ELECTRONIC & RADIO ENGINEER

Incorporating **WIRELESS ENGINEER**

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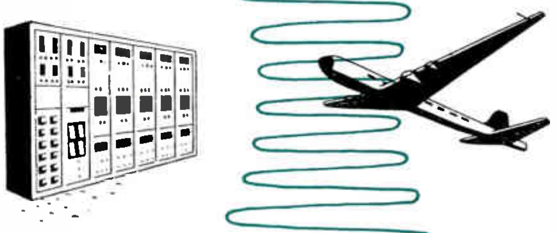
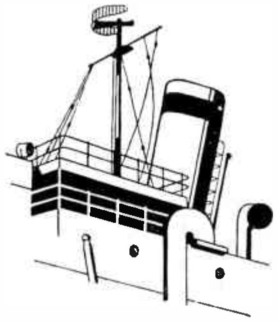
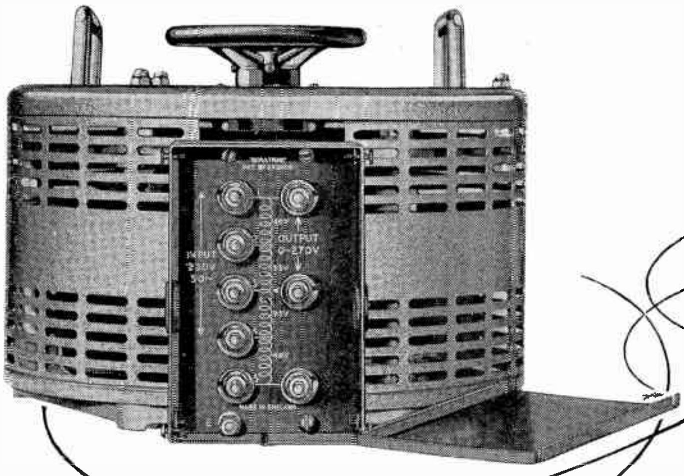
Power Spectrum of Noise-Modulated Carrier
Transistors in H.F. Amplifiers
Molecules and Microwaves

Three shillings
and sixpence

JULY 1957 Vol 34 *new series* No 7







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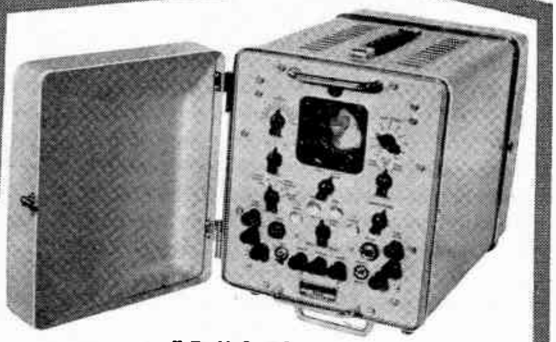

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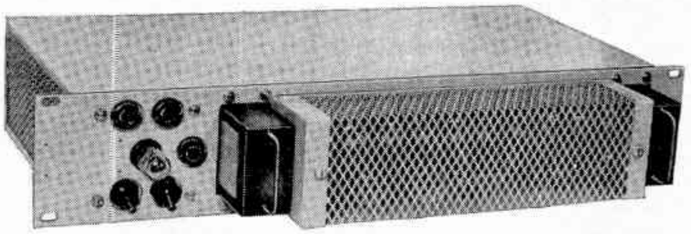

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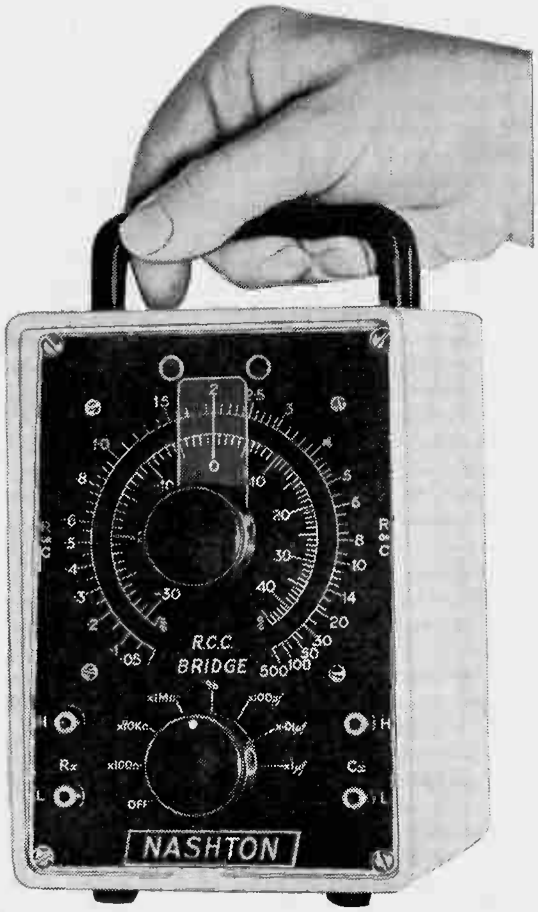

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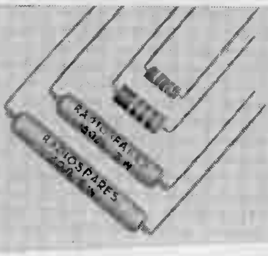

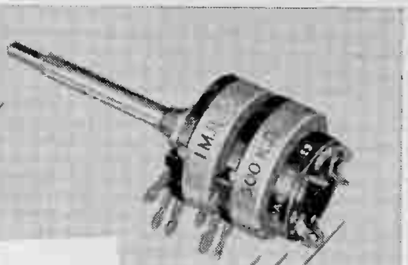

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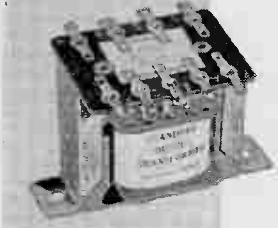

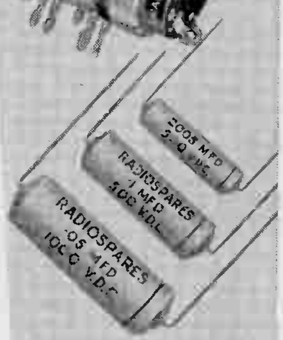

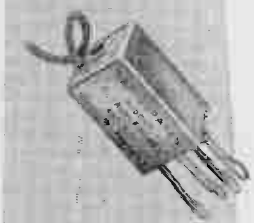

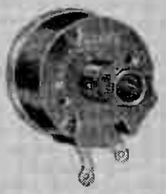

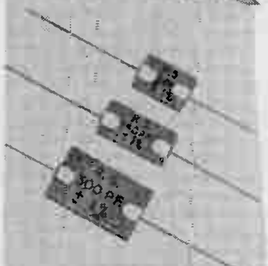

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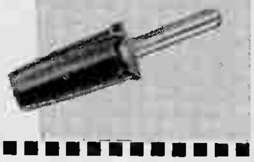

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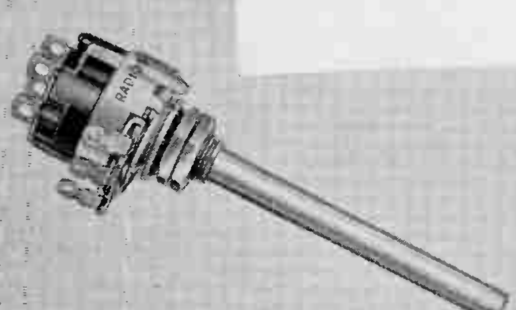

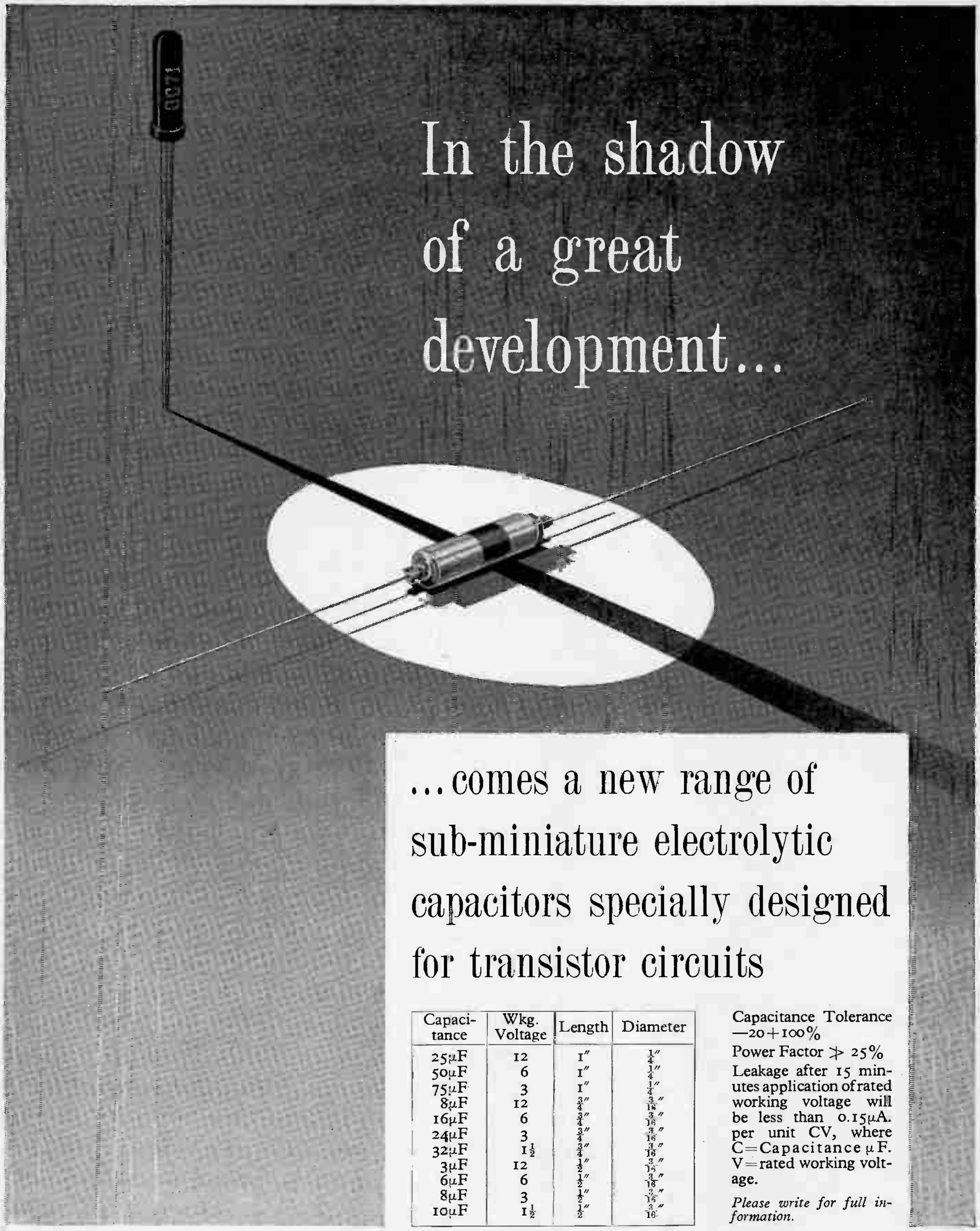

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8μF	12	$\frac{3}{4}$″	$\frac{3}{16}$″
16μF	6	$\frac{3}{4}$″	$\frac{3}{16}$″
24μF	3	$\frac{3}{4}$″	$\frac{3}{16}$″
32μF	1$\frac{1}{2}$	$\frac{3}{4}$″	$\frac{3}{16}$″
3μF	12	$\frac{1}{2}$″	$\frac{3}{16}$″
6μF	6	$\frac{1}{2}$″	$\frac{3}{16}$″
8μF	3	$\frac{1}{2}$″	$\frac{3}{16}$″
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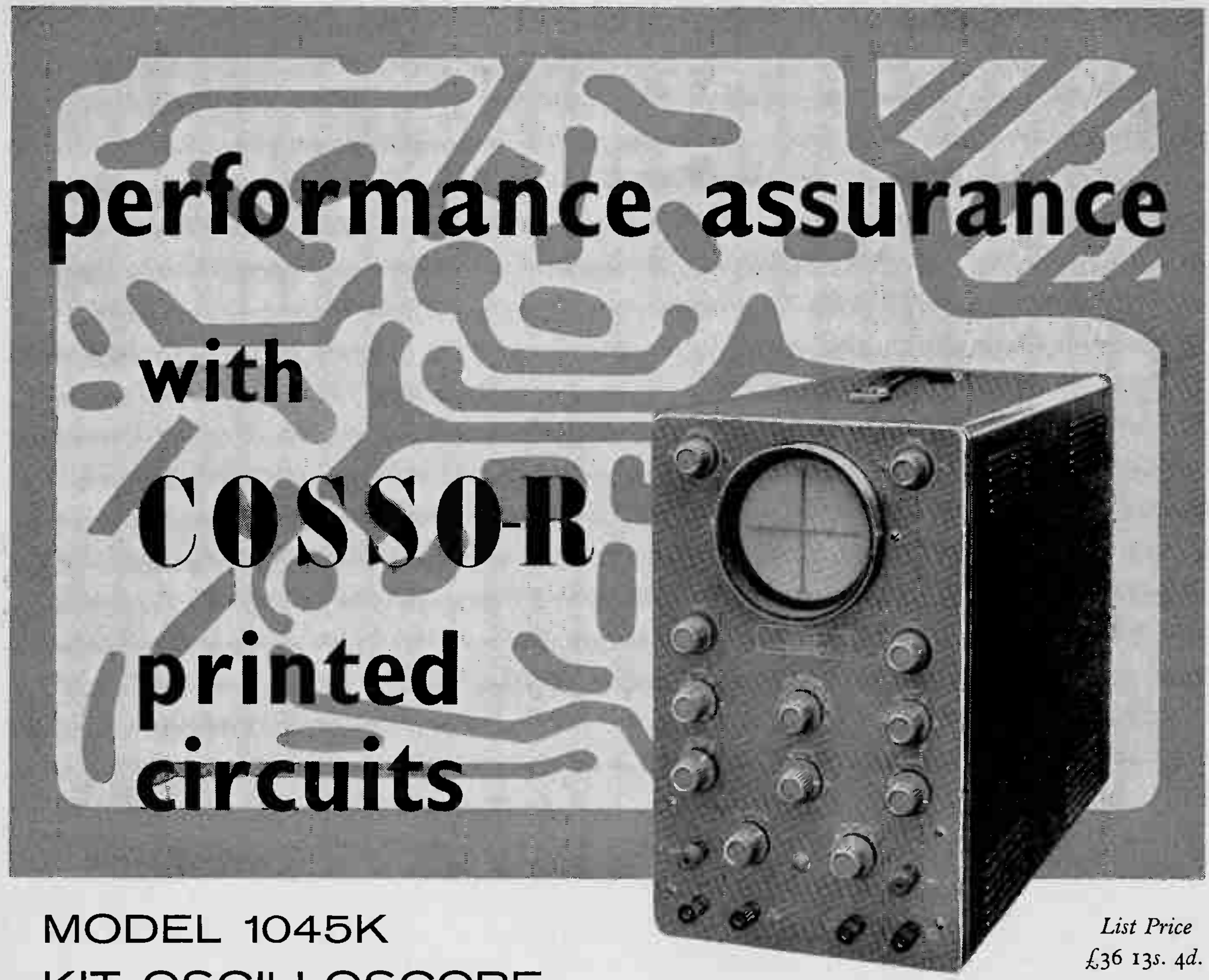

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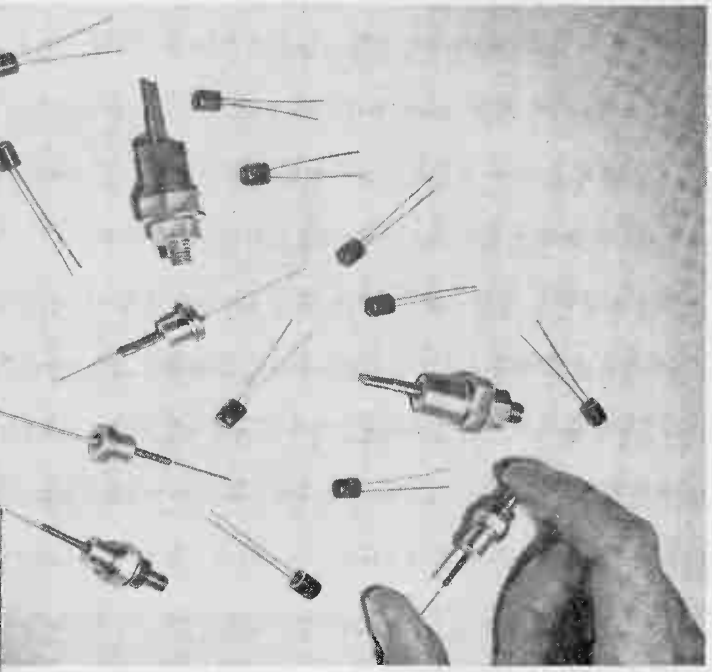

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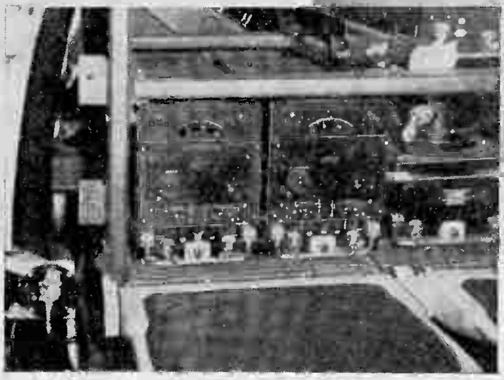

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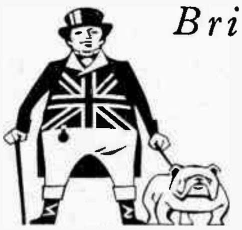

