0	$+\dfrac{R}{Q+R}$
Anode-Cathode ..	$+\dfrac{R}{r+(\mu+1)R}$	$+\dfrac{R}{r+(\mu+1)R}$	$+\dfrac{R(1+\frac{r}{Q})}{r+(\mu+1)R+\frac{rR}{Q}}$

7. Conclusion

It is believed that the foregoing treatment will be of interest as an investigation of an alternative representation of the triode valve, under the restrictions stated, to conventional equivalent circuits. In providing a different approach it throws a new light on the relationship between the valve and its external network, and for this reason would appear to have some instructional value. The emphasis placed on the transmission aspect of the valve performance corresponds to its operation upon the signal and provides equivalent networks analogous to those employed for coupling purposes. The method is particularly suitable for displaying the impedance properties of the valve and for computing its input and output impedances. Other active devices such as the newly developed Transistor are amenable to similar treatment. Progress has been made in extending the analysis to multi-electrode types and to oscillator circuits, on which aspects it is hoped to publish further papers.

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APPENDIX 1

Matric Representation of Principal Networks

It is of interest to derive the matrices corresponding to the principal cases of the networks treated in the foregoing paper. The sign conventions adopted by E. A. Guillemin[16] and succeeding writers will be preferred to the original formulation of F. Strecker and R. Feldtkeller[17] in order to facilitate comparison with more recent literature[18, 19], and are shown in Fig. 7.

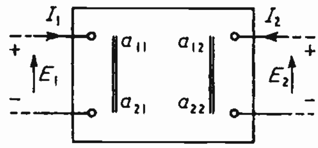

Fig. 7. *Matric conventions for generalized quadripole.*

The general forms of the principal matric equations connecting the input (E_1, I_1) and output (E_2, I_2) quantities of the quadripole are :—

$$\begin{Vmatrix} E_1 \\ E_2 \end{Vmatrix} = \begin{Vmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{Vmatrix} \cdot \begin{Vmatrix} I_1 \\ I_2 \end{Vmatrix}$$

$$\begin{Vmatrix} I_1 \\ I_2 \end{Vmatrix} = \begin{Vmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{Vmatrix} \cdot \begin{Vmatrix} E_1 \\ E_2 \end{Vmatrix}$$

$$\begin{Vmatrix} E_1 \\ I_1 \end{Vmatrix} = \begin{Vmatrix} \alpha & \beta \\ \gamma & \delta \end{Vmatrix} \cdot \begin{Vmatrix} E_2 \\ -I_2 \end{Vmatrix}$$

where the matric elements a_{ij} are as defined in the accompanying table. A significant feature of the transmission type equivalent network is the facility with which the a_{ij} may be evaluated. Since these elements may be determined with zero and/or infinite impedance terminations (i.e., under short- and open-circuit conditions) the expressions for ρ, the grid-anode element of the equivalent network (Section 4, Table 1), reduce to simpler forms, as shown in the following example (Fig. 8).

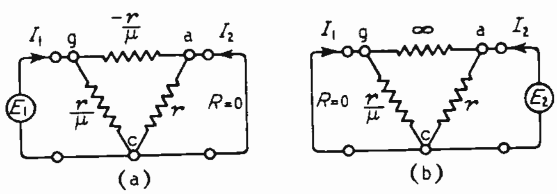

Fig. 8. *Conventional (grid-anode) amplifier working into short-circuit load.*

Evaluation of γ_{ij} of Conventional Amplifier

Taking the case of grid-anode transmission with the configuration of Fig. 3(b), we have :—

$$\gamma_{11} = \frac{I_1}{E_1}\bigg|_{E_2=0} = \frac{0}{E_1} = 0, \quad (E_1 \neq 0).$$

$$\gamma_{12} = \frac{I_1}{E_2}\bigg|_{E_1=0} = \frac{0}{E_2} = 0, \quad (E_2 \neq 0).$$

$$\gamma_{21} = \frac{I_2}{E_1}\bigg|_{E_2=0} = \frac{-\left(\frac{E_1}{-r/\mu}\right)}{E_1} = \frac{\mu}{r}$$

$$\gamma_{22} = \frac{I_2}{E_2}\bigg|_{E_1=0} = \frac{\frac{E_2}{r}}{E_2} = \frac{1}{r}.$$

Thus :—

$$\left\| \begin{matrix} I_1 \\ I_2 \end{matrix} \right\| = \left\| \begin{matrix} 0 & 0 \\ \frac{\mu}{r} & \frac{1}{r} \end{matrix} \right\| \cdot \left\| \begin{matrix} E_1 \\ E_2 \end{matrix} \right\|$$

which agrees with G. Kron's[18] admittance tensor representation of the same arrangement :—

$$Y^{uv} = \begin{array}{c|c|c} {}_{u}\backslash^{v} & g & p \\ \hline g & 0 & 0 \\ \hline p & \frac{\mu_p}{r_p} & \frac{1}{r_p} \end{array}$$

The remaining cases follow similarly and are recorded for reference in the accompanying table.

Table of Matrix Elements

a_{ij}	$f(E, I)_0$	g—a	g—c	c—a
Z_{11}	$\frac{E_1}{I_1} \Big\vert I_2=0$	$+\infty$	$+\infty$	$+\infty$
Z_{12}	$\frac{E_1}{I_2} \Big\vert I_1=0$	0	0	$-\infty$
Z_{21}	$\frac{E_2}{I_1} \Big\vert I_2=0$	$-\infty$	$-\infty$	$+\infty$
Z_{22}	$\frac{E_2}{I_2} \Big\vert I_1=0$	r	$\frac{r}{\mu+1}$	$+\infty$
y_{11}	$\frac{I_1}{E_1} \Big\vert E_2=0$	0	0	$\frac{\mu+1}{r}$
y_{12}	$\frac{I_1}{E_2} \Big\vert E_1=0$	0	0	$-\frac{1}{r}$
y_{21}	$\frac{I_2}{E_1} \Big\vert E_2=0$	$\frac{\mu}{r}$	$-\frac{\mu}{r}$	$-\frac{\mu+1}{r}$
y_{22}	$\frac{I_2}{E_2} \Big\vert E_1=0$	$\frac{1}{r}$	$\frac{\mu+1}{r}$	$\frac{1}{r}$
α	$\frac{E_1}{E_2} \Big\vert I_2=0$	$-\frac{1}{\mu}$	$\frac{\mu+1}{\mu}$	$\frac{1}{\mu+1}$
β	$\frac{E_1}{-I_2} \Big\vert E_2=0$	$-\frac{r}{\mu}$	$\frac{r}{\mu}$	$\frac{r}{\mu+1}$
γ	$\frac{I_1}{E_2} \Big\vert I_2=0$	0	0	0
δ	$\frac{I_1}{-I_2} \Big\vert E_2=0$	0	0	1

APPENDIX 2

Matrical Evaluation of ρ

An organized method of evaluating and of developing general expressions for ρ is provided by matrix algebra.

It is convenient to orient the mesh contours in such a manner that only one traverses the grid lead and denote this mesh 1. Then

$$i_1 = \frac{1}{\Delta} \cdot \sum_{k=1}^{n} \delta_{k1} \cdot e_k$$

where

e_k is the e.m.f. acting in the kth mesh,

Δ is the determinant of the impedance matrix of the entire network and is a function of ρ,

δ_{k1} is the determinant of the submatrix obtained by omitting the kth row and first column of Δ and is also, in general, a function of ρ.

The impedance matrix will generally be non-singular so that $\Delta(\rho) \neq 0$

Therefore, for $i_1 = 0$, we must have

$$\sum_{k=1}^{n} \delta_{k1} \cdot e_k = 0$$

which is a linear equation in ρ.

In the simplest case of a single applied e.m.f. embraced by only one mesh contour, this last equation reduces to

$$\delta_{k1}(\rho) = 0$$

The Physical Society's Exhibition

The 35th Annual Exhibition of Scientific Instruments and Apparatus will be held from 6th to 11th April, 1951. In addition to the main building of the Royal College of Science in Imperial Institute Road, the Huxley Building in Exhibition Road will also be used.

Admission is restricted to members on the morning of 6th April and by ticket, valid for morning or afternoon only, on other days. The hours are 10 to 1 a.m. and 2 to 9 p.m. except on the 7th and 11th when the exhibition closes at 5 p.m. It will not be open on Sunday, 8th.

Tickets are obtainable from the Secretary, The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7, and from the secretaries of learned societies.

R.E.C.M.F. Exhibition

The 8th exhibition of components, materials, test gear and valves opens at Grosvenor House, Park Lane, London, W.1, on 10th April. It is to be open for three days from 10 a.m. to 6 p.m. and admission is restricted to holders of invitation cards from the Radio & Electronic Component Manufacturers' Federation, 22 Surrey Street, London, W.C.2.

Institution of Electrical Engineers

The following meetings will be held at the I.E.E., Victoria Embankment, Savoy Place, London, W.C.2, commencing at 5.30:—19th February, discussion meeting on "Is there an Optimum Speed for a Gramophone Record," opened by G. F. Dutton, Ph.D., B.Sc.(Eng.); 27th February, discussion meeting on "Electrical Measurement by Thermal Effects," opened by Professor J. Greig, M.Sc., Ph.D., L. G. A. Sims, D.Sc., Ph.D., and J. G. Freeman, M.A., Ph.D.; 1st March, "The London-Birmingham Television Radio-Relay Link," by R. J. Clayton, M.A., D. C. Espley, O.B.E., D.Eng., G. W. S. Griffiths, and J. M. C. Pinkham, M.A.; 5th March at 6.0, discussion meeting on "The Best Means of Explaining the Internal Operation of Electronic Valves," opened by A. F. H. Thomson, M.A.; 7th March, "Design Considerations for a Radiotelegraph Receiving System," by J. D. Holland.

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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.

Surface-Wave Transmission Line

SIR,—May I add a few remarks to the comments made by Mr. Rust in the October/November number on the subject of your Editorial of last July. A theoretical analysis of the propagation of this form of wave over a plane surface shows that it is necessary to have an exponential decay of the field strength measured at increasing distances normal to the surface. The electric field then includes a longitudinal component outside the conductor and the phase velocity is less than the free-space value. To bring about this reduced phase velocity the surface impedance of the guide must be reactive and that can be achieved in three ways (1) by a corrugated or roughened conductor surface; (2) by a dielectric-coated conductor; (3) by the internal reactance of the conductor itself. The third of these is generally insufficient for practical purposes because the field extends a long way from the conductor, but the conditions theoretically satisfy the requirements of a surface wave. With a cylindrical conductor one would expect much the same principles to apply except that the field strength at different radii is then subject to an additional attenuation which helps still further in confining it to the immediate vicinity of the conductor.

Taking the case of the surface wave propagated along a wire of circular section when stretched between two horns I agree with Mr. Rust's explanation of the particular virtue of the dielectric-coated wire close to the horns but I suggest that a perfectly smooth bare wire over the rest of the path would not be really satisfactory because the required reactive surface impedance could then only be provided by the internal field of the conductor itself and that is normally insufficient to confine the field within reasonable range of the conductor. A dielectric coating increases the attenuation of the guide by losses in the dielectric and with a longitudinal current one would expect roughening the surface of the conductor to increase its resistance. It would seem, therefore, that for minimum attenuation along the length of the guide a careful compromise is required between a number of different factors.

H. M. BARLOW.

University College,
London.

Mutual Impedance of Parallel Aerials

SIR,—We have recently had to compute the mutual impedance between parallel non-staggered half-wave dipoles over a range of spacing up to one wavelength. Values of sine and cosine integrals were taken from the three volumes in the W.P.A. series of mathematical tables. The results obtained are shown in the table.

These values cannot be compared directly with such previous values as those of G. Barzilai ("Mutual Impedance of Parallel Aerials," *Wireless Engineer*, 1948, Vol. 25, p. 347), because of a curious error that has found its way into many mutual impedance calculations.

Taking the aerials as infinitely thin, the mutual impedance can be expressed as $R \times F$, where F is a complex function of the spacing, involving sine and cosine integrals, and

$$R = \frac{1}{4\pi}\sqrt{\frac{\mu}{\epsilon}} \text{ ohms},$$

μ and ϵ being respectively the permeability and dielectric constant of the medium surrounding the aerials. Thence

$$R = c \times 10^{-9} \text{ ohms}$$

where c is the velocity of light in cm/sec. This gives

$$R = 29{\cdot}979 \text{ ohms},$$

in vacuo, with an error which will probably not exceed one unit in the last place. In air the correct value is about 29·971 at sea level (the values in the table are for vacuo). Now, it is usually considered sufficiently accurate to take R as 30 ohms (see R. A. Smith, "Aerials for Metre and Decimetre Wave-lengths," 1949, p. 43; G. Barzilai, ibid; S. A. Schelkunoff, "Electromagnetic Waves," 1943, p. 83; and numerous other authors). This is in error by about 0·7 parts in 1,000. Nevertheless, previous computers have used this rough value to tabulate mutual impedances to accuracies up to a hundred times better than is justified by the initial approximation. Schelkunoff, for example, gives 73·129 ohms as an 'accurate' value of the self-resistance of a half-wave dipole. This implies an error of not more than half a unit in the third place; i.e., of about 0·007 parts in 1,000. The correct value to this number of decimal places is 73·078 in vacuo (73·059 in air).

After the figures in the table have been multiplied by 30/29·979, comparison with Barzilai's figures shows no differences to the respective accuracies used.

TABLE

Spacing (Wavelengths)	Resistance (ohms)	Reactance (ohms)
0·00	+73·08	+42·51
0·05	+71·61	+24·25
0·10	+67·29	+ 7·53
0·15	+60·39	− 7·09
0·20	+51·36	−19·16
0·25	+40·76	−28·33
0·30	+29·24	−34·41
0·35	+17·49	−37·39
0·40	+ 6·21	−37·40
0·45	− 3·97	−34·76
0·50	−12·52	−29·91
0·55	−19·05	−23·40
0·60	−23·30	−15·86
0·65	−25·20	− 7·94
0·70	−24·85	− 0·25
0·75	−22·48	+ 6·63
0·80	−18·48	+12·25
0·85	−13·31	+16·28
0·90	− 7·48	+18·53
0·95	− 1·54	+18·98
1·00	+ 4·01	+17·73

Comparison with Smith's figures shows that for 42 entries in his table (ibid, p. 10), 7 have differences from the above values of one unit in the first decimal place and 11 of more than one unit.

R. G. MEDHURST,
S. D. POOL.

Research Laboratories of The General
Electric Co., Ltd., England.

NEW BOOKS

The Nomogram

By H. J. Allcock & J. Reginald Jones. 4th edition (1950) revised by J. G. L. Michel. Pp. 238 + x, with 81 illustrations. Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 18s.

Little change has been made from the third edition published in 1941, except for the addition of a new chapter (VI) showing the connection between intersection and alignment nomograms. Appendix III, which is also new, sets forth the conditions under which a nomogram involving three variables u, v, w, can be constructed. It must be possible to write the relation between the variables in the form

$$\Phi(u,v,w) \equiv f_1(u)F(v,w) + g_1(u)G(v,w) + h_1(u)H(v,w) = 0$$

If now

$$x = F(v,w)/H(v,w), y = G(v,w)/H(v,w),$$

between these last two equations we can eliminate first v and then w. The necessary and sufficient condition that a nomogram be possible is that the results of these two eliminations take the forms

$$f_2(v).x + g_2(v).y + h_2(v) = 0, \text{ and}$$
$$f_3(w).x + g_3(w).y + h_3(w) = 0,$$

which are linear in x and y. These conditions, while they do not imply that any arbitrary relation between three variables can be expressed by means of a nomogram, do show that nomograms can be used in a surprisingly large number of cases where a single formula has to be applied repeatedly, and very high accuracy is not required. The procedure for constructing nomograms is clearly explained. The case of three variables is considered in detail and is reduced to a number of standard forms. Nomograms involving more variables are also discussed. Specific examples are given of all the main types discussed. Any mathematical theory, such as elementary properties of determinants, is included when it is needed to understand the constructions described, so that the book is completely self-contained.

There must be many applications for which nomograms could be used and much time thus saved, but for which nobody has thought of trying to use them. This book can therefore be strongly recommended to engineers, designers and research workers. The most profitable results will probably be obtained when the nomograms are designed, and the positions of all relevant points calculated, by a mathematician or mathematically enclined engineer, but the actual construction of the nomogram is carried out by expert draughtsmen.

J. W. H.

Transformers

By F. C. Connelly, Ph.D., A.M.I.E.E., A.R.C.S., D.I.C. Pp. 490 + xiv, with 179 illustrations. Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 35s.

The author has written this book "to meet the needs of laboratory workers, designers, and users of transformers in the light electrical industries." Although the major part of it is devoted to the 'mains transformer,' audio-frequency types, both output and intervalve, instrument transformers and even television scanning transformers are covered although rather less thoroughly.

The book starts with a brief account of the fundamental principles of electromagnetism and goes on to discuss the magnetic properties of iron and steel. This is followed by a chapter giving the simplified theory of the transformer in which the usual relation between turns, voltage, flux density and core area is brought out ; the calculation of the no-load current is also treated here. The next chapter deals with losses and naturally also covers efficiency and voltage regulation.

There is a chapter on constructional details and another in which temperature rise is considered. An approximate method of computation is given and in view of the difficulties involved it leads to surprisingly accurate results—judged by some examples quoted by the author.

Chapter VII, "Designing Small Power Transformers," outlines the design procedure and gives several practical examples in considerable detail. The effect and calculation of magnetic leakage are considered, as well as core excitation ; the Fourier analysis of the voltage and current waveforms are dealt with in later chapters and also the effect of transients.