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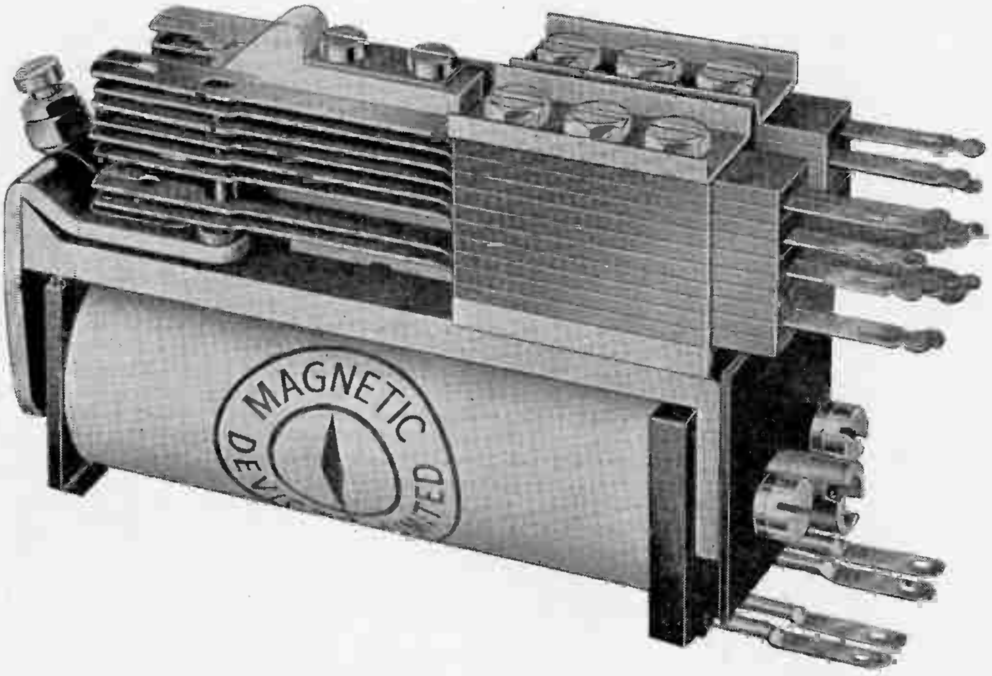


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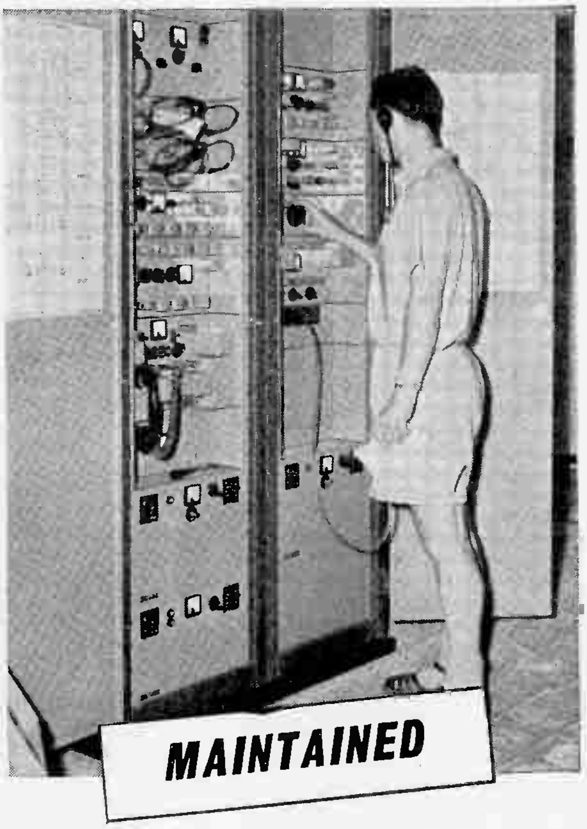
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CONTENTS

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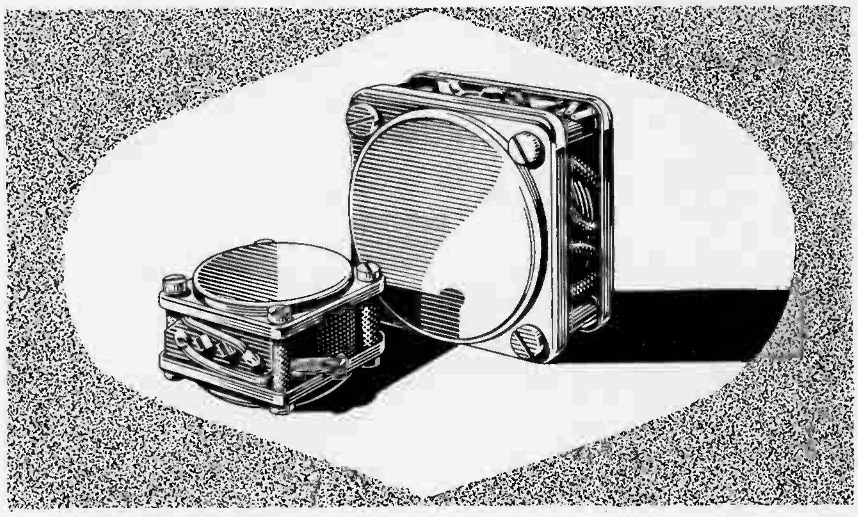

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JULY 1957 *incorporating WIRELESS ENGINEER*

Abbreviations

ELSEWHERE in this issue we publish a list of abbreviations in common use, with their meanings. This is an age of abbreviation and in one's own particular corner of our field one becomes as familiar with them as with the words for which they stand. When one meets those in other corners, however, one is apt to be nonplussed. It is true that one may be no wiser when one knows what the letters stand for, so specialized are the jargons now employed. A definition may still sometimes be needed. However, there is a much better chance of understanding the meaning of a strange phrase than of a strange abbreviation.

Opinions differ about usage with abbreviations. Should they have capital letters or small? Should the letters be separated by stops or not? In arranging the list, we have done what we think should be done and we believe this to be in accordance with the commonest usage. Capital letters are used, in the main, only for the abbreviations of the names of organizations and the like; small letters are used for the purely technical abbreviations. Stops are invariably used except when the abbreviation is one which forms a pronounceable word; the general opinion is then that it is tidiest to treat the abbreviation as a word. Most people use all capital letters for such "words" and so we have done so here. Logically, however, it would be better to treat them as words and use no more than initial capitals. We feel that this would be practically convenient, but we have not adopted it since it is not yet the general practice.

The usage of abbreviations in writing is, of course, a controversial matter. Authors should indicate their meaning when they are first used unless they are so generally known that there is no likelihood of any reader being in doubt. By usage, however, we refer more to the grammar of their employment. At one time they were rarely used except adjectivally, but it is now very common to employ them as nouns. We must confess to some dislike of this practice; whatever we may say, we do not yet write "the i.f. is", but "the intermediate frequency is".

The list of abbreviations in this list is naturally incomplete; if we had tried to make it complete it would never have been published. We hope to supplement it from time to time as new ones come along and as we turn up others which we have missed.

D.F. Aerial System for Decimetre Wavelengths*

AN INVESTIGATION OF CHARACTERISTICS

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

SUMMARY. *The development of two aerial systems, suitable for direction finding on vertically and horizontally-polarized waves respectively, is described. They are designed for a twin-channel cathode-ray type of instrument in which the azimuthal coverage is limited to a selected* 90*-degrees sector, thereby giving unambiguous bearings, improved sensitivity and reduction of site errors.*

Both systems comprise two aerials each combined with a flat-sheet reflector, mounted above a circular earth-plane and oriented approximately at right angles. Cone monopoles are used for vertical polarization and flat, circular-disc dipoles for the horizontal system. Each system has wide-band impedance characteristics and over the band 500–1,000 *Mc/s the v.s.w.r. on the aerials and feeders is never less than* 0·3.

The complete d.f. has not been developed but the probable direction-finding performance of such an instrument, using the aerial systems described, has been estimated. For vertically- or horizontally-polarized signals, received on their appropriate system, azimuthal errors should not exceed ± 5 *degrees in the* 90*-degree sector. By rotating the aerial system to the equi-signal position the errors should be much smaller. For waves of mixed polarization, the horizontal system should have negligible polarization error but the vertical system may have large errors, depending upon the type of aerial used.*

The work described in this paper is directed towards the development of a direction finder for the band 500–1,000 Mc/s, suitable for either vertically- or horizontally-polarized transmissions. Only the aerial system is studied in detail but, to define the scope of the investigation, certain basic objectives have been assumed regarding the form and accuracy of a direction finder of which the aerial systems would be a part. Separate systems are envisaged for the two polarizations.

It was decided that the direction finder should be of the twin-channel, cathode-ray type, which enables bearings to be taken on signals of short duration and which was expected to provide higher sensitivity than was achieved with experimental aural-null systems in this frequency band.[1] It was also decided to limit the azimuthal coverage to 90 degrees to give an unambiguous indication of bearing, to improve sensitivity and to reduce site errors.

Basically, then, the direction finder would consist of an aerial system incorporating two identical beam aerials, oriented in different directions and each connected through a separate receiver to a cathode-ray tube display presenting bearing information over a selected 90-degree sector. The receivers may be of a conventional tuned design or of a crystal-video type. In either case it is desirable that the aerial system should cover the full frequency range without adjustment.

To facilitate taking observations on short transmissions, the system must be capable of giving an immediate indication of the approximate bearing (within ± 5 degrees) of a transmitter within the 90-degree sector, with provision for rotating the aerial system to obtain a more accurate bearing if necessary. This order of accuracy should be obtainable on transmissions polarized with an appreciable component other than that for which the system was designed.

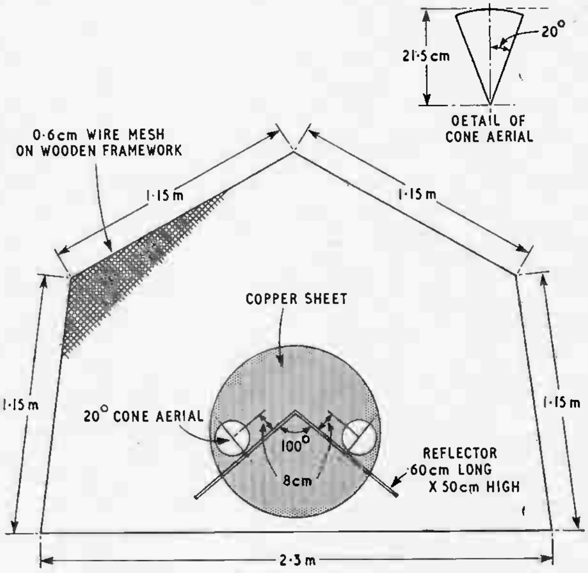

Fig. 1. *Plan view of earth mat and aerial system for vertical polarization*

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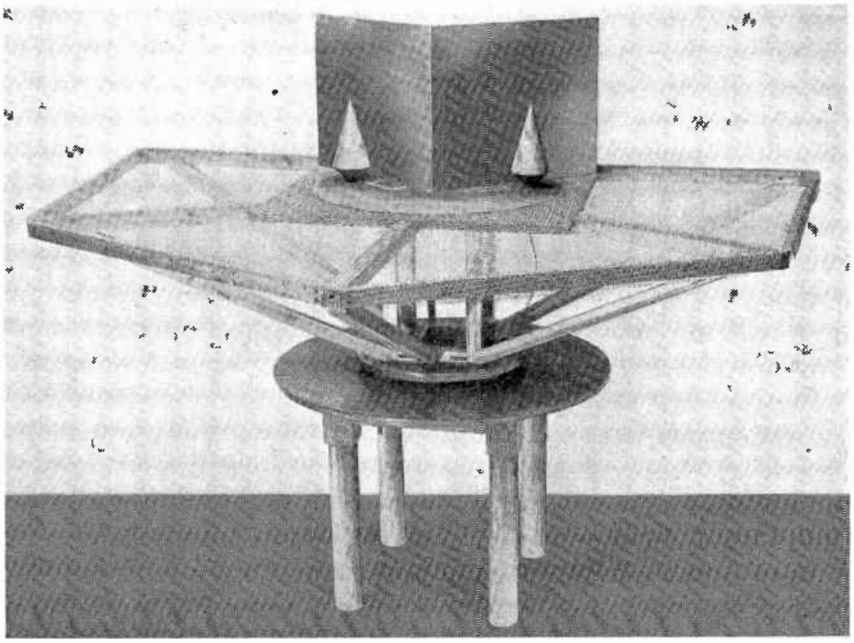
* *Official communication from D.S.I.R. Radio Research Station, Slough.*



Experimental model of an aerial system

To maintain adequate sensitivity over a wide frequency range it is necessary to avoid large changes in the impedance of the aerial system with frequency. It was considered that this requirement would be met if the voltage standing wave ratio on the aerial feeders did not fall below 0·2 with the system terminated in a characteristic impedance of, say, 70 ohms.

An attempt has been made to fulfil these conditions and the investigation has been carried out in two parts. The first and more detailed investigation relates to a system for vertically-polarized transmissions and the second to a horizontally-polarized system.

System for Vertically-Polarized Transmissions

The results may be considered under two headings. First, the design of individual aerial elements including

- (i) reception patterns of single monopole aerials combined with various sheet reflectors,
- (ii) impedance measurement of aerials,
- (iii) design of band-pass filters for the band 500–1,000 Mc/s to limit the response of the system in a crystal-video receiver.

Secondly, the estimation of the direction-finding performance of a twin-aerial system whose design is based upon the measurements made in (i), (ii) and (iii).

Reception Patterns of Aerials

The reception patterns of various aerial and reflector designs were measured in the horizontal plane using a fixed transmitter and rotating the receiving-aerial system, the output from which was connected to a calibrated receiver. The transmitter aerial could be rotated to alter the plane of polarization of the waves.

To isolate the aerial from the observer and to avoid ground reflections, the aerials under test were mounted above a horizontal screen which rotated with the aerial. A plan view of the system with twin aerials and reflectors is shown in Fig. 1. The overall accuracy during these tests was ± 1 dB.

To obtain direction-finding coverage of 90 degrees, a simple arrangement would be for the individual aerials of the receiving system to follow a cosine pattern of reception, and then to orient the aerials so that their maxima were at right angles. In seeking a satisfactory design for the individual components, experiments were made on frequencies from 500 to 1,000 Mc/s with single aerials combined with various configurations of V or truncated-V reflectors having apex angles of 90–240 degrees. Some of the patterns obtained approximated to the ideal cosine law but they were frequency-sensitive. However, reasonable performance was obtained over the whole band with a flat-sheet reflector (i.e., a V reflector with an apex angle of 180 degrees) and as it was mechanically simple, this arrangement was adopted for more detailed investigations.

The separation between aerial and reflector may not substantially exceed $\lambda/4$ without an undesirable minimum in the reception pattern in the direction normal to the reflector; the best separation was found to be about 8 cm (i.e., approximately $\lambda/4$ at 1,000 Mc/s).

Reception patterns were investigated for the aerials given in Table 1.

Suitable patterns were obtained with all the aerials except the open cone and the combination of cone and cylinder. These two aerials were not investigated in great detail and the final choice for more detailed

TABLE 1—*Experimental Vertical Monopole Aerials*

Aerial	Description
A	Cone 15 degrees semi-vertical angle. Right conical top
B	,, 20 ,, ,, ,, ,, ,, ,,
C	,, 25 ,, ,, ,, ,, ,, ,,
D	,, 20 ,, ,, ,, Open top
E	,, 20 ,, ,, ,, Spherical cap
F	,, 20 ,, ,, ,, Capped cylindrical top
G	Aerial A inverted
H	Cylindrical rod 10 cm long by 1·6 cm dia.
I	Thin wire (18 s.w.g.) 10 cm. long

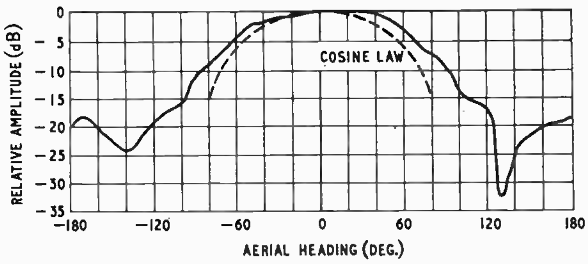


Fig. 2. *Horizontal-plane reception pattern of cone-aerial E, with a flat-sheet reflector, for vertical polarization; frequency* 750 *Mc/s*

investigation in a direction-finding installation was the 20-degree conical aerial with spherical cap. The measured reception pattern for this type of aerial associated with a flat-sheet reflector 50 cm high by 60 cm wide, for the mid-band frequency of 750 Mc/s, is shown in Fig. 2. A cosine pattern is shown also for comparison. Reception patterns were investigated for the whole band 500–1,000 Mc/s and also for other reflector widths from 30 to 70 cm, but widths less than 60 cm were found unsatisfactory owing to rapid variations in the reception pattern with azimuth caused by diffraction round the edge of the sheet.

No measurements were made of the patterns in the vertical plane but the aerial length was kept below $3\lambda/4$ to avoid undesirable minima.

Impedance Measurements

Impedance measurements were made by means of a standing-wave technique using a slotted line and a capacitive probe connected to a calibrated receiver. The voltage standing-wave ratios for the aerial types previously listed are shown in Table 2.

TABLE 2—*Voltage Standing-Wave Ratios for the Aerial Types described in Table* 1

Frequency (Mc/s)	V.S.W.R.								
	A	B	C	D	E	F	G	H	I
400	0·20	—	—	—	—	—	0·31	—	—
500	0·25	0·22	0·24	0·20	0·25	0·56	0·71	0·10	0·03
600	0·25	0·40	0·37	0·31	0·25	0·40	0·36	0·29	0·11
700	0·36	0·50	0·42	0·36	0·42	0·42	0·28	0·42	0·36
800	0·45	0·59	0·45	0·24	0·50	0·42	0·31	0·53	0·48
900	0·55	0·91	0·50	0·56	0·71	0·63	0·77	0·36	0·20
1000	0·63	0·77	0·59	0·50	0·71	0·77	0·83	0·31	0·25
1100	0·63	—	—	—	0·63	—	0·56	—	—
1200	—	—	—	—	0·40	—	—	—	—

Aerial E is that used in the experimental twin-aerial system. It had a poor v.s.w.r. at the low-frequency end of the band and the cone and cylinder combination (aerial F) was designed in an effort to reduce this effect. Unfortunately, the reception pattern of this aerial exhibited lobe splitting at certain frequencies and the design was not further investigated. Aerial G gave some improvement at the low-frequency end, but the impedance changed more rapidly with frequency than that of the spherical-top cone and for this reason the design was considered unsatisfactory.