Three-phase transformers are included and there is a chapter on the effect of rectifiers. High-voltage types, auto-transformers, vibrator transformers, instrument transformers, a.f. output and intervalve transformers, as well as television scanning types and transformers depending on magnetic saturation each have their own chapters. The book concludes with a good deal of useful design data presented in graphs and tables.

The type of power transformer mainly considered is the small one capable of handling powers up to a few hundred watts. If the principle and methods so clearly described are followed there is no reason why anyone shoud not design such transformers with confidence.

More information about the construction of transformers could have been given with advantage. An extra chapter giving hints and tips on winding methods, former construction, etc., for cases where a winding machine is not available would have been useful. There are many cases where it is desired to make only 'one-off' without any special tools.

This is, however, a minor point about an extremely good book which should be of the greatest assistance to everyone concerned with small transformers. There is very little that anyone making a 'mains transformer' wants to know which he will not find in it. The treatment of other types is less full and it would be truer to say that it affords a guide to design rather than a complete treatise.

A fault of the book lies in the mixture of units employed ; B and H are in lines per cm^2 and gilberts per cm, but core dimensions are in inches. On p. 55 the author states that these form the most convenient units in practice. On p. 61, however, the formula for calculating the magnetizing current does not include the factor of 2·54 which is necessary if these units are adhered to. It appears in the example, but not in the formula : in this case, therefore, the author has either expressed H in gilberts per inch or the length of the magnetic path in centimetres.

W. T. C

THE FARADAY MEDAL

The Council of the Institution of Electrical Engineers has made the 29th award of the Faraday Medal to Thomas Lydwell Eckersley, B.A., B.Sc., Ph.D., F.R.S. The award has been made for his achievements in the field of radio research and, in particular, for his outstanding contributions to the theory and practice of radio-wave propagation. These have included the prediction of short-wave performance, the application of phase-integral theory to short-wave problems and the enunciation of a theory of the diffraction of waves round the earth taking into account the earth's resistance.

ABSTRACTS and REFERENCES

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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

534.2 : 551.553 **267**

The Fine Structure of Atmospheric Turbulence in Relation to the Propagation of Sound over the Ground.—E. G. Richardson. (*Proc. roy. Soc. A*, 22nd Sept. 1950, Vol. 203, No. 1073, pp. 149–164.) Simultaneous measurements of the fluctuations in sound intensity at a distance from a steady source, and of the atmospheric turbulence at points along the sound path, are used to discuss the relation between sound scattering and intensity of turbulence. The effect of the latter on the phase relations between signals received at two points is demonstrated.

534.212 **268**

The Propagation of a Sound Pulse in the Presence of a Semi-infinite Open-ended Channel: Part 2.—W. Chester. (*Proc. roy. Soc. A*, 7th Sept. 1950, Vol. 203, No. 1072, pp. 33–42.) The asymptotic behaviour of the disturbance at great distances from the wave front is discussed. For an incident Heaviside unit pulse, the wave inside the channel also tends to behave like a unit pulse, the correction term being a function of the distance from the wave front. The case of an arbitrary pulse is also considered. The results are used to estimate the proportion of energy which returns along the channel when the incident pulse is of finite duration. Part 1: 2683 of 1950. See also 1560 of 1950.

534.321.2 : 621.3.018.78† **269**

The Effect of Nonlinear Distortion on the Perception of Mistuning of Musical Intervals.—W. Weitbrecht. (*Fernmeldetech. Z.*, Sept. 1950, Vol. 3, No. 9, pp. 336–345.) An experimental method is described in which pairs of electrically generated tones selected from the common chord of C in the octave 523.25–1046.50 c/s, on the tempered and again on the just scale, are presented to listeners after passage through a pentode circuit of known adjustable nonlinear-distortion factor. The presentation of the properly tuned combination is alternated with the same combination mistuned, the listener stating whether or not he can hear a difference. Results are shown in charts. The harmonics and combination tones in the audio output are also observed objectively. The response of the ear to extraneous sounds is discussed. Characteristic differences are noted for different musical intervals.

534.321.9 : 621.315.616 **270**

Propagation of Low-Frequency Ultrasonic Waves in Rubbers and Rubber-like Polymers.—P. Hatfield. (*Brit. J. appl. Phys.*, Oct. 1950, Vol. 1, No. 10, pp. 252–256.) Experiments covering a frequency range 50–350 kc/s and temperature range 0–60°C are described. The velocity of low-amplitude ultrasonic waves varies from $1 \cdot 1 \times 10^5$ to $1 \cdot 8 \times 10^5$ cm/s in different rubbers at room temperature; absorption varies from $< 0 \cdot 1$ to 2 db/cm at 50 kc/s and from 0·7 to 11 db/cm at 350 kc/s. Applications of these materials as acoustic lenses and as ultrasonic transmission media are discussed.

534.782.07 **271**

The Phonetic Steno-sonograph.—J. Dreyfus-Graf. (*Onde élect.*, Aug./Sept. 1950, Vol. 30, Nos. 281/282, pp. 356–361.) See 1330 of 1950.

534.845 **272**

Absorption of Sound by Porous Materials.—C. Zwikker. (*Research, Lond.*, Sept. 1950, Vol. 3, No. 9, pp. 400–407.) The control of reverberation by pure porosity effects is examined theoretically for normal incidence of the sound waves on a wall of infinite extent. The coefficient of sound absorption can be determined in terms of the wave impedance and propagation constant, which can be measured by interferometer methods. They may also be deduced if the porosity, specific flow resistance, thickness and structure factor (a factor depending upon the angle between the cell axes and the normal to the front surface) are known. See also 1569 of 1949 (Zwikker, van den Eijk & Kosten) and back reference.

621.395.61 **273**

The Tube Microphone.—H. J. Griese. (*Arch. elekt. Übertragung*, July 1950, Vol. 4, No. 7, pp. 259–266.) Description and analysis of operation of a microphone in which the sound pickup member, of spherical or exponential-horn shape, is connected to the transducer by a slender tube. Directional diagrams and frequency-response curves are shown and discussed, and various constructions are illustrated.

621.395.61 : 621.396.645 **274**

The Brief-Case Field Amplifier.—Hathaway & Kennedy. (See 312.)

621.395.623.7 **275**

Sensitivity, Directivity and Linearity of Direct-Radiator Loudspeakers.—H. F. Olson. (*Audio Engng*, Oct. 1950, Vol. 34, No. 10, pp. 15–17.) Discussion of the characteristic curves of direct-radiator dynamic loudspeakers shows that rigid large-angle cones with suspensions of high mechanical resistance produce more uniform frequency response and directional characteristics than loudspeakers with light vibrating systems, which, though possessing greater sensitivity and giving greater intensity directly in front of the cone, have considerably greater nonlinear distortion. The heavier type also handles much greater power without overloading.

621.395.623.7 **276**

A New Loudspeaker of Advanced Design.—D. J. Plach & P. B. Williams. (*Audio Engng*, Oct. 1950, Vol. 34, No. 10, pp. 22–23..65.) The loudspeaker comprises three independently driven reproducers, covering the whole audio range to above 18 kc/s, with cross-over at 600 c/s and 4 kc/s. In the low-frequency unit a 3-in. voice coil drives a 15-in. plastic diaphragm shaped like the mouth of a horn, into the throat of which the mid-frequency unit is inserted. This uses a dished plastic diaphragm driving through an annular gap into a horn formed by part of the magnet system of the low-frequency unit. The flare of this horn passes smoothly into that of the low-frequency diaphragm, which thus acts as an extension of the mid-frequency horn and provides good loading, resulting in smooth response at high efficiency down to and below the cross-over at 600 c/s. The high-frequency unit is independently mounted in the front of the assembly. It also has a flared horn, the diameter of the mouth being 1·5 in. Tests indicate the high quality of the reproduction of all types of broadcasting material.

621.395.623.7.001.4 **277**

Transient Testing of Loudspeakers.—M. S. Corrington. (*Audio Engng*, Aug. 1950, Vol. 34, No. 8, pp. 9–13.) A theoretical discussion of the relation between the sound-pressure curve of a loudspeaker and its transient response to a suddenly applied unit sine-wave is illustrated by experimental results on a 12-in. loudspeaker. It is concluded that the unit sine-wave is preferable to the unit impulse as a test, the former being more selective and easier to interpret, since it emphasizes the ringing of peaks of nearly the same frequency as its own.

AERIALS AND TRANSMISSION LINES

621.315.21 : 621.397.5 **278**

High-Frequency Cables in Television.—R. C. Mildner. (*J. Televis. Soc.*, April/June 1950, Vol. 6, No. 2, pp. 65–75.) A survey of the properties of balanced and unbalanced transmission lines.

621.315.61 **279**

Conductance of Insulators for Overhead Lines at Carrier Frequencies.—Gregoretti. (See 379.)

621.392 : [621.3.015.7† : 621.314.2 **280**

Pulse Transients in Exponential Transmission Lines.—E. R. Schatz. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1208–1212.) The pulse response of exponential transmission lines is analysed and it is suggested that such lines may be used advantageously as pulse transformers for short, rapidly rising pulses, particularly where high power is involved. A subsequent paper will discuss design problems and experimental results.

621.392.09 **281**

Surface-Wave Transmission Line.—G. Goubau. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, May 1950, Vol. 14, No. 5, pp. 10–11..30.) A paper published by Sommerfeld in 1899 describes a surface wave guided by a cylindrical conductor of finite conductivity. The field of such a wave extends very far from the conductor but can be concentrated closer to the conductor by reducing the phase velocity. Such a reduction can be achieved by applying a dielectric coating to the conductor, or by modifying its surface by cutting a screw thread throughout its length. Under such conditions the wave mode differs from Sommerfeld's wave both in the extent and structure of the field, and finite conductivity is no longer an essential condition for the existence of the non-radiating wave mode. Experiments show that this mode can be easily excited on dielectric-coated or threaded wires, with an efficiency up to 90%. For excitation, a metal horn is connected to the outer conductor of the coaxial feeder and the wire to the inner conductor. At the receiving end an identical arrangement is used. Losses in such a system are discussed; there is an optimum thickness of the dielectric coating for which the insertion loss is a minimum. Experiments at 2·0 kMc/s with a Cu wire 2·6 mm in diameter and of length about 38 m verified this conclusion. Further experiments at 1·6 kMc/s on an enamelled wire 3·2 mm in diameter and 183 m long, supported at points about 24 m apart, gave a measured loss of 5 db, which is in good agreement with the calculated value of 4·5 db. The supports, and the bends in the wire due to the supports, had no measurable effect on the attenuation. The corresponding attenuation for RG-8/U cable is 70 db. The horns used were the same in all the experiments and had an aperture of 33 cm. The greatest observed increase of attenuation due to rain-drops collecting on the wire was <1·5 db.

621.396.67 **282**

An Antenna Analyzer.—A. C. Todd. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 82–87.) The polar diagram in the horizontal plane of an array of vertical grounded aerials is calculated by an electronic computer and presented in rectangular or polar co-ordinates on the screen of a c.r. tube. Results are in good agreement with those obtained by ordinary calculation methods, which take a much longer time.

621.396.67 : [621.396.11.029.62 : 531.74 **283**

Short-Wave Installations with Controllable Directional Characteristics and their Application to the Measurement of Angles of Incidence.—Kotowski, Schüttlöffel & Vogt. (See 434.)

621.396.67 : 621.397.6 **284**

Designing the Bridgeport U.H.F. Antenna.—R. M. Scudder. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 76–80.) The development and construction are described of a television aerial sensibly omnidirectional in the horizontal plane, with a voltage s.w.r. <1·15 in the band 529–535 Mc/s. The aerial consists of a linear array of vertical $\lambda/2$ slots in a tube of diameter $10\frac{3}{4}$ in., with coaxial feed, and has an overall height of 40 ft. Its power gain is 17 and vertical beam width 3°. See also 2425 of 1950.

621.396.671 **285**

The Transmission and Reception of Elliptically Polarized Waves.—G. Sinclair. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, p. 1216.) Correction to paper abstracted in 1341 of 1950.

621.396.671 **286**

Asymmetrically Driven Antennas and the Sleeve Dipole.—R. King. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1154–1164.) General expressions for impedance and current distribution of asymmetrically driven, cylindrical aerials are derived from an integral equation, which is solved by the method of successive approximations. An approximation for the impedance is obtained which involves a series combination of the known impedances of symmetrically driven aerials. Impedance and current distribution of a cylindrical $3\lambda/4$ aerial, driven $\lambda/4$ from one end, are evaluated and its wide-band properties are discussed.

Expressions for the impedance and current distribution of a sleeve dipole are readily obtained from the foregoing, since the sleeve dipole with its image is equivalent to two superposed asymmetrically driven aerials. Impedance and current distribution are determined for a $3\lambda/4$ sleeve dipole above a conducting plane, when it is driven $\lambda/4$ from the plane; its wide-band properties are much superior to those of a simple dipole.

621.396.677 287

Dielectric Directive Radiators.—P. Mallach. (*Fernmeldetech. Z.*, Sept. 1950, Vol. 3, No. 9, pp. 325–328.) A discussion of end-on radiators, particularly the tubular type. Radiators made of materials with dielectric constants ranging from 2·5 to 64 were investigated. An experimental set-up for obtaining the radiation pattern is described, and the effect of variation of dimensions and form is shown in graphs. The tubular dielectric radiator is smaller than the equivalent horn; the dielectric-rod radiator even smaller. See also 1604 of 1949.

621.396.679.4 : 621.315.212 288

Coaxial Feed Systems for Antennas.—J. F. Clemens. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 154..182.) A variation of the 'delta match' method enables any unbalanced coaxial cable to be used to feed balanced horizontal aerials. Formulae are given for calculating the total inductive reactance between feed points and the length of shorted cable required for resonance. Results obtained with experimental aerials at 300 Mc/s and 29 Mc/s are described.

CIRCUITS AND CIRCUIT ELEMENTS

621.314.2 289

Optimum Use of Nickel-Alloy Steels in Low-Level Transformers.—L. W. Howard. (*Audio Engng*, Oct. 1950, Vol. 34, No. 10, pp. 20–21, 50.) Discussion of the design and manufacturing problems involved in the production of small transformers for various low-level applications. The transformers are as small as possible and are hermetically sealed. For the lowest levels three nickel-steel magnetic shields interleaved with copper shading rings are used. Owing to their low saturation point these steels are not suitable for high-level applications, for which silicon steels are preferred.

621.314.2.018.424† 290

Design of Broad-Band Transformers for Linear Electronic Circuits.—H. W. Lord. (*Elect. Engng, N.Y.*, Nov. 1950, Vol. 69, No. 11, pp. 1020–1025.) Paper presented at the A.I.E.E. Summer and Pacific General Meeting, Pasadena, Calif., June 1950. Analysis and design data are given for modulation transformers intended to operate with negligible variation of gain and phase and with low distortion. Generalized frequency/response curves are given for a range of relevant circuit parameters. The performance of a typical 3-W transformer is in close agreement with theory over the frequency range 20–30 000 c/s.

621.314.3† 291

A Review of Transductor Principles and Applications.—R. Feinberg. (*Proc. Instn elect. Engrs*, Part II, Oct. 1950, Vol. 97, No. 59, pp. 628–644.)

621.316.8 : 621.396.822 292

A Note on the Identity of Thermal Noise and Shot Noise.—B. Meltzer. (*Phil. Mag.*, Dec. 1949, Vol. 40, No. 311, pp. 1224–1226.) The noise in a given frequency range in an ohmic conductor, originally calculated by Nyquist, can be rigorously treated as pure shot noise. A new expression kT/Re is obtained for the average direct current in either direction in a circuit of resistance R in temperature equilibrium, the current being carried by elementary charges of magnitude e.

621.316.8 : 621.396.822 293

The Statistical Analysis of Electrical Noise.—D. K. C. MacDonald. (*Phil. Mag.*, Aug. 1950, Vol. 41, No. 319, pp. 814–818.) Recent papers by Meltzer on electrical noise (see 2141 of 1950 and 292 above) are criticized. In particular, no distinction was made between average and mean-square values of the statistical variables. The results of a general discussion of the statistics and frequency spectrum of fluctuations are applied to determine particle velocity in Brownian motion; agreement with Exner's observations is satisfactory.

621.318.572 294

Speed of Electronic Switching Circuits.—E. M. Williams, D. F. Aldrich & J. B. Woodford. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, p. 1180.) Correction to paper abstracted in 1353 of 1950.

621.318.572 295

32-Channel High-speed Commutator.—N. Alpert, J. Luongo & W. Wiener. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 94–97.) An electronic switching device for information channels, using a system of binary counters and gating valves to obtain a sampling rate of 1 000/sec.

621.319.45 : 546.883 296

Tantalum Electrolytic Capacitors.—M. Whitehead. (*Bell Lab. Rec.*, Oct. 1950, Vol. 28, No. 10, pp. 448–452.) Capacitors of the conventional foil type using tantalum instead of aluminium, and a new type in which the anode is a highly porous cylinder of sintered tantalum, are described. The advantages of the tantalum capacitors are brought out in a general discussion of their properties, including their relatively small size, low permissible operating temperature and high leakage resistance.

621.392 297

Note on a Useful Extension of Thévenin's Theorem.—L. Tasny-Tschiassny. (*Proc. Instn elect. Engrs*, Part I, Sept. 1950, Vol. 97, No. 107, p. 234.) "*Theorem*: If an impedance Z be connected between two terminals of a network, the potential difference between any second pair of terminals will be equal to that between the terminals of two generators, operating in parallel and having internal e.m.f.'s equal to the voltages across the second pair of terminals when $Z = \infty$ and when $Z = 0$, and internal impedances, equal to the Thévenin impedance of the network measured between the first pair of terminals, and to Z, respectively.

Corollary: The current in any branch of the network, any Thévenin impedance, an equivalent Y-impedance, or an equivalent Δ-impedance in the network will, for any value of Z, be numerically equal to the terminal voltage of the two generators, if their internal e.m.f.'s are made numerically equal to the currents, or impedances concerned, when $Z = \infty$ and when $Z = 0$, respectively."

621.392.4 : 621.316.727 298

A Study of the Cathode-Degeneration Phase Inverter.—S. Malatesta. (*Alta Frequenza*, June 1950, Vol. 19, No. 3, pp. 145–148.) Calculation of this circuit, in which anode and cathode voltages vary in phase opposition, is simplified by considering the anode current as a function of a voltage which is the difference between the grid voltage and the mean of the anode and cathode voltages.

621.392.4 : 621.316.727 **299**

Wide-Range Phase Control with Constant Attenuation by Adjustable Impedance in a Resistance-Loaded Bridged-Tee Network.—M. G. Pawley. (*Bur. Stand. J. Res.*, Sept. 1950, Vol. 45, No. 3, pp. 193–200.) Equations are developed and the necessary relations between circuit constants are deduced for phase control by means of an adjustable resistor, inductor or capacitor connected in a selected branch of a bridge-T network. Various applications of such phase-shifting networks are mentioned.

621.392.43 **300**

The Design of Frequency-Compensating Matching Sections.—V. H. Rumsey. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1191–1196.) The general problem of transforming an impedance which changes with frequency into a resistance nearly independent of frequency is considered. A simple procedure for the general solution is evolved and design formulae for the appropriate matching section are derived. The formulae give the parameters of the matching section in terms of the loads at selected frequencies. The technique is mainly applicable to cases where the half-bandwidth is small compared with the centre frequency; it can be applied to any type of transmission line whose characteristic impedance is known.

621.392.5 **301**

The Parameters of a Passive Four-Pole that may Violate the Reciprocity Relation.—B. D. H. Tellegen & E. Klauss. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 81–86.) The properties of these quadripoles at a given frequency are investigated theoretically and the conditions are determined for a quadripole to be passive. See also 980 and 2745 of 1949 and 1879 of 1950 (Tellegen).

621.392.5.018.1 **302**

Design of Single-Frequency Phase-Shifting Networks.—L. G. Fischer. (*Elect. Commun.*, Sept. 1950, Vol. 27, No. 3, pp. 227–230.) A series of design curves is given from which the necessary data may be obtained for designing the most suitable network to meet any specific requirement. Full allowance is made for the loading effect due to the shunting of each section by the succeeding one.

621.392.52 : 621.397.61 **303**

Linear-Phase-Shift Video Filters.—G. L. Fredendall & R. C. Kennedy. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 418–430.) A paper intended primarily to guide designers through the necessary steps in the calculation of the values of capacitors and inductors in the Bode linear-phase-shift filter which satisfies approximately the specified attenuation conditions through the cut-off region and within the pass band. Application of linear-phase-shift filters in the production of 'mixed highs' in the dot-sequential system of colour television is described. Band-pass and band-stop filters with linear phase-shifts are also considered briefly.

621.392.53 : 621.396.645.2 **304**

Anode-Load Compensation Network.—C. Chalhoub. (*Câbles & Transmission, Paris*, Oct. 1950, Vol. 4, No. 4, pp. 325–335.) In wide-band amplifiers the inductor often added in series with the load resistor to eliminate the effect of stray valve capacitances may be supplemented by a series capacitor and parallel inductor to extend the useful frequency range of the amplifier further. The relation between the two types of circuit is established, so that the equations for one may be derived from those for the other. Sets of curves to facilitate design of the compensating network are given, with numerical examples. In fixed-frequency amplifiers the use of the single inductor may be satisfactory when the phase change to be corrected is less than about 35°. In the case of an oscillator comprising two or more resonant circuits used at their resonance frequency, only one of these should have a high Q-value, all the others being suitably damped.

621.392.6 : 621.395 **305**

Theory of 2n-Terminal Networks with Applications to Conference Telephony.—V. Belevitch. (*Elect. Commun.*, Sept. 1950, Vol. 27, No. 3, pp. 231–244.) Networks composed of resistors and ideal transformers, simultaneously matched at all their terminal pairs to a given set of resistors and with prescribed losses between the various pairs of terminals, are treated. A method of design based on the efficiency matrix is applied to 6-terminal and some important classes of 8-terminal networks. Results in the theory of transformer networks are applied to the design of new networks of practical importance for conference telephony. Matched non-dissipative networks interconnecting n telephone circuits and giving a loss of $10 \log_{10} (n-1)$ db between all their terminal pairs are constructed for various values of n. Transformer networks suitable for interconnecting 4-wire circuits are also discussed.

621.395.665.1 **306**

Compressor/Expander Units of l'Administration Française des P.T.T.—M. Lagarde, P. Herreng & A. Gauvenet. (*Câbles & Transmission, Paris*, Oct. 1950, Vol. 4, No. 4, pp. 308–318.) The conditions which such devices should satisfy are examined, and systems using (*a*) Cu_2O rectifiers, (*b*) valve rectifiers, are discussed with reference to stability, degree of compression and distortion. The discussion justifies the selection of the Cu_2O type, and a technical description is given of the units actually used, which have a compression factor of about 1·8 and input and output impedances of 800Ω.

621.396.6 **307**

New Techniques for Electronic Miniaturization.—R. L. Henry, R. K. F. Scal & G. Shapiro. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1139–1145.) Problems arising from miniaturization are considered, with special emphasis on those due to high operating temperatures, which necessitate special types of resistor and the use of a solder with a high melting point. General techniques for conventional and printed circuits are discussed and three types of miniature wide-band high gain i.f. amplifiers, suitable for radar applications, are described in detail. Methods and techniques of production are also outlined.

621.396.611.4 : 621.314.222 **308**

The Transmission Properties of the Cavity Resonator as Interstage Transformer.—A. Käch. (*Arch. elekt. Übertragung*, Aug. 1950, Vol. 4, No. 8, pp. 301–308.) A detailed analysis, emphasizing the importance of inherent losses in the cavity. The equivalent quadripole constants are derived, the resonator with its input and output couplings being regarded as a three-winding transformer. Conditions determining resonance, attenuation, matching, and bandwidth are examined. Optimum operating conditions can be attained merely by varying the degree of coupling. The theory is confirmed by measurements on the input circuit of a microwave receiver, using a frequency of 2 kMc/s.

621.396.615 **309**

A New RC Oscillator Circuit.—M. H. Crothers. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, May 1950, Vol. 14, No. 5, pp. 12–14 . . 25.) Description and theory of the operation of a 2-stage 'π-coupled' amplifier with a RC feedback network. The circuit requires fewer components than the normal type of cathode-coupled feedback amplifier and greater stability is claimed for it.

621.396.619.23+621.396.645].029.64 **310**

A New Microwave Triode: its Performance as a Modulator and as an Amplifier.—A. E. Bowen & W. W. Mumford. (*Bell Syst. tech. J.*, Oct. 1950, Vol. 29, No. 4, pp. 531–552.) Details are given of equipment using the Type-1553-416A triode (510 below) in microwave links operated at 4 kMc/s. Using the valve as a modulator, 10–20 mW output power and a bandwidth of 20 Mc/s were obtained. As an amplifier, average figures are: gain 9 db, bandwidth 103 Mc/s between half-power points, noise figure 18 db, power output (for 3 db gain) 455 mW. A 10-stage cascade amplifier gave 90 db gain, 16 db noise factor and 44 Mc/s bandwidth between the 0·1 db points.

621.396.645 **311**

"Williamson" Type Amplifier using 6A5's.—J. H. Beaumont. (*Audio Engng*, Oct. 1950, Vol. 34, No. 10, pp. 24–26.) Description, with circuit diagram and components list, of a high-fidelity audio amplifier using miniature valves in direct-coupled pairs, driving a push-pull output stage giving a nominal output of 6 W.

621.396.645 : 621.395.61 **312**

The Brief-Case Field Amplifier.—J. L. Hathaway & R. C. Kennedy. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 411–417.) Detailed description of miniature equipment for sound-broadcasting pickup.

621.396.645.29 : 518.3 **313**

Cathode-Follower Response.—R. H. Baer. (*Electronics*, Oct. 1950, Vol. 23, No. 10, p. 114.) A chart shows the permissible video-frequency pulsed input voltage in terms of that calculated for l.f. sinusoidal input.

621.396.645.018.424† **314**

A Distributed Power Amplifier.—A. P. Copson. (*Elect. Engng, N.Y.*, Oct. 1950, Vol. 69, No. 10, pp. 893–898.) The basic theory of the type of transmission line used in distributed-amplification units is presented and a description is given of voltage and power amplifiers using Type-807 beam tetrodes. The response curve is flat to within 1 db from 20 c/s to 30 Mc/s, but the upper limit can be extended when valves with short anode and grid leads at opposite ends of the envelope are available; high transconductance and low shunt capacitance are also required.

621.396.645.018.424† : 621.317.755 **315**

Wide-Band Amplifier for Cathode-Ray-Oscilloscope Observation of Transient Phenomena.—P. Schmid & E. Baldinger. (*Helv. phys. Acta*, 1st Sept. 1950, Vol. 23, No. 5, pp. 478–481. In German.) A 12-stage RC amplifier with a rise time of $1{\cdot}3\times10^{-8}$ sec (from 10% to 90% output voltage) and amplification factor 360.

621.396.645.37 **316**

Graphical Solution for Feedback Amplifiers.—L. D. Barter. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 204 . . 214.) Derivation of the equation for the variation of the gain of a feedback amplifier with frequency, and its application to typical one- and two-stage amplifiers, with graphical solution for the latter case.

621.396.662 **317**

Cascade-Connected Attenuators.—R. W. Beatty. (*Bur. Stand. J. Res.*, Sept. 1950, Vol. 45, No. 3, pp. 231–235.) When two or more calibrated attenuators are connected in series, the total attenuation will not, in general, be the sum of the attenuations of the individual units, owing to mismatch at the junctions. An abac is given from which the limits of the error due to mismatch can be determined from reflection coefficients found by means of voltage s.w.r. measurements at the junctions. Summary in *Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, p. 1190.

621.396.665 **318**

Automatic Audio Gain Controls.—J. L. Hathaway. (*Audio Engng*, Oct. 1950, Vol. 34, No. 10, pp. 27–29.) A discussion of the development of control apparatus for broadcasting transmitters. Two RC circuits with appropriate time constants are used in series to operate a single programme-controlled stage. A small capacitor is charged by single peaks in the control rectifier voltage and gives rapidly acting limiting, while a much larger capacitor is slowly charged and controls average level. An additional refinement provides for the momentary suspension of control, for achieving certain sound effects.

621.397.645.018.424† **319**

Video Amplifier Design.—R. C. Moses. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, May 1950, Vol. 14, No. 5, pp. 15–18 . . 28.) Discussion of compensation circuits enabling amplitude and phase characteristics essentially flat over the whole video band to be obtained

621.392 **320**

Electric Circuit Theory. [Book Review]—H. Tropper. Publishers: Longmans, Green & Co., London, 164 pp., 15s. (*Elect. Times*, 14th Sept. 1950, Vol. 118, No. 3071, p. 426.) A review of fundamental aspects, valuable for advanced engineering students and engineers. No knowledge of mathematics beyond elementary differential calculus is assumed.

621.392 : 517.432.1 **321**

Heaviside's Electric Circuit Theory. [Book Review]—H. J. Josephs. Publishers: Methuen & Co., London; J. Wiley & Sons, New York, 2nd edn 1950, 113 pp., $1.25. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 146, 150.) "A concise and clear treatment of the various fundamental methods as worked out by Heaviside and extended by Carson, Bromwich, and others." See also 2535 of 1946 and 63 of 1947.

GENERAL PHYSICS

53.081+621.3.081 **322**

Symposium of Papers on the M.K.S. System of Units.—(*Proc. Instn elect. Engrs*, Part I, Sept. 1950, Vol. 97, No. 107, pp. 235–258. Discussion, pp. 258–272.) The full text is given of the following papers read before the Institution of Electrical Engineers on 30th March, 1950:—

The M.K.S. or Giorgi System of Units: the Case for its Adoption.—L. H. A. Carr.

The Rationalization of Electrical Units and its Effect on the M.K.S. System.—G. H. Rawcliffe.

The Rationalization of Electrical Theory and Units.—H. Marriott & A. L. Cullen.

Rationalized M.K.S. Units in Electrical Engineering Education.—E. Bradshaw.

534.26+[535.42 : 538.56 **323**

On the Theory of Diffraction.—W. Franz. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369A, pp. 925–935.) "A new method is described for calculating the diffraction of an acoustical or electromagnetic wave by successive approximations. Kirchhoff's theory is a special case of the first step in the new method, which, unlike Kirchhoff's, is not restricted to black screens, and applies to long waves as well as short ones."

535.22 **324**

A Determination of the Velocity of Light.—E. Bergstrand. (*Ark. Fys.*, 10th Oct. 1950, Vol. 2, Part 2, pp. 119–150. In English.) The principle of Fizeau's toothed-wheel method was used, but modern refinements included a Kerr cell between crossed nicols switched by an 8·2-Mc/s oscillator. The path distance was usually about 8 km. A detailed description is given of the equipment and measurements. The final value deduced for the velocity in vacuo is 299 793·1 ± 0·25 km/sec. This is well within the limits of Essen's value of 299 792·5 ± 3 km/sec for radio waves (1751 of 1950) and also of Aslakson's value, derived from shoran measurements, of 299 792·4 ± 2 km/sec (2610 of 1950).

535.42 : 538.566 **325**

Diffraction from an Irregular Screen with Applications to Ionosphere Problems.—Booker, Ratcliffe & Shinn. (See 428.)

537.214 **326**

Energy in Electrostatics.—W. B. Smith-White. (*Nature, Lond.*, 21st Oct. 1950, Vol. 166, No. 4225, pp. 689–690.) Confusion existing in the literature between the notion of energy as a physical entity and as a mechanical potential-energy function is considered, and a formula derived by Guggenheim for an e.s. system containing dielectrics is modified to make it true generally.

537.311.31 **327**

The Theory of the Transport Phenomena in Metals.—E. H. Sondheimer. (*Proc. roy. Soc. A*, 7th Sept. 1950, Vol. 203, No. 1072, pp. 75–98.) Exact expressions are obtained for electrical conductivity and other transport magnitudes of monovalent metals, assuming the electrons to be quasi-free, and these and other formulae are critically discussed.

537.311.31 **328**

Size Effect Variation of the Electrical Conductivity of Metals.—D. K. C. MacDonald & K. Sarginson. (*Proc. roy. Soc. A*, 22nd Sept. 1950, Vol. 203, No. 1073, pp. 223–240.) Results of conductivity measurements on thin wires of pure Na of varying diameter in the absence and presence of magnetic fields are compared with (*a*) values calculated, using the general statistical theory of metals, for the case of wires with square cross-section, (*b*) results of a theoretical investigation of the alteration in conductivity produced in metal films by the application of transverse magnetic fields.

537.312.62 **329**

The Surface Impedance of Superconductors and Normal Metals at High Frequencies: Parts 4 & 5.—A. B. Pippard. (*Proc. roy. Soc. A*, 7th & 22nd Sept. 1950, Vol. 203, Nos. 1072 & 1073, pp. 98–118 & 195–210.) Measurements on single crystals of tin described in parts 1–3 (1014 of 1948) are extended to 9·4 kMc/s and results analysed.

537.312.62 : 538.6 **330**

Field Variation of the Superconducting Penetration Depth.—A. B. Pippard. (*Proc. roy. Soc. A*, 22nd Sept. 1950, Vol. 203, No. 1073, pp. 210–223.) Experimental investigations on superconducting tin and interpretation of results.

537.312.8 : 539.23 **331**

The Influence of a Transverse Magnetic Field on the Conductivity of Thin Metallic Films.—E. H. Sondheimer. (*Phys. Rev.*, 1st Nov. 1950, Vol. 80, No. 3, pp. 401–406.)

537.525.029.64 **332**

Microwave Gas Discharges.—M. A. Biondi. (*Elect. Engng, N.Y.*, Sept. 1950, Vol. 69, No. 9, pp. 806–809.) A.I.E.E. Winter General Meeting paper, 1950. The discharge in a gas excited at microwave frequencies is discussed from a purely physical viewpoint. Some results of experimental investigation are given and a formula for the complex conductivity is developed from the known properties of electrons and ions.

537.527.4 **333**

Positive Point-to-Plane Spark Breakdown of Compressed Gases.—T. R. Foord. (*Nature, Lond.*, 21st Oct. 1950, Vol. 166, No. 4225, pp. 688–689.) Account of an experimental investigation of anomalous decrease of spark breakdown potential with increase of pressure in air, N_2 (oxygen-free), 'freon 12' and SF_6. The occurrence of the phenomenon appears to depend on the presence of (*a*) a divergent field and (*b*) a gas which forms negative ions.

537.56 : 538.56 **334**

The Refractive Index and Classical Radiative Processes in an Ionized Gas.—K. C. Westfold. (*Phil. Mag.*, June 1950, Vol. 41, No. 317, pp. 509–516.) Hartree's classical methods are used to find the effect of the refractive index on the emission and absorption of radio waves in an ionized medium with no magnetic field, and to confirm the results of Smerd & Westfold (95 of January). A quantum theory interpretation is also given.