The impedance diagram and voltage standing-wave ratio of the 20-degree spherical-top cone monopole used (type E) is shown in Fig. 3.

Band-Pass Filters

If the aerial system is to be used with a crystal-video receiver, a band-pass filter is necessary to limit the response of the system to signals outside the band 500–1,000 Mc/s. Filters were constructed of a coaxial-line type consisting of series-capacitor elements and shunt-inductive stubs, the latter providing a d.c. return path for a crystal detector. Each filter consisted of two sections and two end sections, with a characteristic impedance of 70 ohms.

The filters were introduced into the circuit immediately following the aerial adaptors described in the following section. They caused some deterioration of the v.s.w.r. which had a lower limit of 0·2 for the overall system using aerial E when terminated in 70 ohms.

Experimental Twin-Aerial System

The performance of a twin-aerial system can be estimated approximately, from the results on the individual components described. However, to investigate the effects of small differences in the construction of the aerials and filters, and of interaction between them, tests were made on a complete aerial system using the type E aerials, spherical-capped, cone monopoles of 20-degree semi-angle.

The arrangement used is shown in plan view in Fig. 1. The V-reflector was made from 16-gauge aluminium sheet, fixed to a rigid framework, but netting could be used instead of the sheet to reduce windage if necessary.

The earth-mat consisted mainly of half-inch mesh netting, on wooden radial members, but the central area, through which the aerials projected, was a copper sheet to which the netting was soldered. In this series of tests the earth-mat was about 130 cm from the ground. The whole assembly could be rotated about a vertical axis midway between the aerials and a bearing scale indicated the azimuth of the apex of the V (that is, the equi-signal position for the system).

Each aerial was connected to its filter by a 70-ohm cone adaptor fixed to the underside of the earth-mat so that the base of the aerial was in the plane of the mat. If required, the cones could be used as transformers to vary the aerial matching.

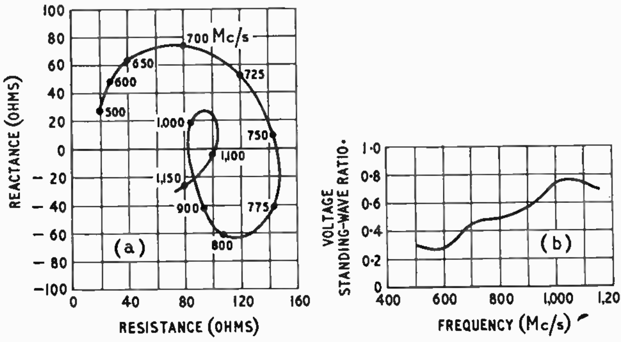


Fig. 3. *Impedance characteristics of cone-aerial E and adaptor; (a) impedance diagram and (b) voltage standing-wave ratio*

The following characteristics of the twin-aerial system were investigated in the band 500–1,000 Mc/s and, although some of the measurements were a repetition of those made initially with a single monopole and sheet reflector, they were repeated to investigate the effects of interaction between the aerials in a complete system.

(i) Reception patterns of each aerial for vertical and 45-degree plane-polarized transmissions.
(ii) Ratio of vertical to horizontal pick-up as a function of azimuth and type of aerial.
(iii) Relative outputs from the two aerials, with and without the filters in circuit, deduced from consecutive measurements on each azimuth for vertically and 45-degree plane-polarized transmissions.

The measurements in (iii) are those from which the direction-finding characteristics were deduced and were made in this manner to minimize the effects of tuning drift and changes in transmitter output or receiver sensitivity. By this means, the ratio of the outputs from the two aerials at any one azimuth could be determined to an accuracy of ± 0·5 dB.

Direction-Finding Characteristics

Accuracy on Vertically-Polarized Transmissions

The results for vertical polarization on a frequency of 750 Mc/s are shown in Fig. 4. They are derived from a comparison of the aerial outputs, and show the reading in degrees which may be expected on a cathode-ray tube as a function of the true azimuth of the transmitter, together with the variation in amplitude of the signal with azimuth.

In the pass-band 500–1,000 Mc/s, substantially similar results were obtained with and without the filters; the variation in output between the aerials, introduced by the filters, did not exceed the accuracy of measurement; i.e., 0·5 dB.

As the reception patterns do not follow a true cosine law, the 90-degree arc of the c.r.t. must have a modified bearing scale to enable the azimuth of the received signal to be measured directly. From Fig. 4 it may be seen that the working azimuthal range of ± 45 degrees about the plane of symmetry of the system is compressed within ± 30 degrees on the c.r.t. For simplicity it is desirable to have a uniform scale, which should apply for all frequencies, such as is represented by the line AA. This is the best straight line fit for the working range and errors using this linear law are tabulated in Table 3 for five frequencies in the band 500–1,000 Mc/s.

Some of the errors indicated in Table 3 are greater than are tolerated by the specified objective (± 5 degrees) but it is considered that they could be reduced to the required limits in a well-constructed apparatus. They could be further reduced by choosing a non-linear law but the difficulties in reading such a scale probably outweigh its advantages.

TABLE 3—*Errors of Twin-cone Direction Finder with Vertically-Polarized Wave*

Bearing Relative to System Heading	Error in Degrees (Observed-True Bearing)				
	500 Mc/s	600 Mc/s	750 Mc/s	900 Mc/s	1000 Mc/s
− 45	0	− 3	+ 3	+ 2	+ 5
− 40	− 3	− 1	0	+ 1	+ 1
− 30	− 7	0	− 4	0	+ 2
− 20	− 7	− 3	0	− 2	− 2
− 10	− 4	− 2	0	+ 1	− 7
0	+ 3	+ 2½	+ 0	0	− 1½
+ 10	+ 7	+ 5	+ 3	0	− 4
+ 20	+ 9	+ 3	+ 2	0	− 6
+ 30	+ 7	0	+ 1	− 3	− 6
+ 40	+ 2	− 4	− 1	− 6	− 6
+ 45	− 1	− 6	− 3	− 7	− 7

The curve of Fig. 4 also indicates the possibility of ambiguous results in that indicated bearings within the ± 30 degree sector on the tube would also be given by some transmissions outside the working range. To avoid confusion, the sensitivity of the system to such signals should be low. With the characteristics shown there is some possibility of confusion and error, but with signals of sufficient duration rotation of the aerial system would always enable an unambiguous bearing to be obtained; an indicated bearing of zero would be given only by signals from forward or backward directions, and there is a difference of more than 20 dB between the response from these two directions.

To consider the probable causes of some of the errors, further experiments were made with cylindrical aerials. During the earlier experimental work on reception patterns with single sheet reflectors, little difference was observed between the patterns for short cylindrical aerials and for the various cones. To confirm this result, the cones were replaced by cylinders 7·5 cm high by 1·6 cm diameter and the measurements repeated at 1,000 Mc/s at which frequency the aerial was resonant and the v.s.w.r. near unity. The results were almost identical with those for the cone aerials.

To determine the significance of irregularities of the curves, the outputs from the 7·5-cm cylinders with no reflector were measured at azimuth intervals of 5 degrees on a frequency of 1,000 Mc/s. Variations in output with azimuth of up to 4 dB were experienced for each in-

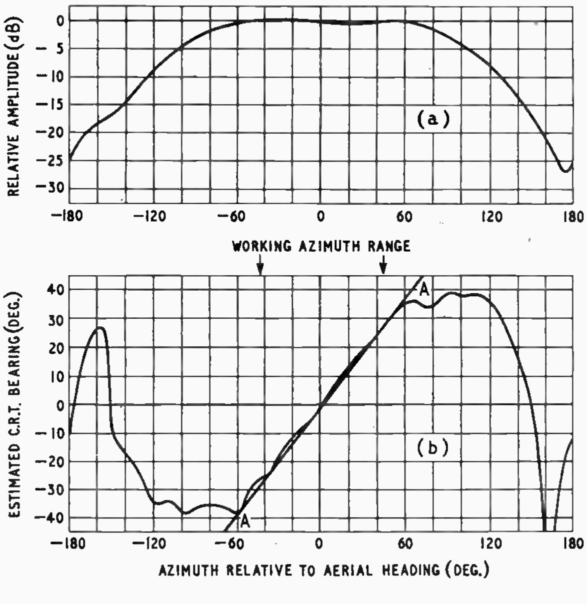


Fig. 4. *Characteristics of twin aerial system for vertical polarization; frequency* 750 *Mc/s.* (*a*) *amplitude response,* (*b*) *calibration curve*

dividual aerial with a marked similarity between the two error curves. It is assumed that the large variations result from diffraction effects associated with the earth-mat. In the presence of the reflector the effect would be greatly reduced, but the experiment suggests that a circular boundary to the earth-mat may be advantageous.

Direction-Finding Errors on Transmissions containing Horizontally-Polarized Components

With waves of mixed polarization, errors may arise from direct pick-up of horizontally-polarized waves on the aerials, from the effects of the finite size of the earth-mat and possibly, in the experimental system, from the effects of undulations in the mat. Errors from this last effect should be negligible in a well-constructed instrument.

The results obtained with the experimental system for transmissions plane-polarized at ± 45 degrees and horizontally incident are shown in Fig. 5 for frequencies of 750 and 1,000 Mc/s. The errors are large at 1,000 Mc/s where they reach a maximum of about 25 degrees, but decrease steadily with frequency. The following experiments were made to investigate the cause of this large error at the high-frequency end of the band.

The pick-up from one cone aerial was examined at various azimuths for waves polarized vertically, horizontally and at ± 45 degrees. With no reflector present, the response of the system to horizontally-polarized transmissions relative to that for vertically-polarized waves (pick-up ratio) varied between − 18 and − 40 dB and for 45-degree polarized waves was approximately the anticipated − 3 dB. This variation of the pick-up ratio with azimuth may be attributed to the irregular shape of the earth-mat.

The experiment was then repeated with the reflector present behind the aerial and a marked change was observed. In the direction normal to the reflector, the pick-up ratio was − 23 dB but, in the direction parallel to the plane of the reflector, the ratio approached unity.

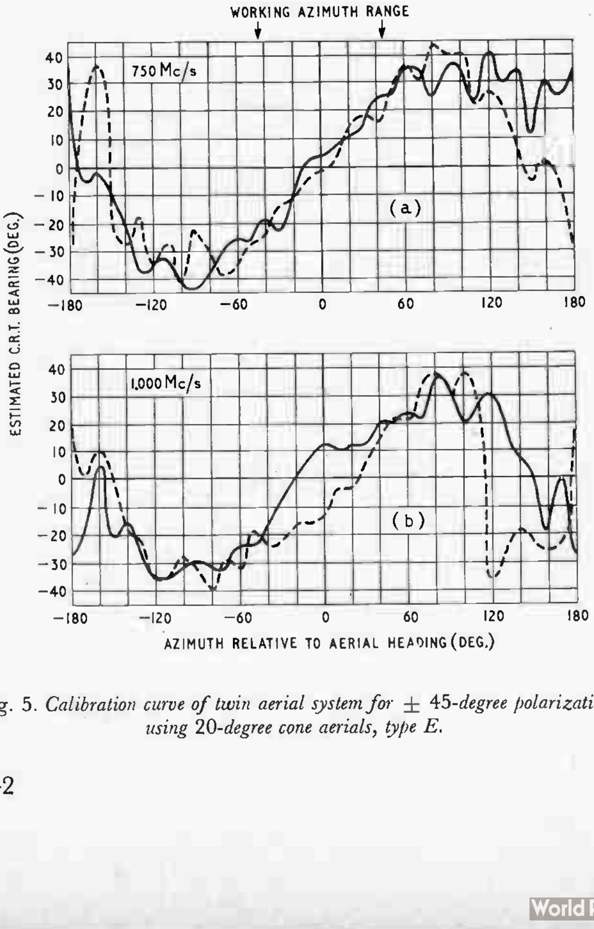


Fig. 5. *Calibration curve of twin aerial system for* ± *45-degree polarization using 20-degree cone aerials, type E.*

Using the cone aerial of 20-degree semi-angle, the maximum diameter of the aerial was 15 cm, bringing it to within 0·5 cm of the reflector. This resulted in capacitive unbalance of the aerial to the reflector which could cause azimuth-dependent horizontal pick-up and seemed to be the major factor in causing the large polarization errors at the high-frequency end of the band.

For further confirmation, measurements were made using cylindrical aerials 7·5 cm high by 1·6 cm diameter in place of the cone aerials. The results without the reflector were similar to those obtained with the cones, but the addition of the reflector made no difference to the horizontal pick-up. In fact, as the vertical pick-up was enhanced by the reflector, the ratio was actually improved.

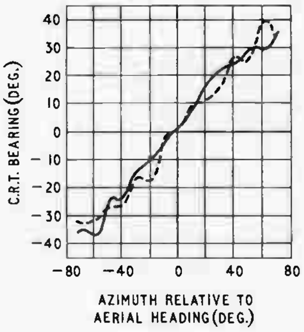


Fig. 6. *Calibration curve of twin aerial system using cylindrical aerials for* ± *45-degree polarization; frequency 1,000 Mc/s*

The direction-finding characteristics for these cylinders at a frequency of 1,000 Mc/s are shown in Fig. 6. The polarization errors are greatly reduced (a maximum of 6 degrees) and may be considered as the residual errors due to the imperfect earth-mat.

The pick-up ratio was studied in detail only at 1,000 Mc/s but, as previously stated, the polarization errors for the cone-aerial system decreased steadily with frequency. At 750 Mc/s the maximum error from transmissions polarized at 45 degrees was about 12 degrees; this was larger than for the cylinders at 1,000 Mc/s, indicating that direct pick-up of horizontally-polarized components was still a contributory cause of the error. At 500 Mc/s, however, the errors were quite small and assumed to arise mainly from the imperfections of the earth-mat.

This conclusion was confirmed, using the cone-aerial system, by extending the earth-mat to 180 cm radius and measuring the polarization error again at 500, 750 and 1,000 Mc/s. At the two higher frequencies no improvement was detected as the finite size of the earth-mat was not the main cause of the error. At 500 Mc/s a slight improvement was obtained.

System for Horizontally-Polarized Transmissions

In view of the simplicity of the flat-sheet reflector and its successful application to the vertically-polarized system, a similar arrangement was adopted for horizontal polarization. The earth-mat was retained to eliminate the ground-reflected ray and to isolate the aerial from the rest of the system, but the aerials considered were various forms of horizontal dipole.

Reception Pattern of Aerials

The problem of obtaining the correct horizontal-plane reception pattern is in one respect more difficult than for a vertically-polarized system. While the vertical aerial close to the sheet reflector approaches a cosine law, the presence of the reflector distorts the inherent cosine pattern of the horizontal aerial and the dipole must therefore be modified to increase the response in directions near the end-on position. This may be done by bending the aerial in the horizontal plane into a U-formation as shown in the plan view of Fig. 7 (b).

The horizontal-plane reception pattern for a typical aerial having this U-shape and spaced 8 cm from a flat-sheet reflector is shown in Fig. 8 for a frequency of 750 Mc/s.

It was confirmed that as in the vertically-polarized system, no worthwhile improvement in front-to-back ratio resulted from the use of a sheet reflector larger than 60 cm wide by 50 cm high. The reception patterns were, however, found to be less critically dependent upon the spacing between the aerial and reflector than in the vertical system but with a similar optimum of approximately $\lambda/4$ at the shortest wavelength.

Balance-to-Unbalance Transformer

To avoid duplication in design of the aerial coupling arrangements for the vertically- and horizontally-polarized systems, a balance to unbalance transformer (balun) is necessary so that the aerial system may be connected directly to the coaxial filter input. The design used is shown in Fig. 7 (b).

The length of the balun is $\lambda/4$ at the mid-band frequency, 750 Mc/s, and consequently at this frequency the shunt impedance of the balun considered as a balanced, screened transmission line, becomes very high while the aerial is approximately resonant. Over the band 500–1,000 Mc/s the v.s.w.r. for this design of balun with the aerial replaced by a 70-ohm termination does not fall below 0·5, and the reactive component does not exceed 35 ohms.

Impedance of the Aerial System

As previously stated, the horizontal-plane reception pattern of the aerial system is substantially independent of the form of the aerial provided that its shape in the horizontal plane remains the same. The shape in the vertical plane may therefore be adjusted to present the best impedance match over the band 500–1,000 Mc/s. The overall impedance characteristics of various aerials, measured through the balun described in the previous section are given in Table 4, which presents the v.s.w.r. as a function of frequency when the system is connected to a 70-ohm coaxial line.

Aerials K, L and M vary in the vertical plane while maintaining the plan shape of Fig. 7 (b). Aerial J has the same vertical form as aerial K but the ends are not bent round to form the U. These two aerials, J and K, have similar voltage standing-wave ratios and bending the ends has little effect upon the impedance. However, as the vertical plane dimension is reduced progressively, given by aerials L and M, the v.s.w.r. deteriorates and becomes outside the required tolerance.