537.562 : 537.311 **335**

The Electrical Conductivity of an Ionized Gas.—R. S. Cohen, L. Spitzer, Jr, & P. M. Routly. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, pp. 230–238.) "The interaction term in the Boltzmann equation for an ionized gas is expressed as the sum of two terms: a term of the usual form for close encounters and a diffusion term for distant encounters. Since distant encounters, producing small deflections, are more important than close encounters, consideration of only the diffusion term gives a reasonably good approximation in most cases and approaches exactness as the temperature increases or the density decreases. It is shown that in evaluating the coefficients in this diffusion term, the integral must be cut off at the Debye shielding distance, not at the mean interionic distance. The integro-differential equation obtained with the use of this diffusion term permits a more precise solution of the Boltzmann equation than is feasible with the Chapman-Cowling theory. While one pair of coefficients in this equation has been neglected, the remaining coefficients have all been evaluated, and the resultant equation solved numerically for the velocity distribution function in a gas of electrons and singly ionized atoms subject to a weak electrical field. Special techniques were required for this numerical integration, since solutions of the differential equation proved to be unstable in both directions. For high temperatures and low densities the computed electrical conductivity is about 60 percent of the value given by Cowling's second approximation."

538.114 **336**

Ferromagnetic Domains.—H. J. Williams. (*Elect. Engng, N.Y.*, Sept. 1950, Vol. 69, No. 9, pp. 817–822.) A résumé of existing knowledge. Domain sizes and shapes are due to the tendency of the ferromagnetic system towards a state of minimum energy.

538.221 **337**

Ferromagnetism at Very High Frequencies: Part 3—Two Mechanisms of Dispersion in a Ferrite.—G. T. Rado, R. W. Wright & W. H. Emerson. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, pp. 273–280.) "The magnetic spectrum of a ferrite is shown to contain two regions of pronounced dispersion. One occurs at radio frequencies, resembles a resonance, and is proved to be due to domain-wall displacements; the other occurs in the microwave range, exhibits typical resonance characteristics, and is attributed to domain rotations." Part 2: 1994 of 1949 (Johnson & Rado).

538.52/.53 **338**

Calculation of Currents Induced in a Solid Sphere: Self Inductance and Mutual Inductance with an Endless Solenoid.—A. Colombani. (*C. R. Acad. Sci., Paris*, 18th Sept. 1950, Vol. 231, No. 12, pp. 570–572.) Corresponding formulae to those previously given for a spherical shell (2766 of 1950) are derived for a solid sphere within an endless solenoid.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.53 : 551.510.535 **339**

The Influence of High-Altitude Winds on Meteor-Trail Ionization.—C. D. Ellyett. (*Phil. Mag.*, July 1950, Vol. 41, No. 318, pp. 694–700.) Mechanisms whereby winds can cause changes in meteor-trail positions are discussed in the light of observations from different sources. Assuming that fluctuation rate depends on frequency, short- and medium-period fluctuations of meteor-trail echoes can be correlated with phase and amplitude variations of waves reflected from the ionosphere. A causal connection is suggested. See also 359 below.

523.53 : 621.396.9 **340**

The Fluctuation and Fading of Radio Echoes from Meteor Trails.—Greenhow. (See 359.)

523.72+523.74] : 621.396.822 **341**

The Solar Atmosphere and the Origin of Radio-Frequency Radiation.—S. A. Korff & Y. Beers. (*Phys. Rev.*, 1st Nov. 1950, Vol. 80, No. 3, pp. 489–490.) Short discussion of the physical conditions prevailing in the sun's atmosphere. The tendency in some recent papers to attach too much physical significance to the 'equivalent noise temperature' T is deprecated, since T is only a measure of the available power of a noise source and gives no information regarding the mechanism of the source.

523.72 : 621.396.822 **342**

Solar Radiation of Wavelength 1·25 Centimetres.—J. H. Piddington & H. C. Minnett. (*Aust. J. sci. Res., Ser. A*, Dec. 1949, Vol. 2, No. 4, pp. 539–549.) Observations covering a period of about six months are described. The observed average intensity corresponded to a black-body temperature of 10^4°K, with a maximum error of about $\pm 5\%$. Day-to-day variations were $<\pm 3\%$, which was the limit of observational accuracy. Short-period fluctuations were $\not> \pm 5\%$, even during intense solar activity. The distribution of intensity over the solar disk, measured by a method analogous to the Michelson interferometer technique, was consistent with 84% of the radiation coming from a uniform disk and 16% from a narrow annulus surrounding it.

523.72 : 621.396.822 **343**

Solar Radiation at a Wavelength of 3·18 Centimetres.—H. C. Minnett & N. R. Labrum. (*Aust. J. sci. Res., Ser. A*, March 1950, Vol. 3, No. 1, pp. 60–71.) Observations were made daily from 24th November 1948, to 1st March 1949. An accurate measurement of received intensity was made by one technique, and a continuous record over several hours was made by a less accurate method. The estimated equivalent black-body temperature was 19 300°K $\pm$ 7% for the quiet sun; temperature increments per unit increase of sunspot area were less than for longer microwaves. Observations were also made during the eclipse on 1st November 1948, to investigate the distribution across the disk. Results were consistent with either 74% of the radiation coming from the visible disk and the remainder from a bright ring round the circumference, or the whole of the radiation coming from a uniform disk of diameter 1·1 times that of the visible disk.

523.72.029.6 : 621.396.822 **344**

Radio-Frequency Radiation from the Quiet Sun.—S. F. Smerd. (*Aust. J. sci. Res., Ser. A*, March 1950, Vol. 3, No. 1, pp. 34–59.) The chromosphere and the corona are considered as two regions of uniform temperature with a discontinuity at the boundary: because of uncertainty regarding these temperatures, a range of values is considered. The intensity distribution across the emitting disk is derived for frequencies from 60 to 30 000 Mc/s, and the size of the r.f. disk is estimated from that of the optical disk. The apparent temperature (an equivalent measure of the flux density at the earth) has a maximum as a function of frequency for each coronal temperature, and as a function of coronal temperature for each frequency. All observed apparent temperatures correspond to chromosphere temperatures from 10^4 to 3×10^4 °K and corona temperatures from $2{\cdot}5 \times 10^5$ to 3×10^6 °K. The effects of a possible general solar magnetic field are small in relation to those due to uncertainties regarding temperature.

523.752 : 621.396.822 **345**

The Derivation of a Model Solar Chromosphere from Radio Data.—J. H. Piddington. (*Proc. roy. Soc. A*, 10th Oct. 1950, Vol. 203, No. 1074, pp. 417–434.) The basic data used are recent radio measurements of disk temperature at frequencies between 600 and 24 000 Mc/s. The coronal contribution to this is calculated and subtracted to give the chromospheric component. Finally an expression is derived giving separately the two components as functions of frequency and position on the disk; the values obtained are in reasonable agreement with experimental observations.

The radio results are combined with data on the intensities of spectrum lines at various levels in the chromosphere to obtain the distribution of electron density and temperature. A marked departure from conditions of hydrostatic equilibrium is indicated.

523.78 "1948.11.1" : 621.396.822 **346**

Measurements of Solar Radiation at a Wavelength of 50 Centimetres during the Eclipse of November 1, 1948.—W. N. Christiansen, D. E. Yabsley & B. Y. Mills. (*Aust. J. sci. Res., Ser. A*, Dec. 1949, Vol. 2, No. 4, pp. 506–523.) Measurements were made at three well separated places in Australasia. Abrupt changes in the slope of the flux-density curves were correlated with the covering and uncovering of small areas of great radio brightness, viz. sunspots past and present, and one prominence; these areas contributed about one-fifth of the total received power. Of the remaining four-fifths, about 40% originated outside the visible disk. No effects of any general solar magnetic field were detected.

523.78 "1948.11.1" : 621.396.822 **347**

Solar Radiation at a Wavelength of 10 Centimetres, including Eclipse Observations.—J. H. Piddington & J. V. Hindman. (*Aust. J. sci. Res., Ser. A*, Dec. 1949, Vol. 2, No. 4, pp. 524–538.) Observations were made at Sydney both before and after the eclipse of 1st November 1948, and conditions during the eclipse were related to the varying day-to-day level of radiation intensity.

The distribution over the solar disk was determined, the most intense radiation coming from near the limb and some radiation from beyond the limb. At least one small high-intensity area was located. The excess of circularly polarized component, either right- or left-hand, observed at eclipse maximum was smaller than the value to be expected for a general solar magnetic field of 50 gauss at the poles.

523.854 : 621.396.822 **348**

Galactic Radiation at Radio Frequencies: Part 1—100 Mc/s Survey.—J. G. Bolton & K. C. Westfold. (*Aust. J. sci. Res., Ser. A*, March 1950, Vol. 3, No. 1, pp. 19–33.) "An aerial array with a 17 beamwidth, on an equatorial mounting, was used to plot the distribution of intensity over the section of the celestial sphere between declination +30° and −90°. The method of eliminating the effect of the aerial polar diagram from the observations is described and the final distribution, expressed in terms of equivalent black-body temperature, is presented in galactic co-ordinates on a series of equal-area charts."

537.562 : 537.311 **349**

The Electrical Conductivity of an Ionized Gas.—Cohen, Spitzer & Routly. (See 335.)

550.381 **350**

The Origin of the Earth's Magnetic Field.—E. C. Bullard. (*Observatory*, Aug. 1950, Vol. 70, No. 857, pp. 139–143.) The Halley Lecture for 1950. Halley's work is outlined and various mechanisms are considered which might possibly account for the existence of the earth's magnetic field and its secular variation. The preferred hypothesis assumes a mechanism resembling that of a self-excited dynamo, the motion of the earth's fluid conducting core producing effects similar to those due to the motion of the dynamo rotor. Electric currents would thus be generated in the core and these could account for the main field; their variations due to the effects of irregular whirls and eddies near the surface of the core could also explain the secular variations of the field. The nature of the field within the core to be expected on such a hypothesis is discussed and the possible value of solar observations in this connection is pointed out.

550.381 **351**

The Experimental Determination of the Geomagnetic Radial Variation.—S. K. Runcorn, A. C. Benson, A. F. Moore & D. H. Griffiths. (*Phil. Mag.*, Aug. 1950, Vol. 41, No. 319, pp. 783–791.) "Theories of the origin of the dipole components of the earth's main magnetic field are of two types; distributed theories attribute it to a fundamental property of rotating matter, core theories to current systems within the core. The variation with depth below the surface of the horizontal field intensity is different for the two theories. Experimental values are given for this variation, obtained by measurements in coal mines, which are near to the values predicted by a core theory, and significantly different from those predicted by a distributed theory. The magnetic effects of the sedimentary rocks and magnetic anomalies due to the basement rocks are shown to have negligible effects on the measurements."

550.384 **352**

'Sudden Commencements' in Geomagnetism.—W. Jackson. (*Nature, Lond.*, 21st Oct. 1950, Vol. 166, No. 4225, pp. 691–692.) Two types of normal sudden commencement are recognized, according as the main movement is not, or is, preceded by a smaller movement in the opposite direction. To investigate Ferraro & Parkinson's suggestion (1142 of 1950) that the frequency of occurrence of the second type may be a function of geomagnetic longitude, this frequency was computed from available magnetograms for 1946–1948 for Sitka. The result did not confirm the above suggestion, but is not regarded by the author as completely decisive.

550.384.4 **353**

Lunar Diurnal Variation of the Vertical Component of the Earth's Magnetic Field at Val-Joyeux.—P. Rougerie. (*C. R. Acad. Sci., Paris*, 16th Oct. 1950, Vol. 231, No. 16, pp. 787–788.)

551.510.535 **354**

Methods for the Determination of the Ionization Distribution beyond the Maximum of the E Layer.—K. Bibl. (*Naturwissenschaften*, Aug. 1950, Vol. 37, No. 16, pp. 373–374.) Information regarding the ionization distribution in the region between the E and F layers can be obtained from a knowledge of the variation with frequency of the delay of the F-layer reflection with reference to the E-layer limiting frequency. For a given ionization distribution, the delay depends only on the ratio f/f_{cE} and on the thickness of the E layer, hence the latter can be found from delay/frequency curves. Using hourly records for the first half of 1949, a value of 35 km is found for the mean half-thickness of the E layer, whereas reflection measurements give a value of about 25 km for the thickness of the lower half. This indicates a more gradual decrease of electron density upwards from the middle layer than in the lower half. The theory is developed to enable the true height to be assigned to any reflection.

551.57 : 621.317.318† **355**

A Method of Measurement of the Charges carried by Small Electrified Particles.—L. Godard & C. Lafarque. (*C. R. Acad. Sci., Paris*, 16th Oct. 1950, Vol. 231, No. 16, pp. 786–787.) An absolute method for charges on particles of fog, mist or rain.

LOCATION AND AIDS TO NAVIGATION

621.396.9+621.396.6 **356**

S.B.A.C., Farnborough.—(See 447.)

621.396.9 + 621.396.933 **357**

A New Basis for the Analysis of Radio Navigation and Detection Systems.—N. L. Harvey. (*Sylvania Technologist*, Oct. 1950, Vol. 3, No. 4, pp. 15–18.) Certain developments in the theory of information transmission are applied to radiolocation systems. A brief explanation is given of the basic principles that (*a*) the transmission and receiver bandwidths are mutually independent system parameters, (*b*) the system resolution is the Fourier transform of the power spectrum, (*c*) the type of modulation used to generate the spectrum is unimportant.

621.396.9 **358**

The Use of Dummy Reflecting Objects in Radar Technique.—C. Stüber. (*Arch. elekt. Übertragung*, July 1950, Vol. 4, No. 7, pp. 275–279.) An account of devices such as Al-foil dipoles and corner reflectors used by the Germans in the second world war for anti-radar camouflage purposes.

621.396.9 : 523.53 **359**

The Fluctuation and Fading of Radio Echoes from Meteor Trails.—J. S. Greenhow. (*Phil. Mag.*, July 1950, Vol. 41, No. 318, pp. 682–693.) The fluctuations of meteor echoes were investigated simultaneously on frequencies of 36 and 72 Mc/s. The flutter period for short-period fluctuations varies inversely with frequency and is independent of the type or velocity of the meteor. This is consistent with distortion of the trail due to winds in the ionosphere. A few cases of longer-period fluctuations have been observed on 36 Mc/s only.

621.396.9 : 621.396.828 **360**

Integration-Noise Reducer for Radar.—W. J. Cunningham, J. C. May & J. G. Skalnik. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 76–78.) The video output of a radar receiver is fed through a gating circuit and integrated. A radar echo appears as an increase in the integrated signal. The duration, pulse-recurrence frequency, and time delay of the gating waveform are adjustable. Improvements in signal/noise ratio of between 5 db and 17 db are obtained.

621.396.932 **361**

An Improved Marine Radar Equipment.—(*Engineer, Lond.*, 11th Aug. 1950, Vol. 190, No. 4933, p. 160.) Short general description of the Marconi 'Radiolocator IV', an instrument for detecting suitable targets up to a range of 40 miles. In switching from shorter to longer ranges the pulse length is automatically lengthened, giving higher definition on the shorter ranges and brighter illumination of targets on the longer. Two self-contained remote-display units may be added.

621.396.933 **362**

Pulse Navigation Systems.—W. L. Barrow. (*J. Brit. Instn Radio Engrs*, Oct. 1950, Vol. 10, No. 10, pp. 313–321.) Reprint. See 648 of 1950.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.583 : 621.385 **363**

Getter Materials for Electron Tubes.—Espe, Knoll & Wilder. (See 499.)

535.215.1 **364**

The Photoeffect in Alkali/Germanium Compounds.—N. Schaetti & W. Baumgartner. (*Helv. phys. Acta*, 1st Sept. 1950, Vol. 23, No. 5, pp. 524–528. In German.)

535.215.1 **365**

Photoelectric Changes Induced in SrO and BaO by Ultraviolet Irradiation.—J. E. Dickey & E. A. Taft. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, p. 308.) The observed photoemission of SrO is plotted against time, for an irradiation $h\nu = 5{\cdot}80$ eV. There was rapid initial rise, with saturation after some minutes. The mechanism involved is discussed briefly.

535.37 **366**

Luminescence Spectra of Different Types of Phosphor under X Rays and Cathode Rays, specially at Low Temperatures.—H. N. Bose. (*Proc. nat. Inst. Sci., India*, Sept./Oct. 1950, Vol. 16, No. 5, pp. 365–366.) Luminescence spectra of various alkali halides and some simple organic compounds, under cathode-ray and X-ray excitation, have been studied at ordinary and low temperatures. With impurity-activated alkali halides the luminescence spectrum of the parent lattice is not much affected by the presence of the characteristic band of the impurity. The results indicate that emitting centres are created by the irradiation, and also by the presence of impurities. With the organic compounds, interesting variants of ultraviolet luminescence have been observed.

535.37 : 546.47.284 **367**

On the Fluorescence and Phosphorescence Emission Spectra of Manganese-Activated Zinc Silicate.—J. H. Schulman & C. C. Klick. (*J. opt. Soc. Amer.*, Sept. 1950, Vol. 40, No. 9, pp. 622–623.) Observations are reported which indicate that the fluorescence and phosphorescence emission spectra of Zn_2SiO_4-Mn are identical. This result contradicts conclusions by Nagy (*ibid.*, 1950, Vol. 40, p. 407).