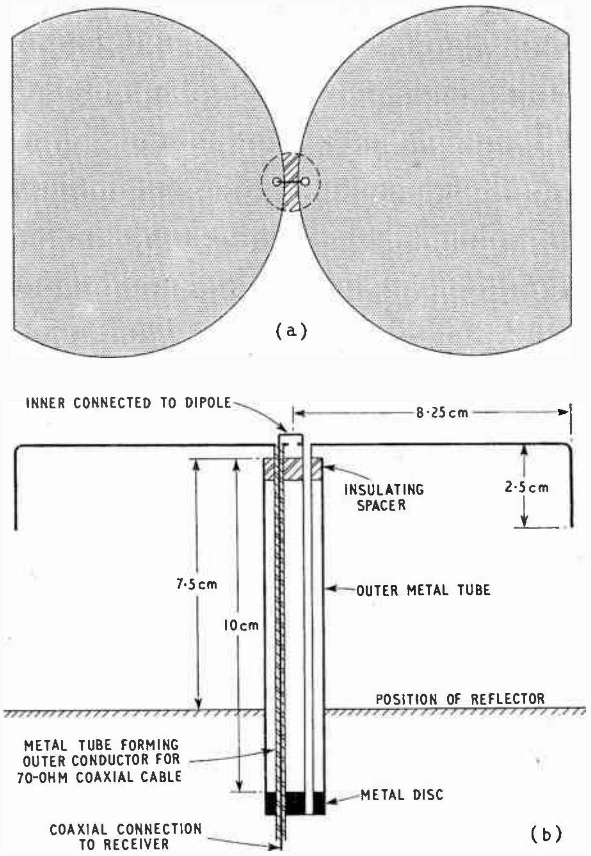


Fig. 7. *Horizontal dipole (type K) with balun; (a) front view, (b) plan view showing balance-to-unbalance transformer*

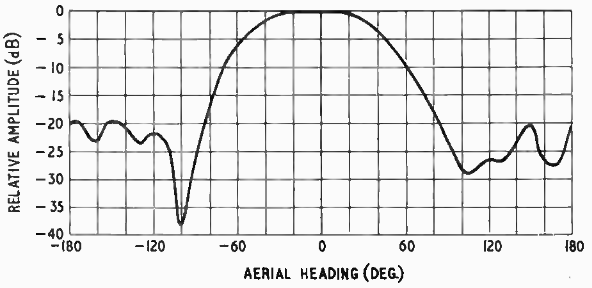


Fig. 8. *Horizontal-plane reception pattern of dipole aerial (type K) with flat-sheet reflector for horizontal polarization at 750 Mc/s*

Fig. 9 shows the impedance diagram and v.s.w.r. for aerial K connected to the balun and mounted 8 cm from the flat-sheet reflector.

Direction-Finding Characteristics

Horizontally-Polarized Radiation

The performance of a twin-aerial system based upon the dipole aerial type K combined with a flat-sheet reflector has been estimated from the reception pattern of the single aerial. This is a less reliable technique than was used for the vertically-polarized case for which measurements were made on a practical twin-aerial

TABLE 4—*Voltage Standing-Wave Ratios of Dipole Aerials*

Aerial	Description
J	Twin circular disc dipole each disc 10·75 cm dia.
K	Similar to J but bent at right angles at 2·5 cm from each end
L	Strip dipole 4·5 cm wide by 10·75 cm long bent similarly to K
M	Rod dipole 0·6 cm diameter by 10·75 cm long bent similarly to K

Frequency (Mc/s)	V.S.W.R.			
	Aerial J	Aerial K	Aerial L	Aerial M
500	0·37	0·33	0·26	0·34
550	0·37	0·38	0·50	0·47
600	0·40	0·34	0·40	0·50
650	0·69	0·65	0·56	0·53
700	0·47	0·50	0·59	0·35
750	0·56	0·49	0·37	0·24
800	0·56	0·81	0·63	0·35
850	0·40	0·41	0·31	0·19
900	0·40	0·44	0·28	0·24
950	0·31	0·37	0·25	0·18
1000	0·33	0·31	0·21	0·11

system, but the result is sufficiently accurate to evaluate the utility of the system. The reception patterns were not completely symmetrical about the direction of maximum pick-up (see Fig. 8) and the average of the two sides of the pattern have been taken for this computation.

The error curve changes with the apex angle of the reflector system and a range of angles was considered. The optimum was about 110 degrees compared with 100 degrees for the vertically-polarized system. The results for frequencies of 500, 750 and 1,000 Mc/s and an apex angle of 110 degrees are given in Fig. 10. It shows the reading in degrees which may be expected on a cathode-ray tube, as a function of the true azimuth of the transmitter. It will be noted that owing to the manner in which the curves are derived, the calculated-error pattern is essentially symmetrical about the head-on position for the aerial system and the curves for the three frequencies pass through the origin. For this reason the curves in the figure are plotted from 0 to 45 degrees on the c.r.t. and not from − 45 to + 45 degrees as in the vertically-polarized case.

As before, however, the best straight-line fit has been applied to the curves and the departures from this line plotted as functions of frequency and azimuth in Table 5.

From an examination of Fig. 10 it may be seen that an improvement in accuracy could be achieved over the central portion of the azimuthal range by increasing the slope of the calibrating line. However, this would increase the error at the ends of the range and would actually limit the total range to about 80 degrees instead of the desired 90 degrees. In this case the use of a non-linear bearing scale for the cathode-ray tube may be desirable.

Radiation Containing Vertically-Polarized Components

The reception patterns for horizontally-incident radiation, plane polarized at ± 45 degrees, were substantially the same as for pure horizontally-polarized radiation. Small errors are introduced by the presence of the vertically-polarized components but the methods used to estimate the performance of a twin-aerial direction-finder from the reception patterns of a single aerial were not sufficiently sensitive to resolve them. They are, however, unlikely to exceed 2 degrees in a direction-finder based on the aerial design described.

General Discussion of Results

In the vertically-polarized system, the reception patterns in the horizontal plane, for vertically-polarized radiation, of a single aerial and flat-sheet reflector were substantially independent of the form of the aerial. The direction-finding errors in Table 2 may therefore be taken as typical for any of the simple capped cones or cylinders described, and the choice of aerial is determined by the relative importance of polarization errors and acceptable voltage standing-wave ratios over the frequency band.

Considering impedance properties only, the spherical capped cone of 20 degrees semi-angle had the most satisfactory characteristics. However, in the presence of a horizontally-polarized component in the incident transmission, a system based upon this aerial would be subject to large polarization errors, reaching a maximum

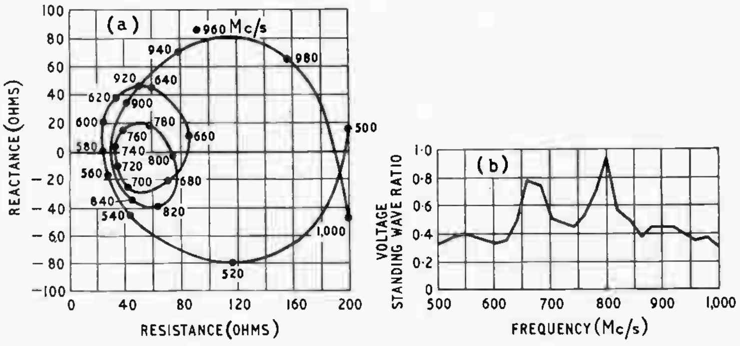


Fig. 9. *Characteristics of dipole aerial (type K) combined with balun; (a) impedance diagram and (b) voltage standing-wave ratio*

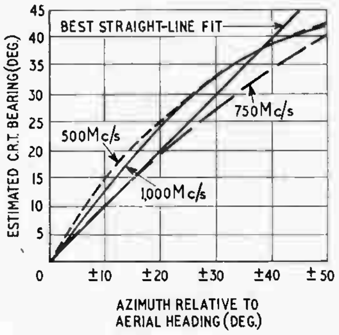


Fig. 10. *Estimated calibration curve of twin dipole system for horizontal polarization*

of 25 degrees at 1,000 Mc/s. The system using the 45-degree cone with a 15-degree conical top, however, (aerial G) had a maximum polarization error of 10 degrees, while the impedance characteristics were almost as good as those of the wider-angle cone. This aerial is then a reasonable compromise between the wide-angle cone and simple cylinder. It should be remembered also that these polarization errors are for horizontally-incident transmissions; with a transmitter presenting an elevation of 45 degrees at the direction finder the errors could probably be double those quoted.

For the horizontally-polarized system the polarization errors were relatively small and the choice of aerial is determined on the grounds of acceptable impedance characteristics. The most satisfactory aerial of those tested, having the required horizontal plane reception pattern, was the bent circular dipole shown in Fig. 7.

TABLE 5—*Estimated Errors of Twin Dipole Direction Finder for Horizontally-Polarized Waves*

Bearing relative to heading of system	Error in degrees (Observed-true bearing)		
	500 Mc/s	750 Mc/s	1,000 Mc/s
0	0	0	0
± 10	+ 5	+ ½	+ 3
± 20	+ 5½	− ½	+ 4½
± 30	+ 3	− 2½	+ 3
± 40	− 1	− 5	− 1
± 45	− 4	− 7	− 4½

Certain general conclusions apply to both the vertical and horizontal systems. The optimum dimensions of the reflector were the same for both, 50 cm high by 60 cm wide. Any decrease in this size resulted in restriction of the operational range of the reception pattern as a result of diffraction at the boundaries of the reflector.

To reduce the effect of irregularities in the earth-mat, the perimeter should be circular. The radius of the mat should be 1·2 metres (2λ at the lowest frequency). Some decrease in polarization error may be obtained at the lowest frequencies by increasing this radius but it is not considered that the improvement justifies the increase in size. The earth-mat should be as flat as possible and the central portion made of sheet material of radius not less than 60 cm (one wavelength at the lowest frequency). The remainder of the mat may be of wire mesh provided that the mesh size is not greater than 2·5 cm ($\lambda/12$ at the highest frequency).[2] It should be as flat as possible and a more rigid construction than was used in the experimental model is desirable.

To facilitate taking bearings on transmissions of either vertical or horizontal polarization, the aerial systems, each with its own earth-mat, could be stacked one above the other. The effect of this has not been tested experimentally but a separation of 1 metre should be sufficient on transmissions for which the angle of elevation does not exceed 30 degrees.

Conclusions

The investigation has demonstrated the feasibility of designing a direction-finder to fulfil the specification indicated in the introduction, and the probable performance of an instrument based on this design may be summarized as follows.

The direction-finding errors given in Tables 3 and 5 for the vertical and horizontal systems respectively in some cases exceed the objective of ± 5 degrees. Some improvement would result from the use of a complete circular earth-mat and from a more rigidly-constructed apparatus than was used in the experiments. An improvement in accuracy would also be obtained from the use of calibration charts for particular frequencies.

In the vertical system, it is reasonable to suppose that the calibration curves for vertically-polarized transmissions would be symmetrical. If the existing curves (illustrated by that for 750 Mc/s in Fig. 4) are smoothed in this manner and sudden changes removed, the maximum error in the working azimuthal range, assuming an equiangular calibration on the c.r.t., does not exceed ± 5 degrees for frequencies from 600 to 1,000 Mc/s. At 500 Mc/s the maximum error does not exceed ± 7 degrees. If the azimuthal range is restricted to ± 10 degrees of the heading of the system, the maximum error is reduced to about ± 3 degrees for all frequencies. In a well-made instrument, this error would be still further reduced in the equi-signal position.

If the transmission were not vertically-polarized, further errors would be introduced which depend upon the type of aerial used in the direction-finder and the azimuth of the transmitter relative to the heading of the system. If the transmission were horizontally-incident and plane-polarized at 45 degrees, the maximum error using the double-cone monopole (aerial G) would be about 10 degrees or up to twice this error for signals incident at 45-degrees elevation.

The results for the horizontal system given in Table 5 have already been smoothed from the method by which the error curves were derived. Using an equiangular bearing scale the maximum error on horizontally-polarized transmissions should not exceed ± 7 degrees. If a non-linear calibration is used this may be reduced to ± 4 degrees over the full azimuthal range or ± 3 degrees (the same as the vertical system) if the range is restricted to ± 10 degrees of the heading of the system. As in the vertical case, the errors would be still further reduced in the equi-signal position.

Errors due to mixed polarization would be small and for horizontally-incident transmissions, plane-polarized at 45 degrees, would be unlikely to exceed 2 degrees.

Acknowledgments

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The paper is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research.

REFERENCES

[1] H. G. Hopkins and F. Horner, "Rotating H-Type Adcock Direction Finders for Metre and Decimetre Wavelengths", *Proc. Instn. elect. Engrs.*, 1951, Part IV, Vol. 98, p. 112.

[2] R. R. Pearce, "Some Experiments on Conducting Screens for a U-Type Spaced-Aerial Radio Direction Finder in the Frequency Range 600–1,200 Mc/s", *J. Instn. elect. Engrs.*, 1947, Part III, Vol. 94, p. 115.

Power Spectrum of a Carrier Modulated in Phase or Frequency by White Noise

By R. Hamer, B.Sc., A.M.I.E.E., and R. A. Acton, M.A.*

SUMMARY. *Measurement of the power spectrum of a carrier, modulated either in phase or in frequency by a uniform Gaussian noise signal, is described, and the results are interpreted in the light of existing theory. A combination of measured and theoretical results is used to prepare generalized curves of f.m. and ph.m. noise spectra.*

It is often convenient when dealing with frequency-division multiplex telephony transmission to represent the multichannel signal by a band of 'white' (i.e., uniform, Gaussian) noise. The error involved in this is insignificant when more than one supergroup (sixty telephone channels) is considered. A knowledge of the average spectral density of a carrier modulated in phase or frequency by a random noise signal is therefore of importance in the design of radio relay systems employing angular modulation.

Several theoretical investigations of the f.m. and ph.m. noise spectrum have been made.[1–4] The methods adopted, although differing in detail, are all based on the use of established relations between power spectra and autocorrelation functions of random-periodic functions of time. The method is more readily applied to phase modulation but, even in this case, the derivation of a useful function for the average power density of the spectrum is difficult. Such an expression, in the form of a rather unwieldy product of two convergent series, has been obtained by Bosse.[4] The application of the method to frequency modulation, although useful, has not so far enabled a general analytical spectrum function to be derived. Here, the results of Stewart[3] and Bosse[4] are examined, and compared with the measured data, enabling generalized curves of f.m. and ph.m. noise spectra to be presented.

1. F.M. Noise Spectrum

It is assumed that a random noise signal, having a Gaussian amplitude distribution and a uniform average power spectrum between frequencies f_1 and f_n, is applied to an ideal frequency modulator. The frequency of the carrier is then a linear function of the instantaneous amplitude of the modulating signal, so that we may regard the modulation as a time function of carrier deviation. Thus, the total modulating signal power, W_m, is,

$$W_m = k^2 \Delta f^2,$$

where Δf is the total r.m.s. deviation of the carrier and k is the voltage/frequency constant of the modulator. The constant k may be replaced by unity in the analysis so that, if $f_1 \ll f_n$, the power spectrum of the modulation becomes

$$W_m(f) \approx \Delta f^2 / f_n$$

between f_1 and f_n, and zero elsewhere. It is convenient to let f_1 tend to zero, since in practical systems f_1 is very much smaller than f_n. (However, the case when f_1 is not zero is considered later.) Under the conditions assumed the f.m. spectrum is continuous, and is shown by Stewart to be

$$W(\omega) = \frac{E^2}{\pi} \int_0^\infty \cos(\omega\tau) \exp. \left[-\frac{\Delta\omega^2 \tau}{\omega_n} \int_0^{\frac{1}{2}\omega_n\tau} \left(\frac{\sin y}{y}\right)^2 dy \right] d\tau \qquad (1)$$

where

ω = angular frequency relative to mean carrier

E = r.m.s. voltage of carrier

$\Delta\omega$ = r.m.s. angular frequency deviation ($= 2\pi\Delta f$), assumed very small compared with the carrier frequency

ω_n = highest modulating angular frequency ($= 2\pi f_n$), assumed very small compared with the carrier frequency

$W(\omega)$ = power of density spectrum, in unit resistance

and τ, y are variables of integration.

Equation (1) can be re-arranged in a more general form by introducing the following new variables

$$x = \frac{f}{f_n} = \frac{\omega}{\omega_n} = \text{normalized relative frequency}$$

$$m = \frac{\Delta f}{f_n} = \frac{\Delta\omega}{\omega_n} = \text{r.m.s. modulation index.}$$

When this is carried out, and E set equal to unity, equation (1) may be written,

$$f_n \cdot W(x) = \frac{1}{\pi} \int_0^\infty \cos\, x\theta\ \exp. \left[-m^2\theta \int_0^{\frac{1}{2}\theta} \left(\frac{\sin y}{y}\right)^2 dy \right] d\theta \qquad (2)$$

where $W(x)$ now represents the power density of the spectrum as a fraction of the carrier power, and θ is a new variable of integration.

Middleton[1] has shown that if f_1 is not zero, but is small compared with f_n, the continuous spectrum is

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substantially unchanged, but a small residual carrier is introduced at the mean carrier frequency. The power of the residual carrier is shown to be [after transforming the variables as in equation (2)]

$$W_D = \exp. - m^2/x_1 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

where W_D is the residual carrier power as a fraction of the full carrier power, and $x_1 = f_1/f_n$.

When the r.m.s. modulation index m is very large, the residual carrier power tends to zero for any possible value of x_1, and the spectrum is then represented by the continuous function of equation (2). For very large m this equation reduces to the well-known Gaussian function

$$f_n \,.\, W_1(x) = \frac{1}{\sqrt{2\pi}m} \exp. - \frac{x^2}{2m^2} \quad \ldots \quad \ldots \quad (4)$$

As noted by Stewart, this result for very large m is independent of the shape of the modulation spectrum and therefore of the value of x_1.

Stewart shows that when m is very small, equation (2) reduces to the following approximation:

$$f_n \,.\, W_2(x) = \frac{2m^2}{\pi^2 m^4 + 4x^2} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

together with a residual carrier at $x = 0$ if $x_1 \neq 0$, given by equation (3). This indicates that when x_1 is zero, the spectrum is continuous and unbounded. In any practical measurement x_1 is not zero, and some difficulty is encountered here in interpreting the theoretical result. If $x_1 \ll 1$ and $m \ll 1$, consideration of the spectrum due to a large number of discrete tones, using the orthodox Bessel function analysis, leads to the following conclusions:

(i) the residual carrier power is substantially the same as the full carrier power; i.e., the power in the sidebands is very small;

(ii) the power density of the spectrum is approximately

$$f_n \,.\, W_2(x) \doteq \frac{m^2}{2x^2(1 - x_1)} \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

for $x_1 \leqslant |x| \leqslant 1$ and approaches zero elsewhere. The range of applicability of equations (5) and (6) may now be established in the following manner. The total power of the spectrum has been normalized to unity in these equations, and it is readily shown that, for equation (5)

$$2\int_0^\infty f_n \,.\, W_2(x)dx = 1$$

Using equation (6), the total power of the continuous spectrum is in this case

$$2\int_{x_1}^1 \frac{m^2}{2x^2(1 - x_1)}dx = \frac{m^2}{x_1} \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

There is now, in addition, a residual carrier of power W_D given by equation (3). Expanding this exponential we have

$$W_D = 1 - \frac{m^2}{x_1} + \frac{m^4}{2{x_1}^2} - \ldots \quad \ldots \quad \ldots \quad (8)$$

Equation (6) is therefore a valid approximation provided the right-hand side of equations (7) and (8) sum to unity; i.e., when $m^2/x_1 \ll 1$. This is also seen to be the condition for the residual carrier power to approach unity, as required.