538.221 **368**

Ferromagnetic Spinels for Radio Frequencies.—R. L. Harvey, I. J. Hegyi & H. W. Leverenz. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 321–363.) An account of the structure, synthesis, properties and uses of ferrites.

538.221 **369**

Theory of Magnetic Anisotropy in Alnico V.—J. E. Goldman & R. Smoluchowski. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, pp. 302–303.)

538.221 : 538.652 **370**

The Magnetostriction of Fe/Pt Alloys.—N. S. Akulov, Z. I. Alizade & K. P. Belov. (*C. R. Acad. Sci. U.R.S.S.*, 21st April 1949, Vol. 65, No. 6, pp. 815–818. In Russian.) Curves are shown for various alloys, the highest value of magnetostriction being found for the system 46%Fe/54%Pt. The effect of different treatments on this alloy is studied.

538.221 : 538.652 **371**

Single-Crystal Magnetostriction Constants of an Iron/Cobalt Alloy.—J. E. Goldman. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, pp. 301–302.)

538.221 : 621.317.4.042.15 **372**

Study of Magnetic Powders at Radio Frequencies.—P. Abadie, I. Épelboïm & B. Pistoulet. (*C. R. Acad. Sci., Paris*, 16th Oct. 1950, Vol. 231, No. 16, pp. 762–764.) Results of various measurements using a resonance technique at frequencies up to 24 kMc/s indicate the normal and anomalous properties of composite powders of dielectric and magnetic materials under conditions of gyromagnetic relaxation.

538.632 : 546.87 **373**

The Electrical Conductivity of Bismuth Fibres: Part 2 — Anomalies in the Magneto-Resistance.—B. Donovan & G. K. T. Conn. (*Phil. Mag.*, Aug. 1950, Vol. 41, No. 319, pp. 770–782.) Experimental results are reported which are considered to constitute the first unequivocal evidence of the existence of a longitudinal Hall coefficient.

621.314.6 : 537.311.33 **374**

On the Back Current in Blocking-Layer Rectifiers.—J. H. Gisolf. (*Phil. Mag.*, Aug. 1950, Vol. 41, No. 319, pp. 754–769.) The theories of Davidov and Schottky are not applicable to the case of large back currents. Mathematical analysis is given which permits the calculation of the resistance to back currents, with allowance for the influence of the field on the threshold energy. The current/voltage characteristic can be obtained in particular cases by numerical integration. Examples given include comparisons between Se rectifiers and crystal detectors. The effect of artificial barrier-layers, such as a thin film of lacquer, on the electrical properties of rectifiers is briefly discussed. The rectifier effect is strongly favoured by an increase of the current density.

621.315.592† + 621.315.61 **375**

Modern Theories on Dielectrics and Semiconductors.—S. Teszner. (*Bull. Soc. franç. Élect.*, Aug. 1950, Vol. 10, No. 107, pp. 367–378.) Discussion of the theory by which such materials may be classified according to their internal structure, and qualitative study of the mechanism of conduction in crystalline solids, the effect of impurities on conductivity, and orbital, ionic, and molecular polarization and their connection with dielectric constant. See also 3445 of 1949.

621.315.592 : 537.311.33 **376**

Theory of Relation between Hole Concentration and Characteristics of Germanium Point Contacts.—J.

Bardeen. (*Bell Syst. tech. J.*, Oct. 1950, Vol. 29, No. 4, pp. 469–495.) "The theory of the relation between the current-voltage characteristic of a metal-point contact to *n*-type germanium and the concentration of holes in the vicinity of the contact is discussed. It is supposed that the hole concentration has been changed from the value corresponding to thermal equilibrium by hole injection from a neighboring contact (as in the transistor), by absorption of light or by application of a magnetic field (Suhl effect). The method of calculation is based on treating separately the characteristics of the barrier layer of the contact and the flow of holes in the body of the germanium. A linear relation between the low-voltage conductance of the contact and the hole concentration is derived and compared with data of Pearson and Suhl. Under conditions of no current flow the contact floats at a potential which bears a simple relation, previously found empirically, with the conductance. When a large reverse voltage is applied the current flow is linearly related to the hole concentration, as has been shown empirically by Haynes. The intrinsic current multiplication factor of the contact can be derived from a knowledge of this relation."

621.315.592 : 537.311.33 **377**

Theory of the Flow of Electrons and Holes in Germanium and Other Semiconductors.—W. van Roosbroeck. (*Bell Syst. tech. J.*, Oct. 1950, Vol. 29, No. 4, pp. 560–607.) "A theoretical analysis of the flow of added current carriers in homogeneous semiconductors is given. The simplifying assumption is made at the outset that trapping effects may be neglected, and the subsequent treatment is intended particularly for application to germanium. In a general formulation, differential equations and boundary-condition relations in suitable reduced variables and parameters are derived from fundamental equations which take into account the phenomena of drift, diffusion, and recombination. This formulation is specialized so as to apply to the steady state of constant total current in a single cartesian distance coordinate, and the properties of solutions which give the electrostatic field and the concentrations and flow densities of the added carriers are discussed. The ratio of hole to electron concentration at thermal equilibrium occurs as parameter. General solutions are given analytically in closed form for the intrinsic semiconductor, for which the ratio is unity, and for some limiting cases as well. Families of numerically obtained solutions dependent on a parameter proportional to total current are given for *n*-type germanium for the ratio equal to zero. The solutions are utilized in a consideration of simple boundary-value problems concerning a single plane source in an infinite filament."

621.315.592 : 621.314.6 **378**

***P*-*N* Junctions prepared by Impurity Diffusion.**—R. N. Hall & W. C. Dunlap. (*Phys. Rev.*, 1st Nov. 1950, Vol. 80, No. 3, pp. 467–468.) By providing a nonlinear distribution of impurities with distance from the barrier, rectifiers can be constructed combining the good forward characteristic corresponding to a large impurity gradient with the high reverse breakdown voltage corresponding to a small impurity gradient.

621.315.61 **379**

Conductance of Insulators for Overhead Lines at Carrier Frequencies.—G. Gregoretti. (*Alta Frequenza*, June 1950, Vol. 19, No. 3, pp. 137–144.) Conductance measurements were made on various types of insulator, after exposure to bad weather, at 50, 100 and 150 kc/s; results are recorded. Partial metallization of a pyrex insulator considerably reduced the variation of its leakage conductance with atmospheric conditions.

621.315.612 **380**

The Dielectric Constant of Inhomogeneous Dielectrics.—G. M. Jonker. (*Chem. Weekbl.*, 22nd April 1950, Vol. 46, No. 2314, pp. 266–268.) A simple discussion of the dependence of the dielectric constant of ceramic materials on the porosity. The pore formation depends on the heat treatment; during sintering, the initially irregularly shaped pores run together to form rounded cavities. Measured values of the dielectric constant for material sintered at different temperatures are compared with values given by Böttcher's formula.

666.1.037.5 **381**

High-Temperature-Lamp Seals.—E. J. G. Beeson. (*Elect. Times*, 19th Oct. 1950, Vol. 118, No. 3076, pp. 605–608.) A description is given of the molybdenum-foil seal, which is in common use but is inconveniently large and costly when large currents (150 A or more) have to be carried. The construction of a quartz/molybdenum-thimble seal of the Houskeeper type is described, which has been developed for very-high-wattage mercury- and gas-discharge lamps.

MATHEMATICS

517.564 **382**

On the Characteristic Values of Spheroidal Wave Functions.—C. J. Bouwkamp. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 87–90.) The first five terms of a power series expansion are given for the characteristic values of such functions of which both order m and degree n are integral and $n \nless m$. Numerical values are given for the case where $m=1$.

517.942.82 **383**

Note on the Inversion of the Laplace Transform.—B. Gross. (*Phil. Mag.*, June 1950, Vol. 41, No. 317, pp. 543–544.) The 'pair property' of the Fourier transform is shown to exist also for the Laplace transform for particular classes of functions.

519.21 : 621.396.822 **384**

Some Statistical Functions useful for the Study of Background Noise.—A. Blanc-Lapierre. (*C. R. Acad. Sci., Paris*, 18th Sept. 1950, Vol. 231, No. 12, pp. 566–567.) Starting from a random time series with a Poisson distribution, three theorems are established relating to nonstationary aleatory functions which occur in the theoretical treatment of background noise.

681.142 **385**

SEAC. The National Bureau of Standards Eastern Automatic Computer.—(*Tech. Bull. nat. Bur. Stand.*, Sept. 1950, Vol. 34, No. 9, pp. 121–127.) A general description of the computer is given, with examples of its application in optical-lens design and in the solution of a partial differential equation representing the flow of heat through a chemically reactive material. The present input-output unit uses a manual keyboard for direct input and a teletype printer for direct output, with a hexadecimal system (base 16) for both numbers and instructions. For indirect operation punched paper tape is used, with an input and output rate of 30 words/min, which can be increased to 10 000 words/min by the use of magnetic wire or tape. The present memory unit is a serial type consisting of 64 acoustic delay lines. The addition of a parallel system of 45 c.s. tubes with a greatly reduced access time is in progress.

681.142 **386**

The N.B.S. Computer Program.—(*Tech. Bull. nat. Bur. Stand.*, Sept. 1950, Vol. 34, No. 9, pp. 128–129.) An outline of the various phases of the programme on digital computers, including fundamental research, engineering development, design and construction, and technical services. In addition to SEAC a second machine, the N.B.S. Western Automatic Computer (SWAC) has been completed in the N.B.S. laboratories at Los Angeles. Five other large-scale computers are under construction by industrial firms for various government services.

51 : [621.396/.397 **387**

Radio and Television Mathematics. [Book Review]—B. Fischer. Publishers: Macmillan, New York, 1949, 440 pp., $6.00. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, p. 1230.)

512.9 **388**

Grundzüge der Tensorrechnung in Analytischer Darstellung—Teil 1 : Tensoralgebra. (Analytical Presentation of the Fundamentals of Tensor Calculus. Part 1: Tensor Algebra.) [Book Review]—A. Duschek & A. Hochrainer. Publishers: Springer Verlag, Vienna, 1948, 129 pp. (*Elektrotechnik, Berlin*, July 1950, Vol. 4, No. 7, p. 264.) Second impression of a useful practical textbook.

517.43 **389**

Calcul Opérationel. [Book Review]—É. Labin. Publishers: Masson et Cie, Paris, 1949, 145 pp., 780 fr. (*Proc. phys. Soc.*, 1st Sept. 1950, Vol. 63, No. 369A, p. 1046.) "This work may be regarded as a list of general rules of the operational calculus...The subject is treated from the viewpoint of Laplace transform and complex variable...[It] is recommended to those who have an adequate knowledge of the underlying mathematical theory."

517.93 : 534.014.1/.2 **390**

Non-Linear Vibrations in Mechanical and Electrical Systems. [Book Review]—J. J. Stoker. Publishers: Interscience Publishers, 273 pp., 40s. (*Phil. Mag.*, July 1950, Vol. 41, No. 318, p. 731.) Deals with the free and forced oscillations corresponding to solutions of the differential equations of Duffing and van der Pol.

MEASUREMENTS AND TEST GEAR

621.3.082 **391**

British Developments in Instrumentation.—J. H. Jupe. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 182..210.) Brief descriptions of a wide range of instruments, including a photocell device for measuring the size of carbon particles in flames, a direct-reading midget magnetometer using the Hall effect in Ge and with three ranges covering 0–25 000 gauss, electronic gauges of many types, new photocells, including one modulated by an alternating field, a 15-channel c.r. camera with 15 1½-in c.r. tubes as an integral part of the unit, and a low-frequency analyser. An echo-free room is also noted.

621.3.083.4 : 621.396.611.21.012.8 **392**

Measurement of the Electrical Characteristics of Quartz Crystal Units by use of a Bridged-Tee Network.—C. H. Rothauge & F. Hamburger, Jr. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1213–1216.) The simplified equivalent circuit of a crystal with a capacitive load is an effective inductance and an effective resistance in series; this, in parallel with a T-network of two equal capacitors and a resistor, forms a network with a zero transmission frequency. Screening of such a system is relatively simple, as the source and the detector have a common earthed terminal. Stray capacitances are included in the calibration of the network capacitors. The accuracy of measurement at about 5 Mc/s was estimated to be within 0·3% for the equivalent series reactance, and within 2·3% for the equivalent series resistance.

621.317.3 : 621.396.611.3 **393**

Principles of Measurements on Coupled Circuits.—W. F. Dil. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 91–115.) Analysis is given of a circuit consisting of a valve feeding two tuned circuits with capacitive and resistive as well as inductive coupling; universal resonance curves are presented. The conditions for symmetrical resonance curves are investigated. Methods for measuring circuit Q values and coupling coefficients are reviewed. Techniques are suggested for measuring the parameters of coupled circuits without loss of accuracy due to disturbance of the normal operating conditions.

621.317.332 **394**

Conductivity Measurements at Microwave Frequencies.—A. C. Beck & R. W. Dawson. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1181–1189.) An investigation of skin effect at 9 kMc/s. The half-power bandwidth of the resonance curve of an open-circuited coaxial line having the wire sample as the centre conductor was measured and the loaded Q derived. By measurement of the transmission loss in the specimen holder, a correction factor was obtained, enabling the Q of the sample alone to be calculated. Numerical results are tabulated for various pure metals and alloys showing the effects of different surface treatments on the resistivity at frequencies for which the current penetration depth is small. The results emphasize the importance of a high polish. Electroplated copper and silver deposits, even when polished, were found to have considerably higher resistivities than the solid metals.

621.317.332 **395**

Conductivity Measurements at Microwave Frequencies.—A. C. Beck. (*Bell Lab. Rec.*, Oct. 1950, Vol. 28, No. 10, pp. 433–437.) See 394 above.

621.317.335.2† : 621.396.619.13 **396**

Some Experiments on the Use of Frequency Modulation in Electrical Measurements.—D. M. Tombs & J. F. Ward. (*Proc. Instn elect. Engrs*, Part II, Oct. 1950, Vol. 97, No. 59, pp. 645–650.) Capacitance changes are measured by the variation produced in the frequency or phase of a signal from an oscillator normally of high frequency-stability. A full description is given of laboratory apparatus used in studying the technique. The results obtained confirmed its value, particularly in respect of stability and sensitivity. Capacitance changes of 5×10^{-4} pF could be measured with a possible error of about 50%. The principal limitation arises from phase fluctuations in the oscillator.

621.317.384 **397**

Microwave Power Measurements.—R. Tozzi. (*Alta Frequenza*, June 1950, Vol. 19, No. 3, pp. 115–136.) Discussion of methods based on the resistance variations of heat-sensitive elements, such as thermistors, introduced into waveguides or coaxial lines. An apparatus constructed at the Research Centre for Microwave Physics at Florence and using thermistors is described; results obtained are reported. The power range of this instrument is 5–10 mW, the maximum error being 5–8%.

621.317.7 : [621.385.3 : 621.315.59 **398**

Production Tester for Transistors.—L. P. Hunter & R. E. Brown. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 96–99.) A.c. test apparatus for rapid determination of transistor voltage gain, current gain and input impedance under different bias and load conditions.

621.317.714.085.414 **399**

Design of Log-Scale D.C. Meters.—A. Stimson & C. F. Taylor. (*Elect. Engng, N.Y.*, Oct. 1950, Vol. 69, No. 10, pp. 877–882.) The mathematical background and underlying principles involved in the design of log-scale d.c. indicating instruments are given. The characteristics of the flux distribution in the magnet system and means for adjusting it are discussed. Application is made to a photographic exposure meter, where the logarithmic scale is used as a slide-rule to give direct indications of exposure times.

621.317.725 **400**
A Valve-Voltmeter Circuit.—R. Kitai. (*Electronic Engng*, Oct. 1950, Vol. 22, No. 272, pp. 420–422.) Description of apparatus designed for the use of students. Special features are rugged construction, overload protection and low cost.

621.317.725 : 621.383.5 **401**
A High-Impedance Voltmeter.—T. A. Ledward. (*Electrician*, 25th Aug. 1950, Vol. 145, No. 3767, pp. 467–469.) Design and use of Se barrier-layer photocells for amplification of the movement of the pointer of a moving-coil instrument. A light Al vane attached to the pointer moves over a pair of differentially connected Se cells, so that a deflection amplification of 20 : 1 is obtained. The light source and reflector are mounted above the vane, outside the instrument. Low amplification is used for reasons of stability and reliability. Ranges of 10 mV, 100 mV, 1 V, 10 V and 100 V at 1 MΩ per volt are available and also a 1 000-V range at 0·1 MΩ per volt.

621.317.726.087 **402**
Chart Recording of Microsecond Pulse Amplitudes.—J. T. Dewan & K. W. Allen. (*Rev. sci. Instrum.*, Oct. 1950, Vol. 21, No. 10, pp. 823–826.) Description of a peak-voltmeter recorder suitable for use in counter circuits.

621.317.733 **403**
Wien-Bridge Network Modifications.—R. Zuidhof. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 192..198.) When the network is used as an RC oscillator circuit, stray capacitance across the series resistor produces undesirable effects. These can be counteracted by the addition of a trimmer across the series capacitor. This modification results in a more constant output and an extended frequency range.

621.317.755 **404**
A Fast Sweep Circuit.—N. L. Davis & R. E. White. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 107–109.) Two methods for obtaining an oscilloscope sweep of 100 in./μs were investigated, one using a modified raster scan and the other using a hydrogen thyratron. The circuits and methods of calibration are described and typical applications of the equipment are illustrated.