It may therefore be concluded that when $m \ll 1$, the shape of the spectrum is considerably influenced by the value of x_1 and is, in fact, determined by the value of m^2/x_1. In view of this, it is not possible to obtain an approximate function for the f.m. noise spectrum when $m \ll 1$ except for the limiting cases where $m^2/x_1 \gg 1$ and $m^2/x_1 \ll 1$. When $m^2/x_1 \gg 1$, x_1 must tend to zero, and equation (5) is applicable; when $m^2/x_1 \ll 1$ equations (3) and (6) are applicable. In other cases, a different spectrum exists for each value of m^2/x_1, with m held constant.

When m is neither very large nor very small, which often occurs in practical f.m. multichannel systems, the double integration in equation (2) cannot be carried out, and the results must rely on measurement.

2. The Ph.M. Noise Spectrum

It is convenient in examining phase modulation by uniform Gaussian noise to let the modulating power be

$$W_m = k^2(\Delta\phi)^2$$

where $\Delta\phi$ is the r.m.s. phase deviation, and k is the voltage/phase constant of an ideal modulator, set equal to unity in the analysis. It is again assumed that the modulating noise band extends from f_1 to f_n. When f_1 tends to zero, an equation for the ph.m. noise spectrum is derived by Stewart which, after transforming the variables as in Section 1, becomes,

$$f_n \,.\, W(x) = \frac{1}{\pi}\int_0^\infty \cos x\theta \exp.\left[- \frac{4\Delta\phi^2}{\theta} \int_0^{\frac{1}{2}\theta} \sin^2 y \, dy \right] d\theta, \qquad (9)$$

using the same symbols as in equation (2). In equation (9) $\Delta\phi$ corresponds to an effective r.m.s. frequency-modulation index m_e where

$$m_e = \frac{1}{\sqrt{3}}\Delta\phi$$

and the equivalent r.m.s. frequency deviation corresponding to the same modulating power as used in deriving equation (2) is

$$\Delta f_e = \frac{1}{\sqrt{3}} f_n \Delta\phi$$

Stewart shows that when $\Delta\phi$ is sufficiently large, the continuous spectrum is approximated by a Gaussian function

$$f_n \,.\, W(x) = \frac{\sqrt{3}}{\sqrt{2\pi}\Delta\phi} \exp. - \frac{3x^2}{2\Delta\phi^2} \quad \ldots \quad (10)$$

It is then the same as the spectrum obtained with f.m. when the r.m.s. modulation index is $\Delta\phi/\sqrt{3}$. A residual carrier is always present, whether x_1 is zero or not, but becomes vanishingly small when $\Delta\phi$ is very large. The power of the residual carrier is, for $x_1 = 0$

$$W_D = \exp. - \Delta\phi^2 \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

When $\Delta\phi$ is very small, the continuous spectrum is given approximately by

$$f_n \,.\, W(x) = \tfrac{1}{2}\Delta\phi^2 \exp. - \Delta\phi^2 \quad \ldots \quad \ldots \quad (12)$$

for $0 \leqslant |x| \leqslant 1$, and approaches zero elsewhere. The spectral density is therefore uniform up to $\pm f_n$ relative to the mean carrier frequency. The series form of the noise spectrum derived by Bosse (for $x_1 = 0$) is not considered in detail here, but his calculated spectral density curves for various values of $\Delta\phi$ are referred to later.

When x_1 is not zero, the Gaussian function of equation (10) is still an adequate approximation, provided $\Delta\phi$ is sufficiently large. When $\Delta\phi$ is very small and $x_1 \neq 0$, it may be deduced from elementary considerations that the residual carrier power should increase to

$$W_D = \exp. - \Delta\phi^2(1 - x_1) \qquad \ldots \qquad \ldots \qquad (13)$$

and the approximately uniform continuous spectrum should be restricted to the range $x_1 \leqslant |x| \leqslant 1$. For intermediate values of $\Delta\phi$, no useful conclusions can be drawn from the theory.

3. F.M. Noise Spectrum with Pre-Emphasis

It is sometimes desirable in f.m. radio systems to apply the modulation through a shaping network, in order to provide increased deviation at the higher modulating frequencies. This 'pre-emphasis' is a type of angular modulation that is partially f.m. and partially ph.m. For example, a pre-emphasis of 6 dB per octave from the lowest modulating frequency to the highest results in ph.m. when applied to a frequency modulator, and is a convenient method of producing ph.m. (see Section 4). In practice, pre-emphasis is usually applied from some intermediate modulating frequency up to the highest, and is not necessarily 6 dB per octave. Since the pre-emphasis is discontinuous, and is applied arbitrarily, it is unprofitable to analyse this case theoretically.

When the effective modulation index is large, the spectrum should follow the Gaussian function whatever form the pre-emphasis takes. It is reasonable to suppose that when the effective modulation index is very small the spectrum takes some form intermediate between those observed for f.m. and ph.m. (a greater pre-emphasis than 6 dB per octave is not normally of interest).

4. Method of Measurement

The test equipment available for the measurements was as follows:

(i) a source of uniform, Gaussian noise (amplified thermal-agitation and valve noise) followed by band-limiting filters;

(ii) a high-grade, wide-band frequency modulator, operating at a mean carrier frequency of 60 Mc/s;

(iii) a panoramic receiver, displaying frequency spectra over the band 55–65 Mc/s;

(iv) a narrow-band superheterodyne communications receiver with an output at the intermediate frequency for measuring purposes;

(v) a video-frequency noise power meter, with a substantially uniform response from a few kilocycles/sec to about 5 Mc/s;

(vi) various signal generators, attenuators, etc.

Although the panoramic receiver was useful in displaying the general shape of the spectrum, it was not suitable for accurate measurement of power density; its primary purpose was to enable the required r.m.s. frequency or phase deviation to be set up, using the equipment layout shown in Fig. 1. The procedure for establishing a given r.m.s. frequency deviation was as follows:

(1) A video-frequency signal generator was connected

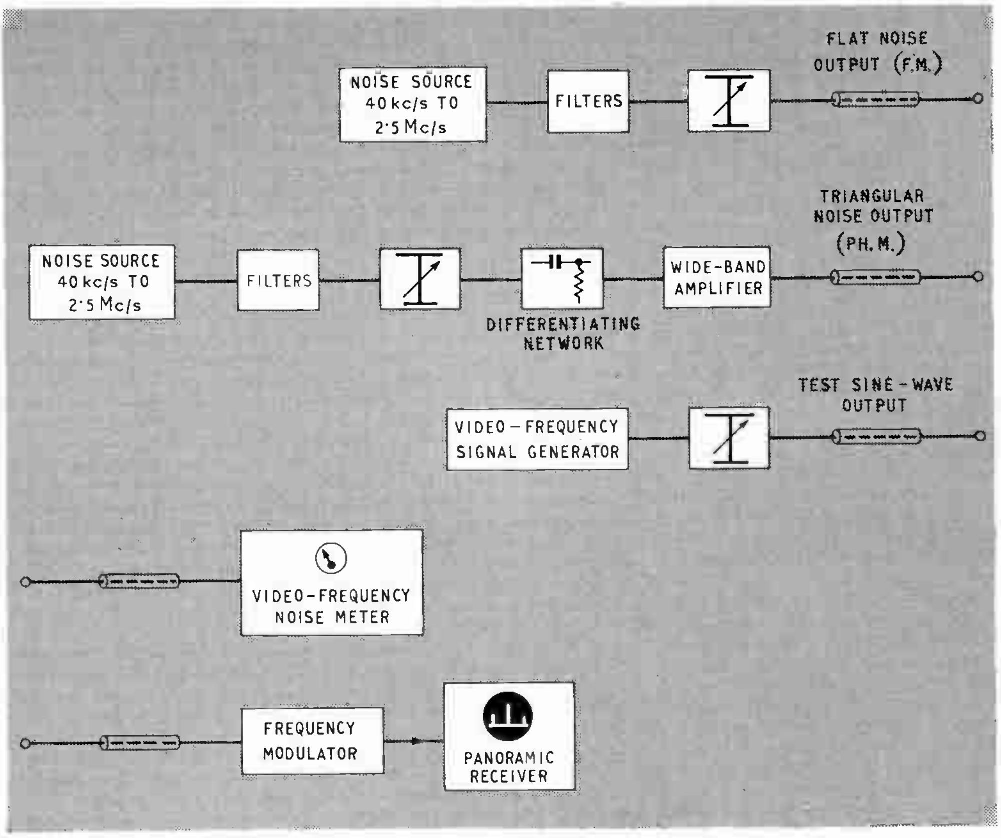


Fig. 1. *Method of setting r.m.s. deviation*

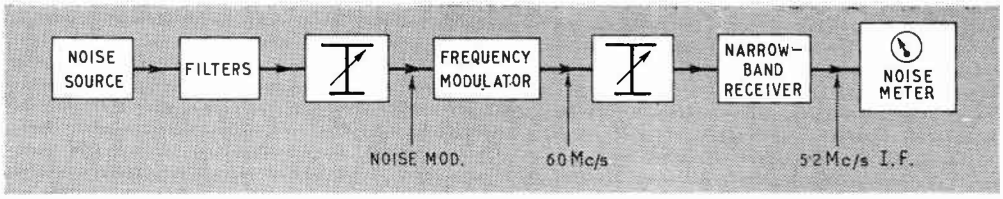


Fig. 2. *F.M. spectra test equipment layout*

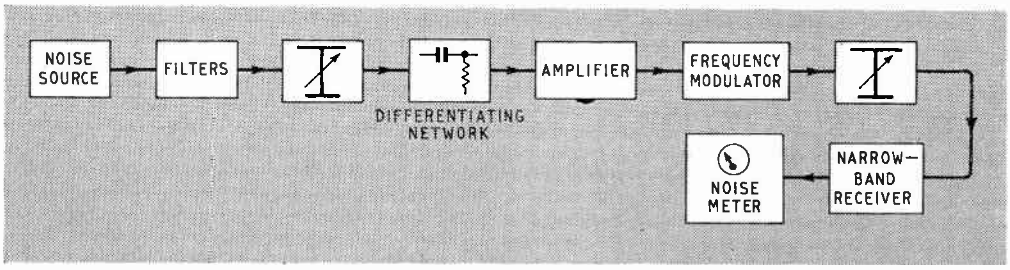


Fig. 3. *Ph.M. spectra test equipment layout*

to the frequency modulator and, at a frequency f_a, the level was adjusted until the carrier component and first-order side frequencies were of equal amplitude. From the well-known Bessel function relation the r.m.s. deviation Δf was then approximately

$$\Delta f = \frac{1{\cdot}43}{\sqrt{2}} f_a$$

(2) The output from the video-frequency signal generator was now measured with the noise power meter, and the reading noted.

(3) The noise source, with the required filters inserted, was next connected to the noise meter, and the level of the noise signal adjusted to the same value as that noted in (2).

The noise signal, when applied to the modulator, then gave the required r.m.s. frequency deviation. The same technique was adopted in setting the phase deviation, the same modulator being used, preceded by a differentiating network. The equivalent r.m.s. frequency deviation, Δf_e, referred to in Section 2, was therefore determined.

A free choice of deviation was possible, within the limits of the modulator, but the modulating signal bands were dependent on available high-grade filters. The lowest frequency of the noise band was limited by the source to about 40 kc/s, which was sufficiently low to be regarded as zero in most of the measurements. Low-pass filters were available with cut-off frequencies of 0·55 Mc/s, 1·05 Mc/s, and 2·54 Mc/s. Thus, neglecting the raising in frequency of the whole noise band by about 40 kc/s, the values of f_n could be taken with very little error as 0·5, 1·0 and 2·5 Mc/s. A high-pass filter with a cut-off frequency of 0·5 Mc/s was used to restrict the noise band when investigating the spectrum with $f_1 \neq 0$.

The spectrum measurements were carried out by applying the output of the modulator to the communications receiver and measuring the noise power in the 25 kc/s i.f. bandwidth of the receiver. The noise power meter was used as a power indicator, the accuracy of the measurements depending on the attenuators in the input to the receiver. The equipment layout for the f.m. measurements is shown in Fig. 2, and that for the ph.m. measurements in Fig. 3.

In investigating the continuous spectra, the power in the i.f. bandwidth was measured at intervals throughout the spectrum band, in decibels relative to the power at the mean carrier frequency. The normalized power density of each spectrum was thus obtained. Also, the power in the known i.f. bandwidth at the mean carrier frequency was measured relative to the full carrier power (with modulation removed). When a residual carrier existed, its power was readily measured relative to the full carrier power.

5. Results of F.M. Spectrum Measurements

Measurements were first carried out to check agreement, as far as possible, with equations (3), (4), (5) and (6), and to establish the limits of their approximate validity. A large number of measurements was then carried out with intermediate values of modulation index.

Confining attention initially to the f.m. spectrum when the r.m.s. modulation index is very small ($m \ll 1$), comparison with theory can be made only when

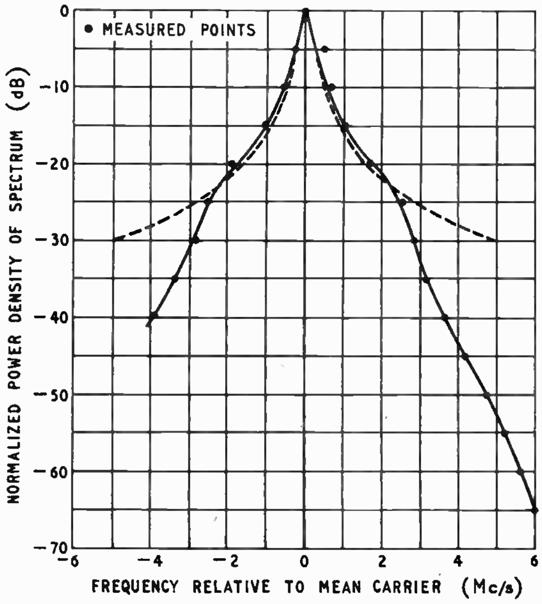


Fig. 4. *Measured f.m. spectrum (normalized power density); $m = 0{\cdot}2$, $\Delta f = 0{\cdot}5$ Mc/s, $f_1 \approx 0$, $f_n = 2{\cdot}5$ Mc/s. Dashed curve theoretical (inverse quadratic equation)*

$m^2/x_1 \gg 1$ or $\ll 1$, as has been noted. It has not been possible to achieve the former condition experimentally, but an approach to it is indicated in the results of Fig. 4. Here, the value of m^2/x_1 is 2·5, and fair agreement with equation (5) [relative to $f_n \,.\, W(0)$] is shown. As m is increased, the measured results approach more closely those applicable when $x_1 = 0$; they cannot then be compared with theory, however, since m ceases to be very small. When x_1 is very small, and $m^2/x_1 \ll 1$ the results should be in close agreement with equation (6), the residual carrier being approximately at full carrier power. This is shown in Fig. 5, where $m^2/x_1 = 0{\cdot}1$ and $x_1 = 0{\cdot}016$. If, with $m^2/x_1 \ll 1$, x_1 is not very small, equation (6) is expected to be a reasonably good approximation; this is shown to be so in Fig. 6, where $x_1 = 0{\cdot}2$.