621.317.755 **405**
Automatic Beam Blanker for Oscilloscopes.—A. L. Dunn, A. R. McIntyre & A. L. Bennett. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 94–95.) A circuit is described in which the sweep itself is used to release the beam and to blank it when the trace is completed. This eliminates background fogging caused by scattered electrons.

621.317.755 : 621.385.029.63/.64 **406**
The Travelling-Wave Cathode-Ray Tube.—Owaki, Terahata, Hada & Nakamura. (See 503.)

621.317.755 : 621.396.645.018.424† **407**
Wide-Band Amplifier for Cathode-Ray-Oscilloscope Observation of Transient Phenomena.—Schmid & Baldinger. (See 315.)

621.317.755.029.63 **408**
An Oscillograph for Decimetre Waves.—H. G. Möller. (*Elektrotechnik, Berlin*, July 1950, Vol. 4, No. 7, pp. 246–249.) By introducing a dielectric covering on the deflector plates the full sensitivity of a c.r. tube can be retained at higher frequencies. A formula is derived connecting phase velocity with the dimensions of the dielectric for the E_0-mode of operation. Numerical examples are calculated.

621.317.772 **409**
Precision Phasemeter for Audio Frequencies.—J. Kritz. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 102–106.) The design of the instrument is based on the method of Ragazzini & Zadeh (1724 of 1950). To obtain an accuracy to within 0·1° when measuring the phase difference between two sinusoidal voltages it was necessary to design each section, including the ring-modulator phase-detector bridge, so as to reduce each component error to below 0·01°. Methods are described for self-calibration of the instrument.

621.317.784 : 621.317.733 **410**
A Bolometer Bridge for the Measurement of Power at High Frequencies.—R. A. Soderman. (*Gen. Radio Exp.*, July 1950, Vol. 25, No. 2, pp. 1–8.) Description of Type 1651-A bridge. Measurements of power up to 500 mW may be made at frequencies from 5 Mc/s to over 1 kMc/s by substitution or direct-reading methods to within ±10% or ±20% respectively. Thermistor or barretter bolometers with resistances in the range 25–400Ω may be used.

621.396.615 **411**
Signal-Generator Output Systems.—H. Molinari. (*Bull. schweiz. elektrotech. Ver.*, 14th Oct. 1950, Vol. 41, No. 21, pp. 798–801. In German.) The calibration of the attenuators usually fitted to signal generators is only valid for a particular load impedance. The factors affecting the voltage at the output terminals of a generator are investigated. For accurate knowledge of the terminal voltage, the load impedance, the no-load voltage V and the internal impedance Z of the generator must be known. Formulae giving V and Z in terms of measured impedances are derived.

621.396.615 : 621.396.619.13 **412**
Design for a Wobbulator.—M. G. Scroggie. (*Wireless World*, Oct. 1950, Vol. 56, No. 10, pp. 369–372.) Design and construction details are given of an instrument for use with the simple c.r.o. previously described (1458 of 1950). The circuit used is adapted from that of Johnson (1898 of 1949) which has the advantages of giving f.m. up to 30% and of requiring only one valve.

621.396.615.14 **413**
A Wide Range Microwave Sweeping Oscillator.—M. E. Hines. (*Bell Syst. tech. J.*, Oct. 1950, Vol. 29, No. 4, pp. 553–559.) Description of a test oscillator using the BTL 1553-416A triode (510 below). A mechanical tuning device varies the frequency continuously at a low-a.f. rate over the frequency band 3·6–4·5 kMc/s.

621.396.615.14 **414**
Microwave Sweep Generator.—L. C. Eisaman. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 101–103.) A Type-6BL6 reflex klystron feeds a resonant cavity tuned by a motor-driven plunger. Frequency sweep is 2·6–3·4 kMc/s; sweep rate 8–10 c/s.

621.396.826.029.51 : 535.568.1 **415**
Polarimeter for the Study of Low-Frequency Radio Echoes.—A. H. Benner & H. J. Nearhoof. (*Rev. sci. Instrum.*, Oct. 1950, Vol. 21, No. 10, pp. 830–834.) A

description of the equipment, with a brief note of typical experimental results. A pulse signal at a carrier frequency of 150 kc/s is received, after reflection from the ionosphere, on crossed loop aerials which separate the two components of the elliptically polarized down-coming wave. By arranging that the c.r. tube, to which the loops are connected through balanced amplifying chains, is illuminated only for the desired epoch, a direct picture of the polarization ellipse is obtained. Arrangements are included to enable the sense of rotation to be determined.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9.001.8 **416**

Measuring Water Velocity by an Ultrasonic Method.—W. B. Hess, R. C. Swengel & S. K. Waldorf. (*Elect. Engng, N.Y.*, Nov. 1950, Vol. 69, No. 11, p. 983.) Description of a method still in the experimental stage. Two 500-kc/s transducers are mounted at a fixed distance apart downstream. Measurements of the phase angle between the transmitted and received signals are made in quick succession using (*a*) the upstream, (*b*) the downstream transducer for transmission and the other for reception. From the two measured phase angles the water velocity is deduced. Average error in tests of the equipment was about 1%.

621.315.212 : 621.317.39 **417**

Measuring Cable Eccentricity.—(*Elect. Times*, 14th Sept. 1950, Vol. 118, No. 3071, p. 430.) Continuous control in the manufacture of cables with extruded insulation is provided by an instrument which indicates any core eccentricity. Operation depends on comparison of the e.m.f.'s induced in the various coils mounted in a gauge head through which the cable, fed with constant a.c., passes.

621.316.718 **418**

An Electronic Speed Control for the Towing Carriage of a Ship-Model Testing Tank.—R. H. Tizard & B. G. V. Harrington. (*Proc. Instn elect. Engrs*, Part II, Oct. 1950, Vol. 97, No. 59, pp. 651–662.) A description of equipment fitted to the carriage of one of the tanks at the National Physical Laboratory. To meet close requirements on the constancy and setting of carriage speed, a closed-loop automatic control system was developed. Details of its original features are given. Mathematical analysis of the system shows that by incorporating a spec: feedback network the stability is little affected by large variations of gain. Test results after six months' operation show great improvement compared with the manually controlled Ward-Leonard system previously used.

621.317.39 : 531.717.1 **419**

The Electronic Measurement of Sliver, Roving, and Yarn Irregularity, with Special Reference to the Use of the Fielden Bridge Circuit.—P. H. Walker. (*J. Textile Inst.*, July 1950, Vol. 41, No. 7, pp. P446–P466.) Irregularities are determined from measurements of the change of capacitance caused by passing the material through the air gap of a fixed capacitor forming one arm of a bridge, the other arms being provided by a specially wound transformer and a variable balancing capacitor. A selective pentode amplifier is used to increase the sensitivity.

621.38.001.8 **420**

Symposium on Electronics, London, September 5-8, 1950.—(*Elect. Times*, 14th Sept. 1950, Vol. 118, No. 3071, pp. 411–417.) Summarized accounts of the lectures at the opening ceremony of the conference arranged by the Electronics Group of the Scientific Instrument Manufacturers' Association and of the papers presented at the various sessions, with a review of some of the instruments exhibited.

621.384.6 **421**

Electronics and the Electrostatic Generator.—B. Jennings. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1126–1138.) Discussion of the construction and operation of particle accelerators using Van de Graaff e.s. generators to give the required high voltage.

621.384.612.2† **422**

The Synchrocyclotron at Amsterdam.—C. J. Bakker. (*Onde élect.*, Aug./Sept. 1950, Vol. 30, Nos. 281/282, pp. 347–350.) General description, with sectional diagrams and photographs, of equipment capable of accelerating protons to 60 MeV.

621.387.4† **423**

On the Temperature Variations in Alcohol/Argon-Filled G-M Counters.—O. Parkash. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, p. 303.)

621.387.4† : 549.211 **424**

Some Properties of Diamond as a Crystal Counter.—H. Ess & J. Rossel. (*Helv. phys. Acta*, 1st Sept. 1950, Vol. 23, No. 5, pp. 484–487. In French.)

621.398+621.317.083.7] : 621.395.44 : 621.311.1 **425**

Multistation Control, Telemetering, and Communication on Single-Frequency Carrier.—W. Derr, T. C. Wren & J. V. Kresser. (*Elect. Engng, N.Y.*, Oct. 1950, Vol. 69, No. 10, pp. 862–867.) Three of the stations of the Sierra Pacific Power Company are controlled from a central station by a power-line carrier system which also provides communication and selective-telemetry facilities.

621.38.001.8 **426**

Electronics in Engineering. [Book Review.]—W. R. Hill. Publishers: McGraw-Hill, 1949, 274 pp., 30s. (*Electronic Engng*, Oct. 1950, Vol. 22, No. 272, p. 445.) "An elementary book of wide scope."

PROPAGATION OF WAVES

535.42 : 538.56]+534.26 **427**

On the Theory of Diffraction.—Franz. (See 323.)

535.42 : 538.566 **428**

Diffraction from an Irregular Screen with Applications to Ionosphere Problems.—H. G. Booker, J. A. Ratcliffe & D. H. Shinn. (*Philos. Trans. A*, 12th Sept. 1950, Vol. 242, No. 856, pp. 579–607.) "An analysis is made of the diffraction effects produced when a plane wave is incident upon an irregular diffracting screen, and the results are applied to the problem of the reflexion of radio waves from an ionosphere which is irregular in the horizontal plane. The nature of the irregular screen is assumed to be given in terms of the variation of electric wave-field in a plane just beyond the screen, and it is assumed that variations occur over the plane in one direction only. It is further assumed that the screen is 'random' in the sense that it is one of an assembly all of which differ from each other, but have statistical properties in common, and deductions are made about the diffraction patterns averaged over the assembly. It is shown that many aspects of the problem can be investigated by use of the theory of 'random' electrical noise as developed by Rice and Uhlenbeck. The angular spectrum (Fraunhofer diffraction pattern) and the Fresnel diffraction pattern are described in terms of their spatial auto-correlation functions, and there is some discussion of a related method of dealing with Fresnel diffraction problems from completely determined screens.

In Part II of the paper the irregular 'fading' exhibited by a radio wave returned from the ionosphere is discussed in terms of two models in which the fading is assumed to be produced by movements of the diffracting centres in the ionosphere. The temporal auto-correlation function of the amplitude of the irregularly fading signal is related to the velocity of the ionospheric diffracting centres."

538.566 **429**

On Sommerfeld's Surface Wave.—C. J. Bouwkamp. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, p. 294.) Papers on this problem by various workers are very briefly reviewed; in particular the discussion by Kahan & Eckart (2892 of 1949) is criticized and their uniqueness theorem is analysed and pronounced unsound.

621.396.11 **430**

A Determination of the Speed of Light by the Resonant-Cavity Method.—K. Bol. (*Phys. Rev.*, 15th Oct. 1950, Vol. 80, No. 2, p. 298.) Brief account of work in progress at Stanford University. A cylindrical cavity 4·5 in. high and 9·8 in in diameter is used and a provisional result of 299.789.3 ± 0·4 km/s has been obtained. There may be a further error due to tarnishing of the cavity walls. See also 1751 of 1950 (Essen).

621.396.11.029.62 **431**

Propagation of Metric Waves beyond Optical Range.—D. W. Heightman. (*J. Brit. Instn Radio Engrs*, Oct. 1950, Vol. 10, No. 10, pp. 295–311.) A qualitative survey of tropospheric and ionospheric wave propagation in the frequency band 30–200 Mc/s. Theoretical treatment is limited to explanations of the basic principles involved. A knowledge of the easily recognized meteorological conditions associated with variations in tropospheric propagation is useful in short-term prediction of radio conditions. Extended ranges are, in general, of little practical value owing to interference from distant transmitters. A selection of long-term observations over various land and sea paths, both tropospheric and ionospheric, is presented in graphical form and results are discussed.

621.396.11.029.62 : 531.74 **432**

Measurement of Small Angles of Elevation of Incoming Electromagnetic Metre Waves. Part 2: The Comparison Method using Two Arrays with Different Directional Characteristics.—L. Pungs & H. Fricke. (*Arch. elekt. Übertragung*, Aug. 1950, Vol. 4, No. 8, pp. 309–315.) The theory of the method was given in Part I [3130 of 1950 (Stenzel)]. The voltages from the two comparison aerials are applied respectively to the two fixed systems of a goniometer, the orientation of the resultant field providing a measure of their ratio, and hence of the angle of elevation of the received wave. Design details are given for aerial systems for measurements with 2·4-m waves. The range of angles measurable with different aerial arrangements is discussed. The effect of uneven terrain on the calibration can be eliminated by providing a horizontal artificial earth or a series of vertical screens of wire mesh.

621.396.11.029.62 : 531.74 **433**

Measurement of Small Angles of Elevation of Incoming Electromagnetic Metre Waves. Part 3 The Frequency Dependence of the Comparison Method.—H. Fricke. (*Arch. elekt. Übertragung*, Aug. 1950, Vol. 4, No. 8, pp. 315–320.) Part 2: 432 above. To avoid interfering transmissions it is necessary to be able to operate over a range of frequencies. Analysis is given of the effect on the goniometer calibration of varying the frequency, which results in change of (*a*) the ratio of wavelength to aerial dimensions, (*b*) the radiation coupling, and (*c*) the effects due to feeder-cable inequalities. The theory is confirmed by measurements made at a mean wavelength of 1·5 m with ±16% variation.

621.396.11.029.62 : 531.74] : 621.396.67 **434**

Short-Wave Installations with Controllable Directional Characteristics and their Application to the Measurement of Angles of Incidence.—P. Kotowski, E. Schüttlöffel & G. Vogt. (*Arch. elekt. Übertragung*, July & Aug. 1950, Vol. 4, Nos. 7 & 8, pp. 247–254 & 325–330.) The advantages of electrical over mechanical methods of controlling aerial directional characteristics are indicated and the technique of electrical control is discussed. A description is given of an installation at Brück a.M. for measuring angles of incidence; this uses three rhombic aerials. Measurements on American and British s.w. broadcast transmissions are reported; the vertical angles lie between 6° and 41°, the angle of incidence increasing with wavelength. Deviations from great-circle paths are also investigated; for the British transmitter the dispersion of these deviations is significantly greater than for the more distant American transmitters.

621.396.11.029.63/.64 **435**

Propagation of Waves of Frequency 300 to 10 000 Mc/s.—P. Marié; L. de Broglie. (*Radio tech. Dig., Édn franç.*, June & Aug. 1950, Vol. 4, Nos. 3 & 4, pp. 157–176 & 195–212. Bibliography, pp. 212–213.) The principles of geometrical optics are applied to the case of radio propagation over a 200-km sea path between points some 500 m above sea-level. Regular variation of the refractive index of the atmosphere is taken into account by using the factor of apparent curvature of the earth. Examples of the daily and seasonal variation of this factor are shown graphically. Expressions are derived for minimum height and radiation angle of the direct ray. Focusing effect and multiple reflections at the surface of the sea are discussed and a chart is derived indicating the conditions under which these effects may occur. The method of calculating diffraction losses is described and two abacs due to Bullington (802 of 1948) are reproduced. An illustrative numerical calculation is made of the received intensity of a p.p.m. signal under given conditions.

L. de Broglie comments in a general way on the application of geometrical optics in the theory of the propagation of radio waves.

621.396.11.029.64 **436**

Propagation of U.H.F. and S.H.F. Waves beyond the Horizon.—K. Bullington. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1221–1222.) Ground-wave field intensities calculated for the cases of plane earth, diffraction over a smooth earth and over a knife edge, are plotted against a parameter defined as the ratio of the clearance above the obstacle to the height of the first Fresnel zone. Good agreement is obtained with experimental results at 4–4·6 kMc/s over both smooth and rough paths. The presentation shows the importance of the clearance and the great range of values of field intensity that may occur beyond the horizon.

621.396.826.029.51 : 535.568.1 **437**

Polarimeter for the Study of Low Frequency Radio Echoes.—Benner & Nearhoof. (See 415.)

RECEPTION

551.594.6 : 621.317.7.087 **438**

The Measurement of Atmospheric Radio Noise in South Africa in the Low Frequency Band.—D. Hogg. (*Trans. S. Afr. Inst. elect. Engrs*, July 1950, Vol. 41, Part 7, pp. 209–225. Discussion, pp. 225–227.) Full details are given of an automatic recorder in which a vertical aerial feeds a superheterodyne receiver tuned to 100 kc/s and having a bandwidth of 6 kc/s. The a.v.c. voltage is eventually applied to a c.r.o. whose spot is photographed for 2 min every 20 min. Calibration voltages are applied daily. For the recording site near Johannesburg the average noise level is 1 or 2 μV/m during the day, rising to 20 μV/m and 100 μV/m during winter and summer nights respectively. Local summer thunder may raise the level to 1 mV/m in the afternoon. Graphs are given of the median and 95% noise levels for winter, summer, and the equinoxes and also of the frequency of occurrence of various noise levels at different times of day. The correlation of the observed data with thunderstorm activity is discussed. Agreement of the measured levels with those predicted from data in Report No. 5 of the U.S. Army Signal Corps is usually good.

621.396.621 **439**

An Advanced Amateur Receiver.—R. P. Haviland. (*CQ*, Oct. 1950, Vol. 6, No. 10, pp. 12–18..66.) A receiver providing good reception for c.w., a.m., f.m., p.m., and s.s.b. with carrier suppression. Proper use of the phasing system of demodulation makes possible the selection of either sideband at will, thus enabling unwanted signals to be cut out more easily. Application of the exalted-carrier principle prevents loss of modulation of the desired signal owing to strong interfering signals. To avoid the complexities of coil switching, a series of converters is used with wideband fixed-tuned h.f. stages. The oscillator is crystal controlled and tuning is accomplished by a tuner which covers the lowest frequency band and becomes a tuned i.f. system on the higher bands.