Fig. 7 shows the results obtained when $m = 1$ and

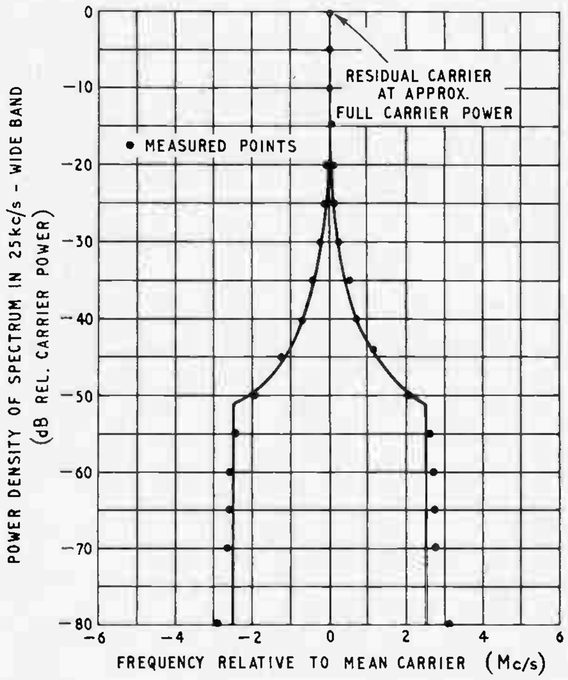


Fig. 5. *Measured f.m. spectrum (normalized power density); $m = 0{\cdot}04$, $\Delta f = 0{\cdot}1$ Mc/s, $f_1 = 40$ kc/s, $f_n = 2{\cdot}5$ Mc/s, $m^2/x_1 = 0{\cdot}1$. Curve theoretical (for $m \ll 1$, $x_1 \ll 1$, $m^2/x_1 \ll 1$)*

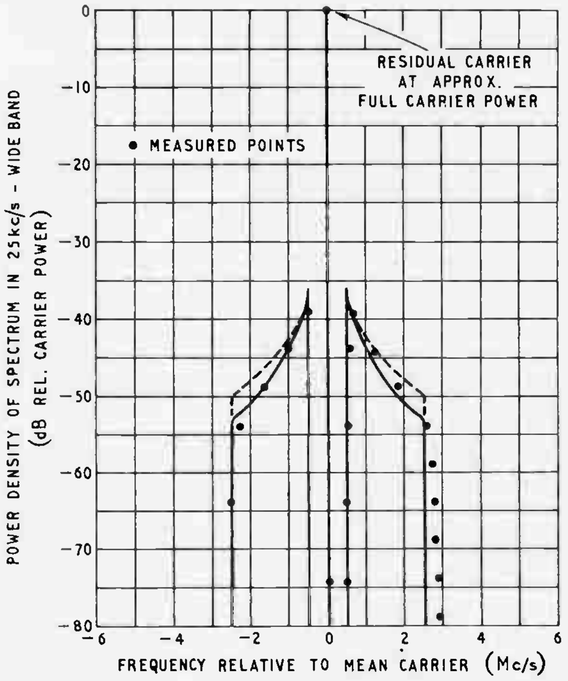


Fig. 6. *Measured f.m. spectrum when $f_1 \neq 0$; $\Delta f = 0{\cdot}1$ Mc/s, $f_1 = 0{\cdot}5$ Mc/s, $f_n = 2{\cdot}5$ Mc/s, $m = 0{\cdot}04$, $m^2/x_1 = 0{\cdot}008$. Solid curve shows estimated true spectrum; dashed curve theoretical (for $m \ll 1$, $m^2/x_1 \ll 1$)*

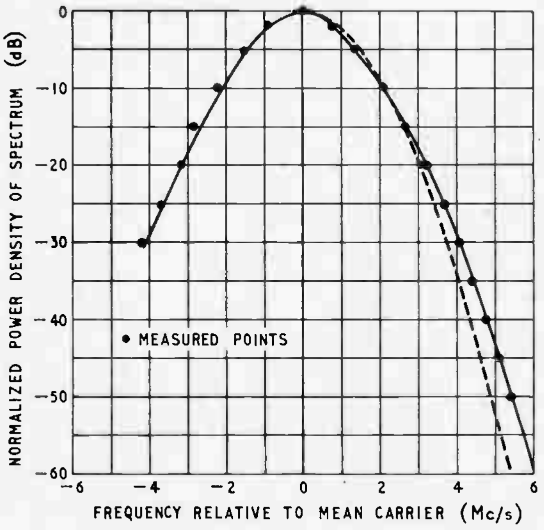


Fig. 7. *Measured f.m. spectrum (normalized power density); $m = 1$, $\Delta f = 1$ Mc/s, $f_1 \approx 0$, $f_n = 1$ Mc/s. Dashed curve theoretical (Gaussian function)*

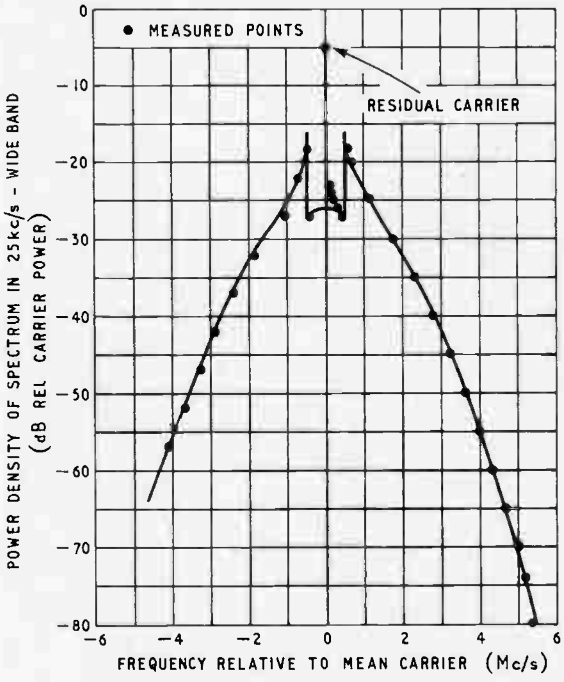


Fig. 8. *Measured f.m. spectrum when $f_1 \neq 0$; $\Delta f = 0{\cdot}8$ Mc/s, $f_1 = 0{\cdot}5$ Mc/s, $f_n = 1$ Mc/s, $m = 0{\cdot}8$ Mc/s. Curve shows estimated true spectrum*

$x_1 = 0{\cdot}04$, and Fig. 8 when $m = 0{\cdot}8$ and $x_1 = 0{\cdot}5$. For $m > 1{\cdot}5$ the spectrum was found to follow the Gaussian function of equation (4) within the experimental error, even with x_1 as large as 0·5.

The results obtained with a modulation pre-emphasis of 6 dB per octave from $\frac{1}{2}f_n$ to f_n are shown in Fig. 9. The spectrum with $m \ll 1$ is a combination of f.m. and ph.m. spectra in the manner expected (curve A), and with $m = 0{\cdot}8$ the nature of the spectrum is shown (curve B). With $m > 1{\cdot}5$ the spectrum was again found to follow the Gaussian function of equation (4).

6. Results of Ph.M. Spectrum Measurements

As in the f.m. measurements, attention was first confined to the spectra with very small and with very large phase deviations.

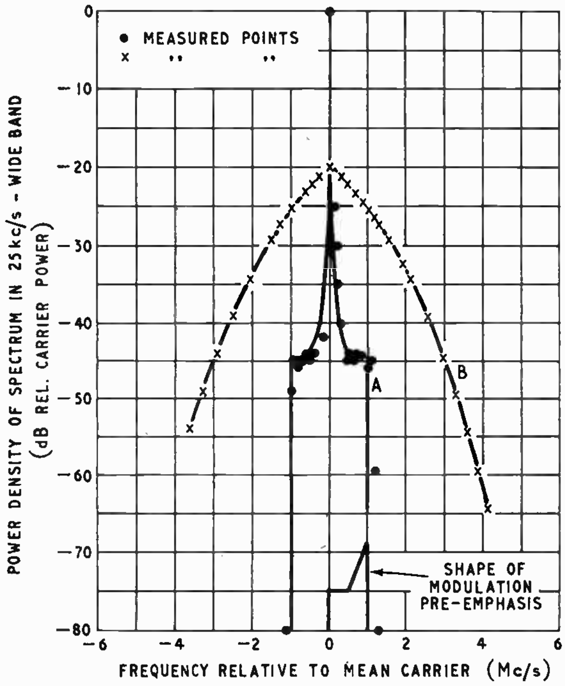


Fig. 9. *Measured f.m. spectrum using modulation pre-emphasis; Curve A,* $\Delta f = 0{\cdot}04$ *Mc/s,* $f_1 = 40$ *kc/s,* $f_n = 1$ *Mc/s,* $m = 0{\cdot}04$*; Curve B,* $\Delta f = 0{\cdot}8$ *Mc/s,* $f_1 = 40$ *kc/s,* $f_n = 1$ *Mc/s,* $m = 0{\cdot}8$*. Curves show estimated true spectra*

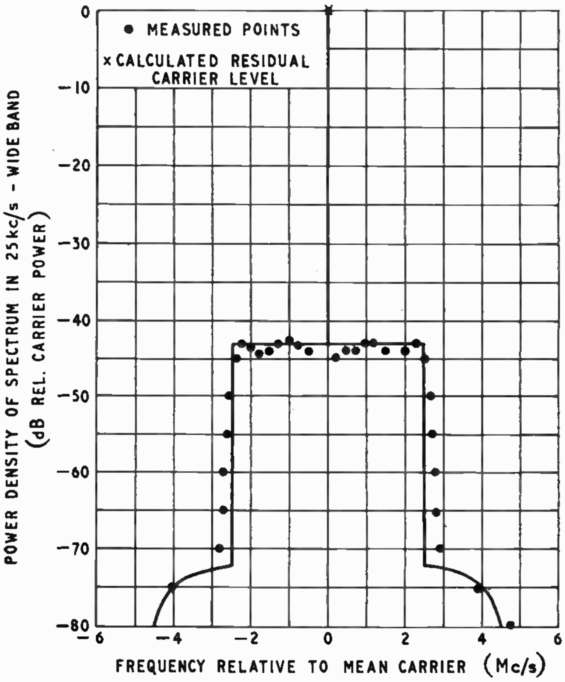


Fig. 10. *Measured ph.m. spectrum;* $\Delta\phi = 0{\cdot}1$ *rad.,* $f_1 \approx 0$, $f_n = 2{\cdot}5$ *Mc/s,* $\Delta f_e = 0{\cdot}14$ *Mc/s,* $m_e = 0{\cdot}058$*. Curve theoretical (after Bosse)*

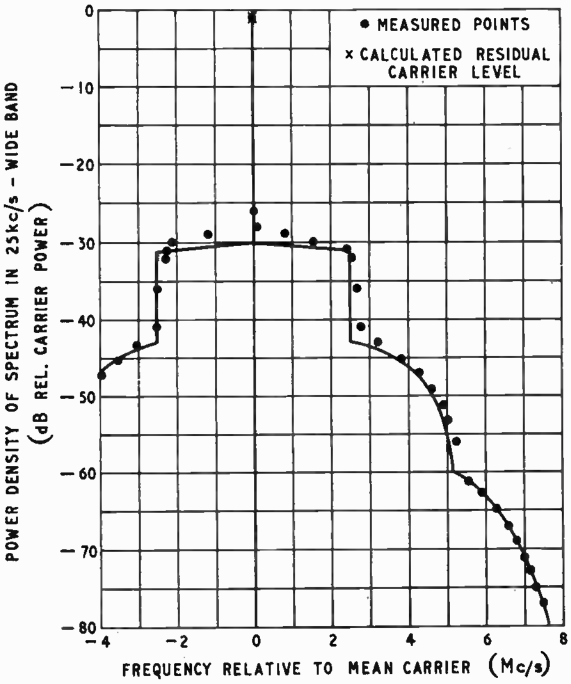


Fig. 11. *Measured ph.m. spectrum;* $\Delta\phi = 0{\cdot}5$ *rad.,* $f_1 \approx 0$, $f_n = 2{\cdot}5$ *Mc/s,* $\Delta f_e = 0{\cdot}72$ *Mc/s,* $m_e = 0{\cdot}29$*. Curve theoretical (after Bosse)*

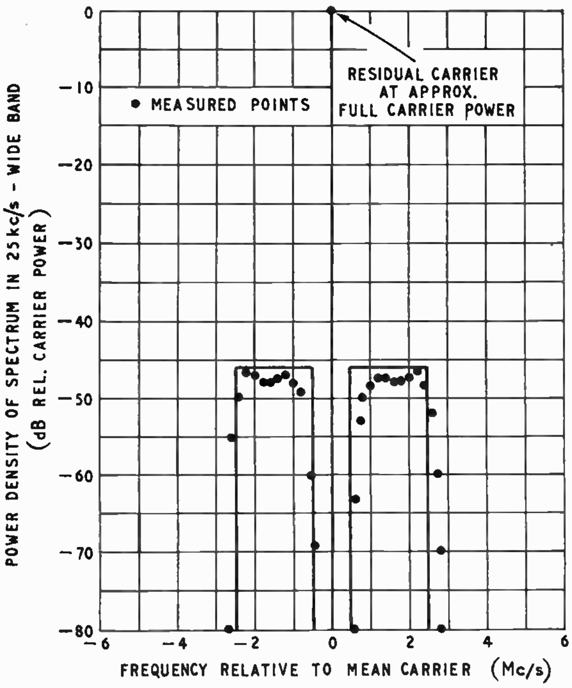


Fig. 12. *Measured ph.m. spectrum when* $f_1 \neq 0$*;* $\Delta\phi = 0{\cdot}07$ *rad.,* $f_1 = 0{\cdot}5$ *Mc/s,* $f_n = 2{\cdot}5$ *Mc/s,* $\Delta f_e = 0{\cdot}1$ *Mc/s,* $m_e = 0{\cdot}04$*. Curve shows estimated true spectrum*

C

When $\Delta\phi \ll 1$, the residual carrier is expected to be at approximately the full carrier power, and the spectrum may be compared with equation (12). The results for $\Delta\phi = 0{\cdot}1$ are shown in Fig. 10. Good agreement is indicated, down to power densities of about 30 dB below the uniform spectrum density. The undulations shown by the measurements over the latter portion are attributable to limitations in the differentiating network and filters.

When $\Delta\phi \gg 1$, the spectrum may be compared with the Gaussian function of equation (10). Close agreement was established for r.m.s. phase deviations greater than 3 radians.

Numerous measurements were carried out with intermediate values of $\Delta\phi$, when x_1 could be regarded as zero, and the results compared with the curves prepared by Bosse. A typical result, for $\Delta\phi = 0{\cdot}5$, is shown in Fig. 11.

When $\Delta\phi$ is very small, and $x_1 \neq 0$, the results may be compared with equation (12), limited to the range $x_1 \leqslant |x| \leqslant 1$. Agreement under these conditions is shown in Fig. 12, where $\Delta\phi = 0{\cdot}07$ and $x_1 = 0{\cdot}2$. When $\Delta\phi$ is very large, the spectrum is expected to follow the Gaussian function of equation (10) even when x_1 is not zero. It was established that this is so for $\Delta\phi > 3$ radians with values of x_1 up to 0·5. At intermediate values of $\Delta\phi$, small undulations were introduced near the mean carrier frequency, otherwise the spectrum corresponded with that obtained when x_1 tended to zero.

7. General Results

The general results established by the methods described are summarized in Tables 1 and 2.

Generalized f.m. noise spectrum curves are shown in Figs. 13 and 14, for the case where the lowest modulating frequency can be assumed to be zero; i.e., when $m^2/x_1 \gg 1$.

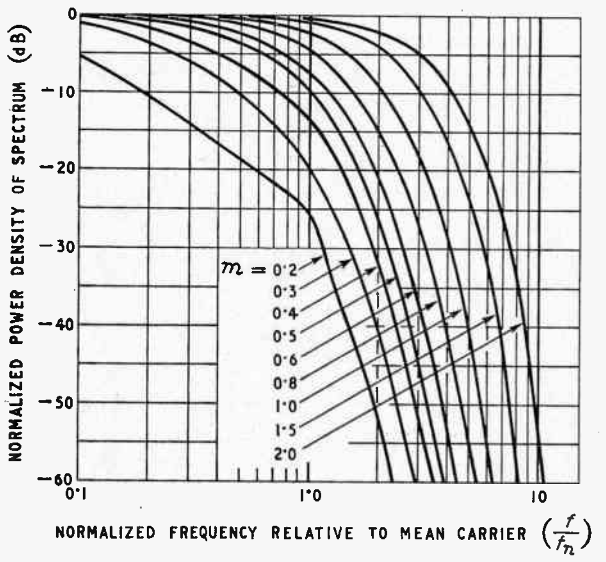


Fig. 13. *Normalized f.m. power spectra (measured). Power density is shown in decibels relative to the power density at the mean carrier frequency. Noise band* f_1 *to* f_n, $f_1 \ll f_n$ *and* $m^2 f_n/f_1 \ll 1$; *r.m.s. modulation index* $m = \Delta f/f_n$ = *r.m.s. deviation*

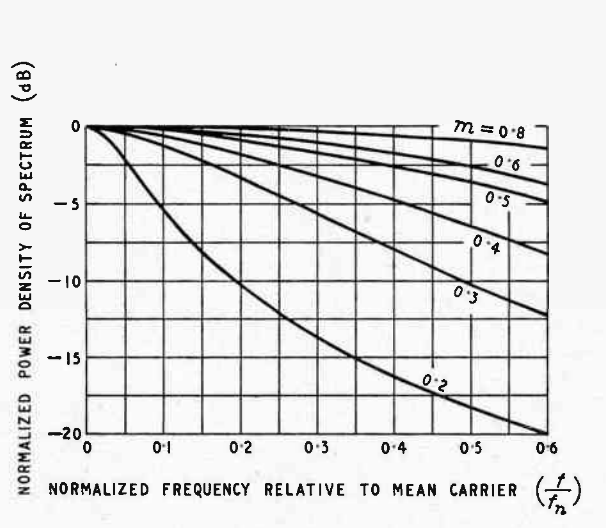


Fig. 14. *Normalized f.m. power spectra (measured). Power density is shown in decibels relative to the power density at the mean carrier frequency.* $m = \Delta f/f_n, f_1 \ll f_n, m^2 f_n/f_1 \ll 1$

TABLE 1—*F.M. Noise Spectra*

r.m.s. mod. index, m	Spectrum when $f_1 = 0$	Spectrum when $f_1 \neq 0$
$m < 0{\cdot}2$	equation (5)	equation (5) if $m^2/x_1 \gg 1$ equation (6) if $m^2/x_1 \ll 1$ residual carrier present [equation (3)]
$0{\cdot}2 < m < 1$	see Figs. 13–15	similar to that shown in Figs. 13–15 if $m^2/x_1 \gg 1$ residual carrier present [equation (3)]
$1 < m < 2$	see Figs. 13–15 approximately Gaussian	approximately Gaussian small residual carrier present [equation (3)]
$m > 2$	Gaussian function of equation (4)	Gaussian function of equation (4) residual carrier negligible

TABLE 2—*Ph.M. Noise Spectra*

r.m.s. phase deviation, $\Delta\phi$	Spectrum when $f_1 = 0$	Spectrum when $f_1 \neq 0$
$\Delta\phi < 0{\cdot}1$	continuous spectrum given by equation (12) residual carrier given by equation (11)	continuous spectrum given by equation (12) over range $x_1 \leqslant \lvert x \rvert \leqslant 1$ residual carrier given by equation (13)
$0{\cdot}1 < \Delta\phi < 0{\cdot}5$	see Fig. 16 residual carrier given by equation (11)	similar to curves of Fig. 16 for $\lvert x \rvert > x_1$ residual carrier given by equation (13)
$0{\cdot}5 < \Delta\phi < 3$	see Fig. 16 residual carrier given by equation (11), approximately	similar to curves of Fig. 16 but with small undulation near mean carrier peaks at $\lvert x \rvert = 1, 2, 3 \ldots$ residual carrier given by equation (13) approximately
$\Delta\phi > 3$	substantially Gaussian [equation (10)] residual carrier negligible	substantially Gaussian [equation (10)] residual carrier negligible