621.396.621 **440**

Design, Construction and Final Adjustment of an Up-to-Date, High-Fidelity Receiver using Modern Valves: Part 1 — The Low-Frequency Amplifier.—J. Rousseau. (*T.S.F. pour Tous*, Oct. 1950, Vol. 26, No. 264, pp. 342–346.) An output of 8 W is obtained from the 3-stage amplifier, which comprises a Type-6AU6 pentode amplifier, Type-EL41 driver, and two Type-6AQ5 output valves in push-pull. This choice of valves is discussed and the selective feedback and coupling circuits are calculated. Circuit diagrams showing component values, and details of the baffle mounting of the two loudspeakers, are given.

621.396.621 : 621.317.35 **441**

On the Energy Spectrum of an Almost Periodic Succession of Pulses.—G. G. Macfarlane. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1212–1213.) Discussion on 217 of 1950.

621.396.621.029.63 **442**

Some Design Considerations of Ultra-High-Frequency Converters.—W. Y. Pan. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 377–398.) Two basic converter designs are considered for use at frequencies between 500 and 900 Mc/s, one using a tuned r.f. amplifier, mixer-oscillator and i.f. amplifier, and the other a crystal mixer followed by a grounded-grid i.f. amplifier. Measurements indicate similar performance characteristics, but the second type is preferable for reasons of cost and simplicity. The influence of the i.f. on the crystal-mixer performance characteristics is discussed. From noise-factor considerations alone, the optimum value of the i.f. is about 40 Mc/s, but owing to other requirements a value of about 135 Mc/s is preferable. Some special tuning circuits, and the effect of the method of oscillator injection on matching conditions, mixer loss and oscillator radiation, are considered. The design and characteristics are described of an experimental converter, continuously tunable through the range 500–700 Mc/s, developed for u h f. television investigations at Bridgeport, Connecticut. See also 1792 of 1950 (Murakami).

621.396.82 **443**

Interference caused by More than One Signal.—R. M. Wilmotte. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1145–1150.) A theoretical survey of the factors involved in determining the effect on a wanted signal of several interfering signals, including noise. Suggestions are made toward the solution of the problems involved, and the related problem of determining the service area of v.h.f. and u.h.f. broadcasting systems is discussed.

621.396.822 : 519.21 **444**

Some Statistical Functions useful for the Study of Background Noise.—Blanc-Lapierre. (See 384.)

621.396.828 : 621.385.2 : 621.315.59 **445**

Germanium-Diode Impulse-Noise Limiters.—R. C. Moses. (*Sylvania Technologist*, Oct. 1950, Vol. 3, No. 4, pp. 1–5.) Proper use of noise-limiting circuits results in an improvement of the signal/noise ratio when certain types of external noise are present. Shunt, series and compound limiters including Ge diodes are described and their properties compared; the choice of the type to be used for any particular purpose depends on such factors as the noise conditions likely to be met, the range of signal levels to be used, and the permissible a.f. distortion.

STATIONS AND COMMUNICATION SYSTEMS

621.396.3/.5 **446**

The Overseas Radio Installations at Frankfurt a. M.—F. Ellrodt. (*Fernmeldetech. Z.*, Sept. 1950, Vol. 3, No. 9, pp. 346–355.) An account in some detail of the telegraphy and telephony transmitting and receiving equipment affording communication in the first place with the U.S.A. Similar 20-kW power amplifiers are provided for all transmitters, with grounded-grid air-cooled Type-RS-720 valves. Part of the telegraphy traffic is on the frequency-shift system; the special quartz-crystal frequency-control arrangement used is described. Multichannel s.s.b. transmission is used, with transmitter frequency range 3·75–23 Mc/s in three bands. Receivers are of the double-diversity type. See also 2893 of 1950 (Kronjäger).

621.396.6+621.396.9 **447**

S.B.A.C., Farnborough.—(*Electrician*, 15th Sept. 1950, Vol. 145, No. 3770, pp. 580–582.) Brief details of some electrical exhibits at the exhibition arranged by the Society of British Aircraft Constructors at the R.A.E. Aerodrome, September, 1950.

621.396.619.13 : 621.3.018.78† **448**

Nonlinear Distortion in Frequency Modulation.—L. J. Libois. (*Câbles & Transmission, Paris*, Oct. 1950, Vol. 4, No. 4, pp. 297–307.) The assumption of a quasistationary condition is justified when the modulation frequency is relatively low, provided that the rate of variation of the instantaneous frequency remains within certain limits. Under these conditions the nonlinear distortion introduced by the following is calculated: (*a*) nonlinearity of static characteristics of the system; (*b*) variation of propagation time with frequency within the modulation band; (*c*) insufficient amplitude limitation before the discriminator; (*d*) reflections in feeders and multiple transmission paths. While elimination of the effects due to the first three causes imposes severe limiting conditions of operation, feeder reflections and multipath transmission are probably the most troublesome, since they can only be reduced by shortening feeders as much as possible and by using highly directive aerials and well isolated transmission paths.

621.396.619.14 : 621.3.018.78† **449**

Distortion: Band-Pass Considerations in Angular Modulation.—A. A. Gerlach. (*Proc. Inst. Radio Engrs*, Oct. 1950, Vol. 38, No. 10, pp. 1203–1207.) An exact open-form solution of the equation for the output signal from a network is derived, the input being an angle-modulated signal. By using transfer functions which are linear exponential functions of frequency, a solution in closed form is obtained. Particular examples are examined to determine the effects of the transfer function characteristics on the output signal. The analysis supports the conclusion that linear phase characteristics are more important than flat amplitude characteristics for the reduction of distortion.

621.396.65 **450**

The TD-2 Radio Relay System.—C. E. Clutts. (*Bell Lab. Rec.*, Oct. 1950, Vol. 28, No. 10, pp. 442–447.) A skeleton description of a relay system with 33 repeater stations, providing two-way communication facilities between New York and Chicago and operating in the band 3·7–4·2 kMc/s. Each of the six channels available in each direction is 10 Mc/s wide. An alarm system indicates failure at unattended repeater stations. Automatic arrangements switch on emergency supplies in the event of power failure.

621.396.65 : 621.397.26 **451**

Television for Scotland.—(See 462.)

621.396.7 **452**

Burnham Radio Station.—F. G. Balcombe & D. E. Watt-Carter. (*P.O. elect. Engrs' J.*, Oct. 1950, Vol. 43, Part 3, pp. 117–124.) The system for routine communication between ships at sea and London is described: the oceans of the world are divided into areas, each with its own station provided with multiple sending and receiving facilities and linked to London by high-speed point-to-point circuits. Burnham is the area station for the east and middle Atlantic and the Mediterranean, and is linked by land line to London.

All ships report to their local area station and the information is logged at Burnham; outgoing traffic from London is routed accordingly, being sent by transmitters at Portishead and Criggion (or Rugby) under control from Burnham. Incoming traffic is handled at Burnham by 32 receivers on the high-frequency band (4–22 Mc/s) using any aerial selected from a fan-shaped array of high-gain rhombic aerials, supplemented by omnidirectional aerials. On low frequencies four receivers are used with Bellini Tosi crossed loops or a nonresonant T-aerial. There are also available vertical $\lambda/4$ aerials resonant at 1·3 Mc/s and 3 Mc/s, and a nonresonant inverted L-aerial for the 500-kc/s frequency band. By an elaborate switching system the amplified signals from any of the aerials may be distributed to any desired combination of the receivers. Ease of working is secured by a comprehensive telephonic intercommunication system.

621.396.712 : 621.396.619.13 **453**

Low-Frequency Technique in U.S.W. Broadcasting.—E. Menzer & H. Voelkel. (*Z. Ver. dtsch. Ing.*, 21st Aug. 1950, Vol. 92, No. 24, pp. 653–657.) The basic principles of design for a f.m. broadcasting station are considered and the precautions necessary in obtaining suitable bandwidth, low distortion and noise level throughout the transmission chain are discussed.

621.39 **454**

Electrical Communication. [Book Review]—A. L. Albert. Publishers: J. Wiley & Sons, New York, 3rd edn 1950, 593 pp., $6.50. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 133–134.) ". . . a concise picture of all aspects of modern communication systems . . . not only useful as a text but as a reference book."

621.39.001.11 **455**

The Mathematical Theory of Communication. [Book Review]—C. E. Shannon & W. Weaver. Publishers: University of Illinois Press, Urbana, Illinois, U.S.A., 117 pp., $2.50. (*Brit. J. appl. Phys.*, Oct. 1950, Vol. 1, No. 10, pp. 270–271.) The book is in two parts. The first part contains a mathematical analysis, leading to 23 theorems, and some detailed expansions and proofs. Part 2 surveys the broad field of the transmission of information. "This book cannot be ignored by anyone with direct professional concern with these applications..."

SUBSIDIARY APPARATUS

621-526 **456**

Magnetic-Powder Clutch Servo.—S. Wald. (*Radio & Televis. News, Radio-Electronic Engng Supplement*, Sept. 1950, Vol. 15, No. 3, pp. 12A–13A, 26A.) Details are given of the design of a dry-powder magnetic clutch capable of operating at speeds up to 5 000 r.p.m. and transmitting a torque of 48 in.-oz. The frictional drag is 2–3 in.-oz and independent of speed. A circuit is given illustrating its use in automatic tuning of a transmitter.

621-526.001.4 **457**

Modern Servomechanism Testers.—G. A. Korn & T. M. Korn. (*Elect. Engng, N.Y.*, Sept. 1950, Vol. 69, No. 9, pp. 814–816.) Methods permitting direct reading of amplitude and phase are presented and discussed.

621.3.013.78† **458**

The Performance of Screening Rooms.—J. Miedzinski & S. F. Pearce. (*Electronic Engng*, Oct. 1950, Vol. 22, No. 272, pp. 414–419.) Experiments have been made by the Electrical Research Association on four rotatable rooms, each about 6 ft 6 in. × 6 ft 6 in. × 7 ft, totally screened with perforated or expanded metal, or wire netting, and enclosing a vertical transmitting loop. The range of frequency used was 0·75–24 Mc/s. Field strengths as the room was rotated were measured at an external point with a modified Type-R.206 army receiver. In general, the highest attenuation is obtained with screening materials having high conductivity, low permeability and close mesh. Formulae are derived for predicting the attenuation produced by a given screen; these are in general confirmed by the experimental results.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24/.26 **459**

Television from France.—M. J. L. Pulling. (*Wireless World*, Oct. 1950, Vol. 56, No. 10, pp. 353–354.) Successful transmissions from Calais used a combination of microwave and metre-wave radio links in series followed by normal telephone-pair and coaxial-cable links to the transmitter in London. Line communication was used for the sound channel. See also *Electrician*, 15th Sept. 1950, Vol. 145, No. 3770, pp. 573–574.

621.397.24 : 621.396.73 **460**

TV on Tour.—R. Roques. (*Télévision*, Oct. 1950, No. 7, pp. 195–198.) Brief description, with circuit diagrams, of a self-contained demonstration unit carried in a 2-ton van.

621.397.26 **461**

High-Speed F.M. Facsimile.—J. V. L. Hogan & C. V. Olson. (*FM-TV*, Oct. 1950, Vol. 10, No. 10, pp. 18–20, 40.) The material for transmission, on a revolving drum, is scanned at a rate of 56·2 in.²/min. The video signal from the scanner modulates the amplitude of a 13-kc/s subcarrier which is then converted to a vestigial-sideband a.m. signal and applied to a f.m. transmitter. At the receiving end, the subcarrier from the f.m. receiver is converted into a video signal and fed to a recorder. This uses electrolytic recording paper on a revolving drum, mains-synchronized with that at the transmitter. Special signals are transmitted for a period of about 10 sec to indicate page separation points.

621.397.26 : 621.396.65 **462**

Television for Scotland.—(*Elect. Times*, 14th Sept. 1950, Vol. 118, No. 3071, p. 421.) A brief note on the project for a microwave link to extend the television service to Scotland.

621.397.331.2 : 778.5 **463**

Television Transmission of Images of Variable Transparency by Non-storage Systems: Present Systems and Proposed New System for High Definition.—R. Monnot. (*Onde élect.*, Aug./Sept. 1950, Vol. 30, Nos. 281/282, pp. 362–381.) Theoretical and practical aspects of non-storage systems in telefilm technique are discussed. Two particular scanning systems are described: (*a*) the Farnsworth dissector tube and (*b*) the 'flying spot'. Their operation as high-definition systems is discussed and their merits are compared. The proposed new system uses a projector with continuously moving film but without a compensating lens, and combines (*a*) and (*b*) for line scan and picture analysis respectively. The scanning spot takes the form of a short line and the screen is slightly persistent.

621.397.5 : 535.623 **464**

An Analysis of the Sampling Principles of the Dot-Sequential Color-Television System.—R.C.A. Laboratories Division. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 431–445.) The following appendices to the paper abstracted in 2640 of 1950 are given: (*a*) reproduction of high-frequency detail with a low sampling rate; (*b*) transmission of the dot-sequential colour-television signal on coaxial cables of restricted bandwidth; (*c*) the action of the dot-sequential colour-television system in the presence of an abrupt red/green transition.

621.397.5 : 535.623 **465**

Analysis of Dot-Sequential Color Television.—N. Marchand, H. R. Holloway & M. Leifer. (*Sylvania Technologist*, Oct. 1950, Vol. 3, No. 4, pp. 9–15.) A mathematical analysis is presented of the pulse sampling and sorting processes. Colour distortion and cross-talk introduced by sideband clipping is examined, and an equivalent sampling and sorting method is described which is more economical than pulse sampling. The mixed highs are shown to have negligible effect on the colour presentations, while providing resolution equivalent to present monochrome standards.

621.397.5 : 535.623 **466**

Frequency-Interlace Color Television.—R. B. Dome. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 70–75 & *FM-TV*, Oct. 1950, Vol. 10, No. 10, pp. 12–14..40.) A proposed new system. The video frequencies associated with a monochrome television signal are bunched around harmonics of the line frequency and a large part of the spectrum is unused. Use of this part of the spectrum enables two other colours to be transmitted simultaneously without any increase in bandwidth. In spite of the complexity of the transmitted signal the receiving circuit is simple; it requires no complicated filters and only six more valves than a conventional monochrome circuit; it can also be used to receive black-and-white transmissions. The system has not yet been fully tested.

621.397.5 : 535.88 **467**

Improvements in Large Screen Television Projection.—T. M. C. Lance. (*J. Televis. Soc.*, April/June 1950, Vol. 6, No. 2, pp. 46–56.) Paper presented at the International Television Congress, Milan, September 1949. The development of a projection system for cinema use is described. The position of the projector is restricted by inherent limitations of the Schmidt optical system; the projector must be within 10° of the axis normal to the screen and its distance from the screen has been standardized at 40 ft. The high luminous flux required has been obtained by the adoption of a triode electrode system with an anode voltage of 50 kV and a beam current of 15 mA. In the construction of the c.r. tubes, difficulties were encountered due to the high heat dissipation at the screen and the necessity of avoiding electrical discharges. The design of a suitable cathode and electrode system is described and the development of a special phosphor of the mixed-silicates type which is little affected by temperature rise is discussed.

621.397.5(083.74) **468**

Transmission Standards in Television.—J. L. Delvaux. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 659–661. In French.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of the various factors affecting the choice of television frequency, bandwidth and line standards, with particular reference to the determination of the optimum structure of the television channels for the European network. See also 2346 of 1949.

621.397.5(083.74) **469**

A Comparative Analysis of Certain Television Standards.—L. H. Bedford. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 630–632. In English.) Paper presented at the International Television Conference, Zürich, 1948. Discussion of British and American practice, with particular reference to the polarity of modulation and to the significance of equalizing pulses.

621.397.5(083.74)(45) **470**

Proposals for the Standardization of Television in Italy, and New Electronic Generator for Television Synchronization.—A. V. Castellani. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 608–615. In Italian.) Paper presented at the International Television Conference, Zürich, 1948. Summary abstracted in 879 of 1949.

621.397.5(42) **471**

Studio and Outside Broadcasting Television Practice in Great Britain.—T. H. Bridgewater. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 538–545. In English.) Paper presented at the International Television Conference, Zürich, 1948. A general account of (*a*) the equipment used, including cameras and their mountings; (*b*) studio design and lighting; (*c*) mobile control room equipment; (*d*) film transmitters; (*e*) studio production and outside broadcasting operations.

621.397.5(45) **472**

Television in Italy.—A. Banfi. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 547–549. In Italian.) Paper presented at the International Television Conference, Zürich, 1948. A short historical account.

621.397.6 **473**

Some Aspects of Television Circuit Technique: Phase Correction and Gamma Correction.—T. C. Nuttall. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 615–622. In English.) Paper presented at the International Television Conference, Zürich, 1948. The advantages of using phase- and gamma-correction methods are pointed out and suitable circuits are described. A gamma corrector combined with a black-level control circuit has been found very effective in a television film scanner, with standard films having a wide range of contrast. Operation is quite automatic.

621.397.6 : 621.396.67 **474**
Designing the Bridgeport U.H.F. Antenna.—Scudder. (See 284.)

621.397.6.018.424† **475**
Wide-Band Systems for Television.—E. Labin. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 623–630. In English.) Paper presented at the International Television Conference, Zürich, 1948. See 2342 of 1949.

621.397.61 : 621.392.52 **476**
Linear-Phase-Shift Video Filters.—Fredendall & Kennedy. (See 303.)

621.397.61 : 621.396.619.13/.14 **477**
Phase-to-Amplitude Modulation for U.H.F.-TV Transmitters.—W. E. Evans, Jr. (*Electronics*, Sept. 1950, Vol. 23, No. 9, pp. 102–106.) The outputs from two ph.m. transmitters driven from the same crystal oscillator are combined so as to produce an a.m. signal. It is not necessary for the r.f. amplifiers to have linear amplitude characteristics. The system would be especially useful for high-power (above 500 W) u.h.f. valves which are difficult to modulate by other means. An experimental television transmitter on a frequency of 530 Mc/s with a peak power output of 150 W has been operated successfully. A specially designed dual ph.m. tube, producing a $\pm 45°$ phase deviation in two 265-Mc/s channels, simplifies the equipment.

621 397.611.2 **478**
Development of a Super-Iconoscope: the Ériscope.—A. Lallemand. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 561–562. In French.) Paper presented at the International Television Conference, Zürich, 1948. A short account of the principles and construction of the ériscope. See also 537 of 1949 (France).

621.397.611.2 **479**
[Picture] **Analyser Tubes with Transparent Signal-Plate.**—P. Tarbès. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 562–564. In French.) Paper presented at the International Television Conference, Zürich, 1948. Different methods of obtaining satisfactory thin layers of Pt or Pd on mica, by evaporation or cathodic deposition, are discussed. A process which improves the solidity of the deposit and enables it to withstand better the heating effects during the mounting of the screen in its glass container, consists in depositing on the mica by evaporation a thin layer of Cr and then applying a top layer of Pt or Pd by cathodic deposition. Another method of protection is to apply a very thin layer of silica over the metal layer. Iconoscopes with transparent screens and symmetrical sweep are particularly suitable for simple types of equipment where the absorption in the metal layer and the consequent reduced sensitivity are relatively unimportant.

621.397.611.2 **480**
Image-Storage Problems.—F. Schröter. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40 No. 17, pp. 564–566 In German.) Paper presented at the International Television Conference, Zürich, 1948.

621.397.611.2 **481**
Light-Transfer Characteristics of Image Orthicons.—R. B. Janes & A. A. Rotow. (*RCA Rev.*, Sept. 1950, Vol. 11, No. 3, pp. 364–376.) The signal-output/light-input characteristics are given for various target voltages and target-mesh spacings. The effects of interelement capacitance and electron redistribution on the transfer curves are considered. The presence of ghost images can be minimized by defocusing by adjustment of the photocathode voltage. Two types of anti-ghost tubes are described briefly.

621.397.611.2 : 778.5 **482**
A Non-Storage Picture-Analysing Tube for Film Scanning.—N. Schaetti. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 569–570. In German.) Paper presented at the International Television Conference, Zürich, 1948. See also 1261 of 1950.

621.397.611.2.001.8 **483**
New Television Camera Tubes and Some Applications outside the Broadcasting Field.—V. K. Zworykin. (*J. Soc. Mot. Pict. Televis. Engrs*, Sept. 1950, Vol. 55, No. 3, pp. 227–242.) The operation and performance characteristics of television camera tubes, from the iconoscope to the image orthicon and vidicon, are briefly described, recent developments being particularly considered. The application of the vidicon in industrial television equipment and possible uses of television technique in astronomy are outlined.

621.397.62 **484**
Permanent-Magnet Lenses for Television Tubes.—B. R. Overton : D. Hadfield. (*Electronic Engng*, Sept. 1950, Vol. 22, No. 271, pp. 401–402.) Comment on 1787 of 1950 and author's reply.

621.397.62 : 535.88 **485**
Large-Screen Television Projection by the Eidophor Method.—H. Thiemann. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40. No. 17. pp. 585–595. In German.) Paper presented at the International Television Conference, Zürich, 1948. Detailed discussion of the principles of the method and illustrated description of the equipment used. Summary noted in 875 of 1949. See also 296 of 1948, which refers to a full account of the method.

621.397.62 : 535.88 **486**
Problems of Theatre Large-Screen Television Projection.—A. G. D. West. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 595–603. In English.) Paper presented at the International Television Conference, Zürich, 1948. See 1523 of 1949.

621.397.62 : 535.88 **487**
Philips Projection Television.—(*Wireless World*, Oct. 1950, Vol. 56, No. 10, pp. 365–367.) Test report on a standard production model, Type 600A, which uses a $2\frac{1}{2}$-in. c.r. tube operated at a final-anode voltage of 25 kV. A Schmidt optical system projects an image on to the back of a built-in screen to give a picture $13\frac{1}{2} \times 10$ in. The picture is sufficiently bright for daylight viewing, but due to the screen construction the angle of view is limited to about $\pm 30°$. The circuits are conventional, except for the c.r. tube supply, which is obtained through a voltage-tripler rectifier from a 9-kV damped sine wave developed in a ringing transformer connected in the anode circuit of a pentode.

621.397.62 : 621.396.68 **488**
Flyback E.H.T.—W. T. Cocking. (*Wireless World*, Aug. & Sept. 1950, Vol. 56, Nos. 8 & 9, pp. 279–282 & 313–316.) The major disadvantage of this system lies in

its rather poor voltage regulation. This causes changes in the picture size and defocusing, as the overall brightness of the picture alters. The regulation depends upon the scanning circuit itself as well as the rectifier system; the effect of each of these systems is considered separately. Graphs are presented showing, for any required regulation, the ratio of energy in the deflector-coil circuit to the energy drawn from the h.v. system by the c.r. tube. Changes in the Q value of the circuit comprising the deflector-coil and transformer have little effect on the regulation, but the available h.v. for the same circuit capacitance increases with higher Q values. Because of the high source impedance, the regulation with a voltage-doubling rectifier is only slightly poorer than with a half-wave rectifier.

621.397.621.2 **489**
New Scanning Circuit.—P. R. J. Court. (*Wireless World*, Aug. 1950, Vol. 56, No. 8, pp. 287–290.) A self-driven line-scanning output stage for use in conjunction with an 'efficiency diode'. The frequency and amplitude controls are not appreciably interdependent, and the output linearity is not affected unduly by the impedance of the output valve, thus permitting the use of almost any type of output pentode or tetrode. The performance is at least equal to that of an equivalent separately driven circuit.

621.397.621.2 **490**
A Self-Oscillating Line-Deflection Circuit. — J. Haantjes. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 633–635. In English.) Paper presented at the International Television Conference, Zürich, 1948. A circuit with good linearity and short fly-back time which is easily synchronized and requires relatively little power. See also 2934 of 1949 (Haantjes & Kerkhof).

621.397.621.2 : 621.319.55 **491**
New Self-Excited Generators for Deflection Currents.—R. Urtel. (*Bull. schweiz. elektrotech. Ver.*, 20th Aug. 1949, Vol. 40, No. 17, pp. 641–644. In German.) Paper presented at the International Television Conference, Zürich, 1948. Generators of sawtooth waves with external excitation are first considered and then the necessary modifications for self-excitation. Circuits with automatic switching from positive to negative feedback are described and their action is explained. Waveform diagrams are given in all cases.

621.397.645.018.424† **492**
Video Amplifier Design.—Moses. (See 319.)

621.397.8 **493**
The Influence of Transmission Bandwidth on Television Picture Quality.—J. Schunack. (*Arch. elekt. Übertragung*, Nov. & Dec. 1949, Vol. 3, Nos. 8 & 9, pp. 301–304 & 323–327, & Feb. & March 1950, Vol. 4, Nos. 2 & 3, pp. 75–81 & 113–120.) The production of picture defects by limitation of transmission bandwidth is explained. Experimental results obtained with various illumination patterns confirm the theoretical conclusions. For maximum picture quality $N_{max}.S=1$, where N_{max} is the highest transmitted frequency divided by the scanning speed, and S is the length of the scanning aperture edge; this corresponds to a doubling of the usual bandwidth.

621.397.8.029.63 **494**
Television Transmission and Reception on 480 Mc/s.—M. Morgan. (*J. Televis. Soc.*, April/June 1950, Vol. 6, No. 2, pp. 57–63.) For experimental cinema relay links the frequency band 470–490 Mc/s was chosen because suitable valves are available and because of the adoption of a.m. with vestigial-sideband modulation. A genera description is given of the transmitting and receiving equipment, which was used in the demonstration following the paper by Lance (467 above) at the International Television Congress, Milan, 1949.

621.397.62.004.5/.6 **495**
Television Servicing. [Book Review]—S. Heller & I. Shulman. Publishers: McGraw-Hill Book Co., New York, 1950, 434 pp., $5.50. (*Electronics*, Nov. 1950, Vol. 23, No. 11, pp. 136, 138.) Includes a service analysis on each portion of the receiver. "These thorough analyses can be used to extremely good advantage by the beginner who lacks the practical approach . . . the book is well worth having."

TRANSMISSION

621.396.619.13 **496**
Linearization of Modulation Characteristic with Relatively Large Frequency Deviation.—R. Šatas. (*Arch. elekt. Übertragung*, July 1950, Vol. 4, No. 7, pp. 255–258.) Mathematical analysis is given for a f.m. circuit in which a push-pull arrangement of two valves with square-law I_a/V_g characteristics is connected as a variable reactance in parallel with the LC circuit determining oscillator frequency. Experimental results for the particular case of a f.m. transmitter with carrier frequency 2 Mc/s and deviation 150 kc/s gave good support to the theory. The highest ratio of frequency deviation to carrier frequency attainable with low non-linear distortion was 0·15–0·25, using reactance valves of specially suitable type.

621.397.61 : 621.396.619.13/.14 **497**
Phase-to-Amplitude Modulation for U.H.F.-TV Transmitters.—Evans. (See 477.)

621.396.665 **498**
Automatic Audio Gain Controls.—Hathaway. (See 318.)

VALVES AND THERMIONICS

533.583 : 621.385 **499**
Getter Materials for Electron Tubes.—W. Espe, M. Knoll & M. P. Wilder. (*Electronics*, Oct. 1950, Vol. 23, No. 10, pp. 80–86.) The requirements of getter materials for use as bulk, coating or flash getters are specified. The suitability of various metals for each application is discussed with reference to the vapour pressure of the metal and its efficiency as a getter. Over 70 references are given.

537.533 : 621.385.832 **500**
Note on the Image Formation in Cathode-Ray Tubes.—R. Dorrestein. (*Philips Res. Rep.*, April 1950, Vol. 5, No. 2, pp. 128–130.) The theory of Gaussian beams is applied to the electron beam in a c.r. tube with a conventional type of gun. Neither the paraxial cross-over nor the cathode image yields the smallest possible spot, but some intermediate point, the location of which depends on the relative values of the beam radii at cross-over and where the cathode image is formed. In practical cases this point nearly coincides with the cross-over point.

621.385.029.63/.64 **501**
Traveling-Wave Tubes: Part 4.—J. R. Pierce. (*Bell Syst. tech. J.*, Oct. 1950, Vol. 29, No. 4, pp. 608–671.) Chapters 12–17, concluding the monograph. Theoretical treatment of power output, transverse motion of electrons, field solutions, magnetron amplifier,

and double-stream amplifier. A brief conclusion and a bibliography for 1946–1949 are given. Part 3: 3203 of 1950.

621.385.029.63/.64 **502**

Travelling-Wave Valves.—H. Kleinwächter. (*Elektrotechnik, Berlin,* July 1950, Vol. 4, No. 7, pp. 245–246.) Research work abandoned during the war was concerned with the development of a travelling-wave valve on lines different from present designs. Retardation of the wave was effected by surrounding the evacuated cylinder enclosing the beam with a dielectric-filled waveguide of external diameter increasing in the direction of propagation. Methods of using the transverse electron energy and of increasing the efficiency were also investigated.

621.385.029.63/.64 : 621.317.755 **503**

The Traveling-Wave Cathode-Ray Tube.—K. Owaki, S. Terahata, T. Hada & T. Nakamura. (*Proc. Inst. Radio Engrs,* Oct. 1950, Vol. 38, No. 10, pp. 1172–1180.) Pairs of repeatedly folded parallel wires are used instead of the conventional deflecting plates, and the phase velocity of the travelling wave and the electron velocity are equalized, thus making the deflection sensitivity independent of frequency. A theoretical analysis of the principle is given; the sensitivity may be easily increased to 0·1 mm/V at 30 kMc/s. The inversion-spectrum method is used to obtain experimental confirmation of this analysis. Measurements of the degree of a.m. and observations of u.h.f. voltage waveform are described to illustrate the applications of the tube.

621.385.032.213 : 546.841-3 **504**

Thermionic Properties and Activation of Thoria.—G. Mesnard. (*C. R. Acad. Sci., Paris,* 16th Oct. 1950, Vol. 231, No. 16, pp. 768–770.) Results are discussed of an experimental study of the emission from tungsten filaments with thoria coatings of mean thickness 40 μ, immediately after high-temperature activation for 1–2 min. Richardson's equation holds for short-period emission within a certain temperature range. Emission increases progressively as the activation temperature is raised. Values of A and ϕ in the equation fall slightly until an activation temperature of about 2 150°K is reached, when they increase, particularly A, in greater proportion than the current, reaching values of 100 A/cm² and over 2·5 V respectively. Large current densities are not always obtained, especially when the cathode has been treated with collodion to render it less fragile. To ensure a long life, the operating temperature should not go above 2 000°. A suggested explanation of the observed effects is the formation of insertion atoms of thorium during the progressive crystallization produced by the initial heating.

621.385.032.216 : 539.167.3.001.8 **505**

Use of Radioactive Elements in the Investigation of Oxide Cathodes.—J. Debiesse. (*Onde élect.,* Aug./Sept. 1950, Vol. 30, Nos. 281/282, pp. 351–355.) More detailed account of the work noted in 3592 of 1949 (Beydon et al).

621.385.2 **506**

The Electric Field at a Thermionic Cathode as a Function of Space Current.—P. L. Copeland & D. N. Eggenberger. (*Phys. Rev.,* 15th Oct. 1950, Vol. 80, No. 2, p. 298.) The method given by Ivey (780 of 1950) for calculating the field at the cathode of a diode is examined analytically, and it is concluded that the function expressing the ratio of the field in the absence of current to that in the presence of current does in fact depend on valve geometry.

621.385.2.01 **507**

Theory and Experiments on Electrical Fluctuations and Damping of Double-Cathode Valves.—K. S. Knol & G. Diemer. (*Philips Res. Rep.,* April 1950, Vol. 5, No. 2, pp. 131–152.) The internal resistance and the noise are calculated for valves with two hot cathodes opposite one another. Measurements on such valves with indirectly heated cathodes confirm the theoretical calculations and show that, contrary to Fürth's theory (2419 of 1948), the equivalent noise-temperature of such valves does not exceed the real cathode temperature. Measurements on valves with directly heated cathodes are not in such good agreement with theory; the slight discrepancies are discussed.

621.385.3 : 621.315.59 **508**

The p-Germanium Transistor.—W. G. Pfann & J. H. Scaff. (*Proc. Inst. Radio Engrs,* Oct. 1950, Vol. 38, No. 10, pp. 1151–1154.) A brief description of some characteristics of n- and p-germanium is given, and also an account of the laboratory preparation and observed properties of the p-type transistor, which has a higher cut-off frequency and a lower current multiplication than the n-type. The forward current/voltage characteristic of the emitter in very highly resistive p-type transistors has a negative-resistance region of the voltage-maximum type so that, if the series resistance is low, when the emitter bias exceeds this maximum a sudden increase in emitter current occurs; this phenomenon has been called the 'snap effect'.

621.385.3 : 621.315.59 **509**

The Transistor as a Reversible Amplifier.—W. G. Pfann. (*Proc. Inst. Radio Engrs,* Oct. 1950, Vol. 38, No. 10, p. 1222.) The 'forming' process which has been used in the n-germanium transistor to increase the effectiveness of an electrode as a collector does not seriously reduce its efficiency as an emitter. If the process is applied to both contact points, an improved reversible transistor amplifier is obtained.

621.385.3.029.64 **510**

Design Factors of the Bell Telephone Laboratories 1553 Triode.—J. A. Morton & R. M. Ryder. (*Bell Syst. tech. J.,* Oct. 1950, Vol. 29, No. 4, pp. 496–530.) A close-spaced planar triode for use at 4 kMc/s with a gain-bandwidth product of 1 100 Mc/s. Considerations affecting choice of electrode spacing, input and output circuit elements, and emission current density are discussed in terms of gain-bandwidth and power-bandwidth figures of merit. See also 2964 of 1949 (Morton).

621.385.029.63/.64 **511**

Traveling-Wave Tubes. [Book Review]—J. R. Pierce. Publishers: D. Van Nostrand, New York, 1950, 223 pp., $4.50. (*Proc. Inst. Radio Engrs,* Oct. 1950, Vol. 38, No. 10, p. 1229.) "A most competent treatment of the theory of the traveling-wave tube, containing the generally accepted basic theory which will serve as a very useful guide to tube designers, and some material of more controversial nature which will inspire many fruitful discussions and will stimulate creative thought." See also 501 above and back references.

MISCELLANEOUS

621.396 : 061.4 **512**

Radio Exhibition Review.—(*Wireless World,* Oct. 1950, Vol. 56, No. 10, pp. 342–349.) Reports by members of the technical staff of *Wireless World* on television and broadcasting receiver developments, sound-reproduction equipment, test and measurement apparatus, and miscellaneous exhibits at the 17th National Radio Exhibition, Castle Bromwich. See also 266 of January.