Fig. 15 (*right*). *Power density of f.m. spectra at mean carrier frequency (measured); solid line denotes estimated true curve.* $x = f/f_n$ *where f is frequency relative to mean carrier,* $W(x)$ = *power density of spectrum,* $x_1 = f_1/f_n$

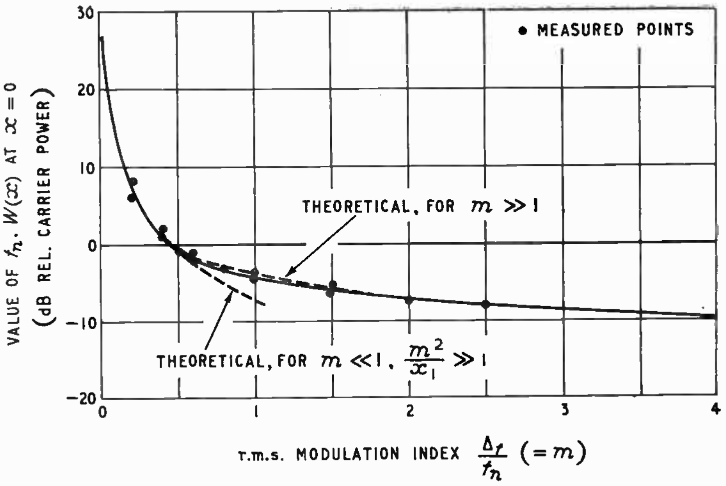
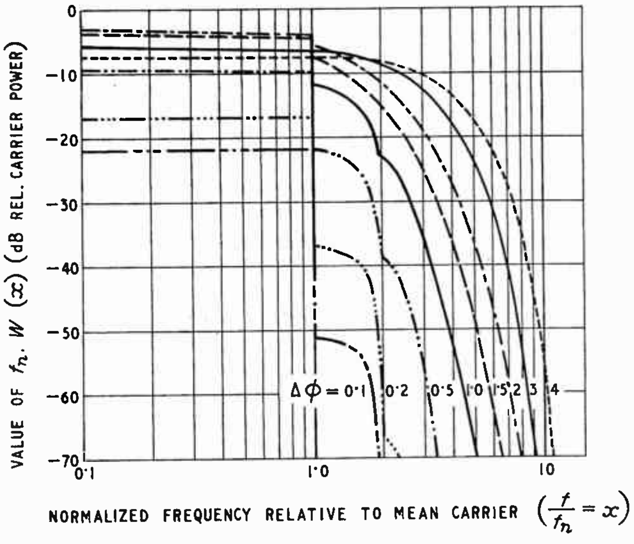


Fig. 16 (*below*). *Normalized ph.m. power spectra (measured).* $W(x)$ = *power density of spectrum,* $f_1 \ll f_n$; *normalized relative frequency* $x = f/f_n$; *residual carrier not shown.* $\Delta f_e = f_n \Delta\phi/\sqrt{3}$, $m_e = \Delta\phi/\sqrt{3}$



The normalized power density of the spectrum, for various values of *m*, is plotted against normalized frequency, f/f_n, on a logarithmic scale in Fig. 13. The detail near the mean carrier frequency is shown in Fig. 14, with a linear scale of normalized frequency. When the actual power spectrum, relative to the carrier power, is required, it is necessary to determine the power density at the mean carrier frequency, $W(0)$. This is given by equation (5) when $m \ll 1$ and by equation (4) when $m \gg 1$, with x set equal to zero in each case. These two equations are shown as curves of $f_n . W(0)$ against *m*, in Fig. 15. The estimated true curve, shown in the figure, may be used to determine the value of $f_n . W(0)$, and hence in any particular case, $W(0)$.

The ph.m. noise spectrum measurements are considered to confirm the theoretical results derived by Bosse, for the case where x_1 can be assumed to be zero. Curves relating the value of $f_n . W(x)$ to the normalized relative frequency are shown in Fig. 16, for various values of $\Delta\phi$. The residual carrier power is not shown, but is readily calculated from equation (11).

Acknowledgments

The authors wish to thank the Engineer-in-Chief of the Post Office for permission to publish this article. The work described was carried out in the laboratories of the Post Office Radio Experimental and Development Branch, and the assistance of Mr. R. W. White in affording the necessary facilities is gratefully acknowledged. The authors also wish to thank Mr. R. G. Wilkinson for the help given in carrying out the measurements.

REFERENCES

[1] D. Middleton, "The Distribution of Energy in Randomly Modulated Waves", *Phil. Mag.*, July, 1951.

[2] L. A. Zadeh, "Correlation Functions and Spectra of Phase and Delay-Modulated Signals", *Proc. Inst. Radio Engrs.*, April, 1951, Vol. 39, p. 425.

[3] J. L. Stewart, "The Power Spectrum of a Carrier Frequency Modulated by Gaussian Noise", *Proc. Inst. Radio Engrs.*, October, 1954, Vol. 42.

[4] G. Bosse, "Die Berechnung des Spektrums bei Vielkanal-Richtfunkverbindungen mit Frequenzmodulation", *Frequenz*, 1953, Vol. 7, No. 8, p. 239.

BIRTHDAY HONOURS

In the Queen's Birthday Honours List, Air-Commodore A. V. Harvey, C.B.E., M.P., a director of Mullard, is created a Knight Bachelor for political and public services.

Air-Marshal R. G. Hart is appointed a Knight Commander of the Order of the British Empire, and Brigadier L. H. Harris, who was for some years Controller of Research at the Post Office before being appointed Engineer-in-Chief in 1954, also becomes a K.B.E.

Group Captain E. Fennessy (Managing Director of Decca Radar) is promoted to C.B.E., and A. T. Black (Director of Electronic Productions [Munitions], Ministry of Supply) is appointed C.B.E.

Among the new O.B.E.s are: E. H. Betts (Deputy Controller, Telecommunications Liaison Group, War Office); Captain K. W. James, R.N. (Ret.) (Senior Chief Executive Officer, Government Communications Headquarters) and Dr. A. R. A. Rendall (Head of Designs Department, B.B.C.). Dr. Rendall is a member of the editorial advisory board of *Electronic & Radio Engineer.*

New members of the Order of the British Empire include: H. D. Bruce (Head of Electronics Application Department, W. H. Smith & Co. Ltd.); W. J. Quill (Chief of Systems design and Planning, Radar Division, Marconi's Wireless Telegraph Co.; A. J. Smith (Chief of Production Control, Commercial Engineering Factory, E.M.I. Electronics) and F. W. Townsend (Experimental Manufacturing Manager, Plessey Company).

"THE VECTORSCOPE"

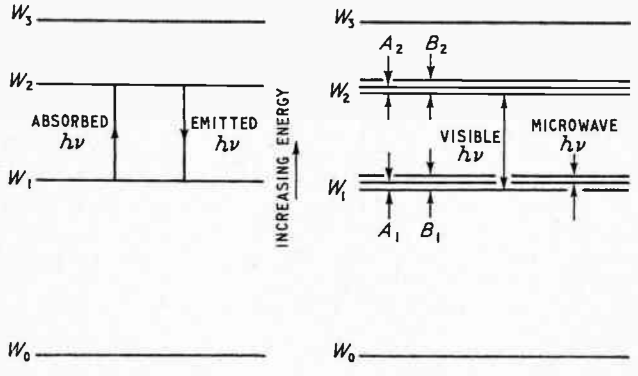
In this article, which appeared in the June issue, the blocks on page 203 were transposed. Fig. 8 should be Fig. 9, and vice versa.

The Fringe of the Field **By Quantum**

MOLECULES AND MICROWAVES

The principle of the molecular amplifier, or generator, of microwave radiation is ultimately that of the sodium flame, the mercury-arc, or any other atomic or molecular source of one or more monochromatic beams of radiation. There is, indeed, a good deal in common with the experiments of Horton and Davies, Franck and Hertz, and the others who succeeded about forty years ago in relating the quanta of energy absorbed by various processes, the quanta of radiation subsequently emitted, and the mechanism by which the atoms stored the quanta in their excited state in the meantime. If I start by talking about visible light rather than microwaves, there is good precedent ; for much of the basic work on the principles of optical spectroscopy was in fact done in a different energy range, the ultra-violet. And it may turn out to be useful after all, for in some cases microwave emitters are excited by supplying energy in the form of visible radiation.

In every case involving monochromatic radiation by an atom (or molecule), at least two energy states W_1 and W_2 are involved [Fig. 1(a)]. Absorption of energy $(W_2 - W_1)$ raises the atom from the lower to the higher 'excited' state. In due course, after a short lifetime in the higher state, it reverts to the lower state emitting energy $(W_2 - W_1)$ as a quantum of radiation of frequency ν, where $(W_2 - W_1) = h\nu$. Other states may be concerned—for example, the initial excitation may have been from a lower level W_0 to W_1, or W_2 may have been reached by radiating $(W_3 - W_2)$ from a higher level W_3, but this simply means that more than one monochromatic emission can happen. (The word 'state' is here used of the molecule as a whole, and 'level' to indicate the energy which changes when the state changes.) The energy *absorbed* on the upward journey comes from thermal-agitation collisions, electronic or ionic collisions, incident radiation of the right frequency, or all three together (when there is some latitude about the frequency) ; and some of the atoms will derive it by absorbing a quantum emitted by a neighbour.



(a) (b)

Fig. 1. *Energy levels and radiation quanta ; (a) levels associated with visible radiation, W_1 and W_2 separated by about 2 eV ; (b) levels associated with microwave radiation, A and B in the fine-structure of W separated by about 10^{-6} to 10^{-7} eV*

The energy emitted is nearly always in the form of a quantum of the definite frequency ν, subject to a slight spread depending on the conditions, and it is observed as a single spectral line in the ordinary sort of spectroscope. For the mercury green line 5461, the energy $(W_2 - W_1)$ is of the order of 2 electron-volts, and ν is about 5×10^{16} c/s. ; it is always accompanied by other lines, which we could often do without, most of them from larger level differences up to about 10 electron-volts. Transferring this kind of process to the microwave region is simply a matter of finding something with a pair of energy levels which differ by about a millionth or less of the differences for visible radiation (for 10^{10} c/s this is about 4×10^{-7} electron volts), and encouraging the excited molecules to deliver their radiation in the right place. Also, it is desirable not to have matters cluttered up with numerous other pairs of levels in the same range, so that the right substance has to be selected with care.

A high resolution optical spectroscope shows that spectral lines are not strictly monochromatic. First, [Fig. 1(b)] they possess a 'fine-structure', which shows that W_1 and W_2 are really groups of levels W_1, W_1+A_1, $W_1 + B_1$, . . . and W_2, $W_2 + A_2$, $W_2 + B_2$ . . . where all the A, B . . . are energies relatively small compared with the W terms. If, for example, A_1 and B_1 differ by about 10^{-7} eV or so, and *if transitions between the states $W_1 + A_1$ and $W_1 + B_1$ are possible*, then the quantum involved in going from one to the other will be of microwave frequency. Indeed, the determination of such very finely separated levels belongs to microwave or even r.f. spectroscopy. But the optical spectroscope can show that the levels are there, for if the source is in a strong magnetic field, or in a strong electric field, the differences $A, B, \ldots$ are accentuated, and the fine-structure becomes an elaborate observable pattern. The electric-field increase in the separation of adjacent levels, actually making the lower still lower, and the higher still higher, is called the Stark effect, and it is one of the ways used to separate out molecules in the two different states.

Quantum numbers, the origin of the multiplet levels, and the reason for the Stark splitting, are too much to go into now ; but it should be said that separations of the right order are available in gaseous polyatomic molecules, and in the electron-spin levels in both solids and gases.

Next, the lines have a finite breadth, denoted by $\Delta\nu$, which usually means the spread between the frequencies on either side at which the intensity is half the maximum value. There is a natural limit to the sharpness of all spectral lines, set by the uncertainty principle. If Δt is the mean lifetime of a molecule in the excited state and $\Delta\nu$ the frequency spread, then $\Delta\nu \cdot \Delta t = 1$. But this breadth is very much less than the more or less controllable broadening due to the independent effects of temperature and pressure.

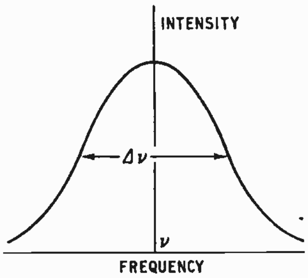


Fig. 2. *Intensity pattern of spectrum line, showing what is usually meant by the width* $\Delta\nu$

The high-pressure mercury-arc run at full power is a good example of how *not* to get sharp lines, for these 'lines' appear as quite broad bands, with an intensity structure more or less as Fig. 2. At high temperatures, the spread of molecular velocities gives a Doppler effect broadening (which was incidentally first observed and explained by Stark) for which $\Delta\nu$ is proportional to the square root of the absolute temperature. At high pressures, there is 'collision broadening', due to the interruption of the radiation by the collisions of molecules with one another. Although the theory of this is complicated, if we were to regard the interval τ between collisions as setting an upper limit to the excited lifetime, we should expect on uncertainty grounds to find $\Delta\nu$ proportional to $1/\tau$, as indeed it is ; and some simple kinetic theory shows that $1/\tau$ is directly proportional to the pressure of the gas. Thus, for sharply defined monochromatic radiation (if that is what is indeed required, though a narrow bandwidth limits the performance of a microwave amplifier), the temperature must be low and the gas pressure almost indistinguishable from a pretty high vacuum, which means that there will be little power available to play with.

From the power aspect, therefore, the whole business of gaseous molecular amplification looks unpromising from the outset, for all that has been said about lines in the visible mercury spectrum applies to microwaves. But the limitations imposed by thermal agitation apply less forcibly to solids, and a good deal of progress has been made in applying the *principles* so far outlined to the solid state. The article by J. P. Wittke in the March 1957 number of *Proc. I.R.E.* from which I have taken most of my information, and a short article by S. Weintroub in *Nature* for 4th May 1957, draw attention to developments proceeding in this field. But gases are enough to be going on with for the moment.

There is a further effect, not peculiar to gases, which limits the power that can be absorbed. Only molecules in the lower state can absorb radiation, and each excitation reduces the molecules available to be excited. Unless molecules are able to emit radiation, or lose energy by collision, to replenish the lower state as fast as they are promoted, the power absorption falls off, and the breadth of the *absorption* line increases. This is called power saturation ; it is relevant to molecular-beam devices, although there is little power about anyhow. It is the largest of the frequency-spreading effects as a rule, and is probably the most important limiting factor in the general application of molecular processes to power amplification.

The Ammonia "(3,3)" Resonance

Ammonia is one of the substances fulfilling the requirement of two sharply-defined energy levels unaccompanied by others in the same range. The inversion of the NH_3 molecule, in which the N atom may be at about $3{\cdot}6 \times 10^{-9}$ cm above or below the plane of the three H atoms, and can change from one position to the other, provides two energy levels differing by about 2×10^{-7} eV. It is difficult to see in simple terms how this happens, for the two states, each the mirror image of the other, are equally stable, and are states of equal energy ! The N atom oscillates spontaneously between the two configurations (a) and (b) of Fig. 3, distending the H triangle slightly on the way through ; and the frequency of oscillation is about 2×10^{10} c/s. Since ammonia absorbs radiation of this frequency strongly, and excited ammonia molecules radiate this frequency, perhaps we ought just to be satisfied, for obviously a pair of convenient energy levels have been inserted somehow.

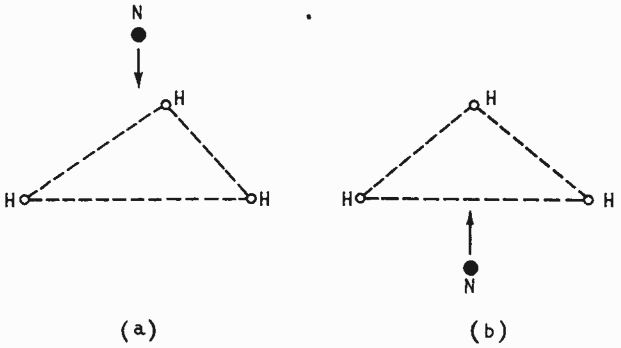


Fig. 3. *The two configurations, (a) and (b), of the ammonia molecule* NH_3*, involved in the (3,3) resonance line at about* 2×10^{10} *c/s. They are equally stable, and of equal energy, yet the change from one to the other absorbs (or emits) a quantum of radiation of this frequency*

It is profitless to try to say in terms of Fig. 1 which of the two is the higher and which the lower state ; but it is helpful at least to know that neither of them can be in *both* states. There is a quantum-mechanical explanation, which shows that a system which has two equal potential minima does by some abstruse mathematical interaction between the wave-functions for the two configurations produce the effect of two separate energy states. But, in any case, the exclusion principle would lead us to expect that a given molecule cannot have two energy states which are both *at the same time* exactly the same. Therefore, (a) may be either an excited or an unexcited state, but not both at once ; and the same holds for (b). But although the drawings may not help us to distinguish the states, the molecules themselves give the show away by their behaviour. Excited molecules are those which will change by radiating, unexcited ones those which will change by absorbing the appropriate quantum. And the Stark effect, which widens the energy difference between the two states by the interaction of the molecule's dipole moment with a strong electric field, will sort them out if the field is inhomogenous, for the excited molecules move towards the weaker region and the unexcited molecules towards the stronger region of the field.

The term "3,3" is to distinguish this resonance from other flip-flop inversions of the molecule ; it stands for the levels involved. I have not done justice to the ammonia molecule I know. It was the earliest example giving a microwave resonance, and has been studied and used in one way and another since 1934. But its importance does not make it any easier to explain ! A full and very clear account, which may be more helpful, is given in Chapter 21 of A. R. von Hippel's "Dielectrics and Waves" (John Wiley and Sons).

The Molecular Beam Maser

Molecular amplification by stimulated emission of radiation (maser for short) is the object and name of the molecular beam device of Gordon, Zeiger, and Townes* (Fig. 4). A beam of ammonia molecules issues through fine slits into a high vacuum, where it passes through the Stark effect focuser, and thence to the resonant cavity coupled to waveguides. The focuser has alternate electrodes at high positive and low negative voltages, giving zero field along the axis and a strong field near the electrodes. Excited molecules are thus driven towards the axis, whence they travel on to radiate, and unexcited molecules are pulled clear of the beam. This method of focusing is standard microwave technique, but its use actually to transfer power makes one wonder for a moment. It looks suspiciously like Maxwell's demon in disguise—in sorting molecules out *to make use of them* is it taking liberties with the Second Law of Thermodynamics ? It is, of course, decreasing the entropy of the ammonia beam, but in the most law-abiding and orthodox manner ; for the Stark effect is furnishing the energy to do it.

The 'ser' part of 'maser' takes place in the cavity, where the excited molecules are triggered off to radiate by the action of microwave radiation of frequency ν which is fed into the cavity by a waveguide. This is not absorbed by the molecules ; it merely stimulates them to emit their own radiation, which reinforces it. If losses are low enough, or the beam density sufficient to provide power exceeding the losses (which is the same thing), oscillations (subject to power saturation limitation) can be maintained by feeding the output back to the input waveguide. In these circumstances the maser acts as an amplifier of infinite gain.

This arrangement, fulfilling all the requirements for a very small $\Delta\nu$ (it is, in essence, simply the 'ammonia clock' frequency standard) has a bandwidth of about 6 kc/s, handles about 10^{-10} watts, and gives high gain and very low noise. Since, at very low pressures, the mean free path of the molecules exceeds the distance they have to travel, collision broadening is absent. The corresponding τ is the time taken to tranverse the apparatus. The bandwidth $\Delta\nu$ could be increased by reducing τ, either by shortening the apparatus, or by raising the temperature which increases the molecular speed.

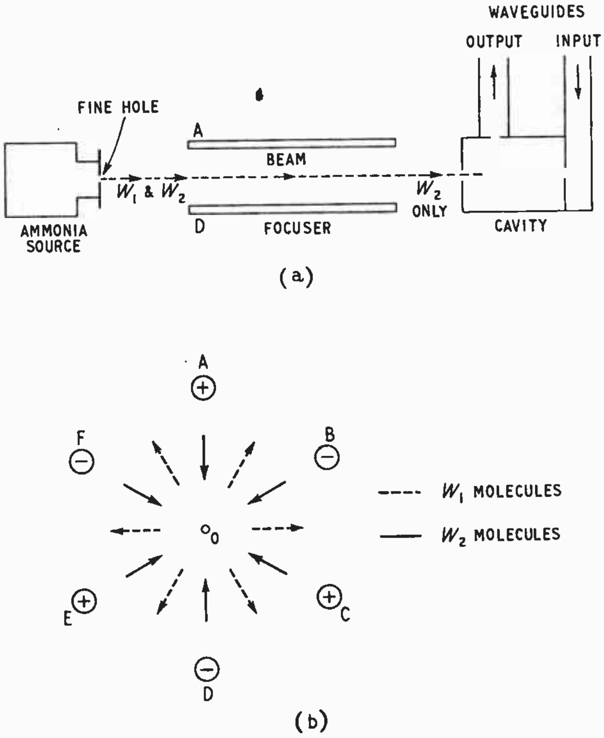


Fig. 4. *(a) General arrangement of the maser molecular-beam amplifier, as given in an article by C. H. Townes.† The space between source and cavity (all in fact, except the source) is highly evacuated. (b) End-on view of the Stark-effect focuser ; alternate electrode rods are at positive and negative potentials ; A and D are also shown in (a). The field at the axis 0 is zero, increasing towards the electrodes. Molecules in the two states move as indicated by the arrows*

State Separation in General

From a general point of view, decreasing the entropy of the ammonia beam is a disturbance of thermodynamical equilibrium, just like igniting the charge in an engine cylinder, and with the same end in view. Apart from the power-scale (which has already been noted !) and the different order of the energy also, the chief difference is that there are only two energy states to consider, instead of very large numbers. The mathematics of the kinetic theory, and the Maxwell-Boltzmann law for energy distribution, can thus be taken over bodily with this important simplification. (In some maser devices, more than two states are involved, but still only a few.)

In any system in equilibrium, the number of molecules N_1 in state 1 with energy W_1, and the number N_2 in state 2 with energy W_2 (where $W_2 > W_1$) have definite values, equilibrium being maintained because the rate of transfer between the two is the same both ways.

The ratio N_2/N_1 is given by $N_2/N_1 = e^{-(W_2-W_1)/kT}$

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* *Phys. Rev.*, Vol. 99, 15th August 1955

† "Recent Advances in Science", (New York University Press, 1956)

from which, since $W_2 > W_1$, $N_2 < N_1$, so that in equilibrium the lower state is always the more densely populated.

If there are only two such states, then $N_1 + N_2 = N$, the total number of molecules. And, if the transfer takes place by radiation of frequency ν, then $(W_2 - W_1) = h\nu$, and $N_2/N_1 = e^{-h\nu/kT}$
or, approximately, by rearranging,

$$\frac{N_1 - N_2}{N} = \frac{h\nu}{2kT}$$

The first thing the maser does is to try to upset the equilibrium and increase N_2 at the expense of N_1, by supplying energy. Its action in merely discarding the lower-state molecules is in effect a rather inefficient way of doing this, but there are other ways. For example, in the method of 'optical pumping', a suitable gas is irradiated by *plane-polarized light*, so that a molecule is raised from W_1 to a state far above either W_1 or W_2; the selection rules governing possible changes between states by radiation forbid some and allow others according to the state of polarization and, when the return is made by emitting ordinary light, the molecule can return only to W_2 instead of W_1. Obviously, a good deal of cunning is needed to seek out levels with just the right energy difference, and just the right selection-rule differential. Another method, suggested by the equation for N_2/N_1, is simply to increase T. The 'hot-grid' amplifier has one wall of a rectangular waveguide hotter than the other, with a high-potential grid close to it which applies the Stark effect on the heated molecules to return chiefly those with W_2 to radiate in the waveguide. Pulsed modulated radiation, sweeping through the frequency ν in a time shorter than the excited lifetime ('adiabatic fast passage'), is yet another way. Or again, using the standard paramagnetic resonance technique, the d.c. magnetic field can be changed adiabatically through its resonance value. At the emitting end, however, all really do the same thing in extracting the energy emitted as the system endeavours to return to the unsorted equilibrium distribution between N_1 and N_2. Far from attempting to circumvent the Second Law of Thermodynamics, in fact, all the processes are excellent illustrations of the application of the Law, when looked at from that point of view. They want looking at rather carefully, perhaps, and may make us wonder whether we really understand some of the thermodynamics that we always take for granted. This side of things has been examined thoroughly by N. F. Ramsey, whose discussion I hope to get on to in next month's article.

Push-Pull 'Magic Eye' Tuning Indicator

A 'MAGIC EYE' with a push-pull deflection system and a pair of built-in triodes has been developed in Germany. The valve is used in circuits like that of Fig. 1, with input voltages balanced to earth.

The sideways deflection of the electron beam is proportional to the difference between the input voltages in both magnitude and direction. The width of the beam gives an indication of the magnitude of two equal input voltages.


(a) (b) (c)

Fig. 2. *Mask for E82M, showing patterns obtained with equal and unequal inputs to the control grids*

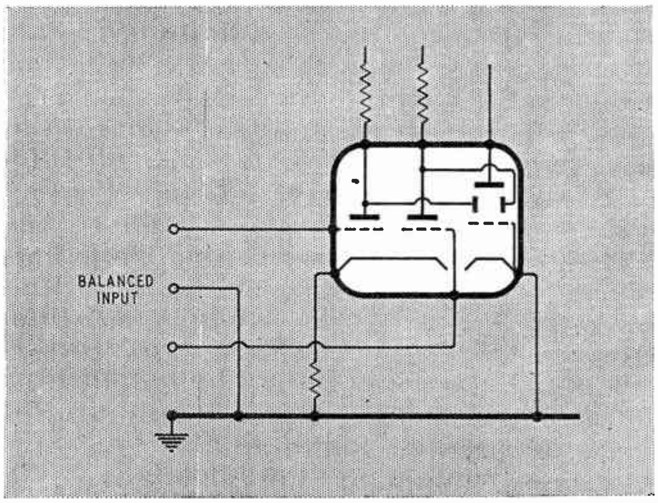

Fig. 1. *Typical circuit using the new 'magic eye' valve*

The beam of the new valve (type E82M) is of rectangular cross-section, and strikes a fluorescent screen deposited on the inside of the glass envelope. Various masks have been devised for use with the valve in different applications. That of Fig. 2 (a) is useful for balance indication, the balanced condition producing a pattern as Fig. 2 (b), and an unbalance of one polarity as Fig. 2 (c).

Suggested applications for the E82M are as a bridge balance indicator, as a tuning indicator in f.m. receivers, for voltage comparison, and as an Eccles-Jordan binary stage which gives a visual indication of its state.

(Described in *Philips tech. Rev.*, Vol. 18, No. 8, pp. 243–5.)

Transistors in High-Frequency Amplifiers

By **W. Guggenbühl, D.techn.Sc. and M. J. O. Strutt, D.techn.Sc., D.Eng.(Lond.), F.I.R.E.***

SUMMARY. *The properties of transistors and their behaviour in amplifier stages in the high-frequency region (i.e., the region of complex parameters) are dealt with. The first part considers the physical reasons for the frequency dependence of transistor parameters. The representation of these effects in the common-emitter equivalent circuit is shown. In the second part, the formulae for the maximum gain in common-emitter stages are presented, and the stability of h.f. amplifier stages is discussed. Data on noise behaviour of the h.f. amplifiers are given for the design of input stages. The last section deals with the problems arising from the extension of the frequency range of transistors. The various proposed solutions of these problems are compared.*

Transistor amplifier design based on calculations with real values of matrix elements is restricted to relatively low frequencies only. It has been shown that the power gain of typical low-frequency transistors may be frequency-dependent above only a few kilocycles[1]. To some extent this frequency dependence may be avoided by proper circuit design. Furthermore, this limit is much higher for modern high-frequency transistors than it is for the earlier low-frequency types. In many cases, however, one is forced to use transistors at frequencies where the gain decreases with increasing frequency[2]. This may be seen from Fig. 1, which shows the optimal-attainable power gain of the earthed-emitter circuit for typical low-frequency and high-frequency transistors.

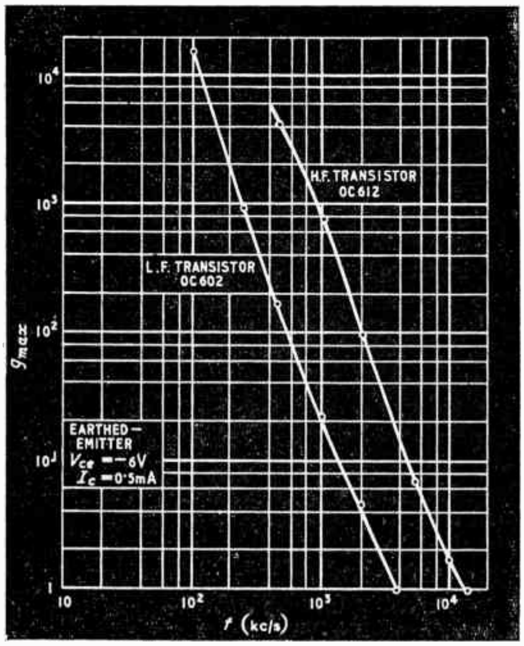

Fig. 1. *Optimal power gain* g_{max} *of transistor selective amplifiers versus frequency f. Transistors* OC602 *and* OC612 *in earthed-emitter connection* (*Ref.* 2)

It follows from these gain-versus-frequency curves that the amplifier stages of broadcast receivers operate partly in this region of frequency-dependent transistor parameters. The detailed calculation of such high-frequency stages is very extensive and the results are not easy to survey. This paper gives a review of the qualities of high-frequency transistors and of the various problems which arise in using them in circuits.

1. Causes of Frequency-Dependence

1.1. *Charge Storage in the Base Region*

An alternating voltage applied to the emitter of a junction transistor causes a periodical change of the free-carrier concentration distribution in its base region. This charge storage effect arising during each cycle of the voltage is one of the main causes for the frequency-dependence of junction transistor properties. This is explained in Fig. 2, as follows:

A distribution curve[3] for the carrier concentration p in the base region of a p-n-p transistor at a d.c. emitter current I_e is drawn in Fig. 2(b). This concentration curve may be calculated from W. Shockley's equations for a junction transistor[4]. An increase of the current by ΔI_e involves an increase in the carrier concentration. The distribution curve in the base region for this higher current $I_e + \Delta I_e$ is also drawn in Fig. 2(b). Therefore, an increase of the current I_e is only possible if the charge represented by the hatched area has been fed to the base region. When the concentration of holes increases, the number of free electrons must increase too, due to the neutrality condition for electric charges in the base region. The holes for the storage charge are fed by the emitter, the electrons mainly by the base contact. The practical effect of this charge storage on the high-frequency behaviour is characterized chiefly by the frequency dependence of the short-circuit current amplification factor α. This α is defined as the quotient of the alternating currents i_c/i_e of a transistor in the earthed-base connection with a short-circuit applied to the

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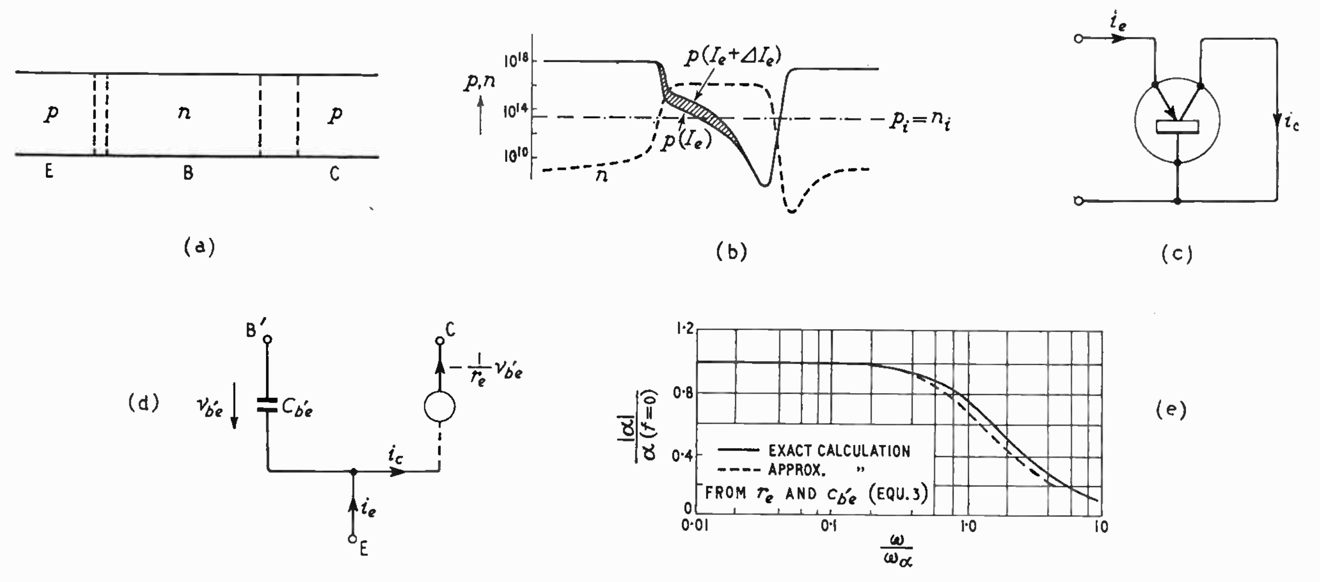

Fig. 2. *Charge storage in the base region and its influence on frequency behaviour of a transistor. (a) Transistor geometry with depletion layers. (b) Distribution of free carrier density in a junction transistor at two currents I_e and $I_e + \Delta I_e$; p = density of holes, n = density of electrons. (c) Definition of short-circuit current amplification factor: $\alpha = i_c/i_e$ in an earthed-base transistor. (d) Equivalent circuit for the hole transport through the base region of an ideal junction transistor in earthed-emitter connection. Hole storage is represented by the capacitance $C_{b'e}$. (e) Short-circuit current-amplification factor $|\alpha|$ versus frequency (calculated) in the earthed-base connection*

output terminals [Fig. 2(c)]. If recombination in the base region, as well as the majority-carrier content of emitter and collector current (electrons in p-n-p transistor) are neglected, the frequency dependence of α may be explained as follows:

An alternating voltage $v_{b'e}$ applied between base B′ (B′ = intrinsic base) and emitter E causes an alternating current i which passes through the emitter and the collector contact. Its magnitude is restricted by the diffusion process of the minority carriers through the base region. This obstruction to the carrier motion may be represented by a resistance r_e. In the equivalent circuit of the transistor in the earthed-emitter connection, this current i due to a voltage $v_{b'e}$ may be represented by a current source of intensity:

$$i = -\frac{v_{b'e}}{r_e} \quad \cdots \quad (1)$$

between emitter and collector [Fig. 2(d)]. The diffusion resistance is given by the equation[4]:

$$r_e = \frac{kT}{eI_e} \quad \cdots \quad (2)$$

In this equation k is the Boltzmann constant, T the absolute temperature, e the magnitude of the electron charge, and I_e the direct emitter current. This current i is accompanied by a capacitive current between emitter and intrinsic base, which delivers the charge, necessary for the 'charge storage' described above, to the base region. The charge storage is represented by the capacitance $C_{b'e}$ in the equivalent circuit of Fig. 2(d). If the magnitude of the emitter alternating current has a constant value, the base to emitter voltage $v_{b'e}$ decreases with increasing frequency due to the capacitance $C_{b'e}$. According to $i_c = -v_{b'e}/r_e$, the collector alternating current decreases as well. Therefore the magnitude of the current amplification factor α decreases with increasing frequency. According to Fig. 2(d), the frequency dependence of α is given by the equations

$$\left.\begin{aligned} -i_e &= j\omega C_{b'e}\, v_{b'e} + \frac{1}{r_e}\, v_{b'e} \\ -i_c &= v_{b'e}/r_e \\ \alpha &= \frac{i_c}{i_e} = \frac{1}{1 + j\omega C_{b'e}\, r_e} \end{aligned}\right\} \quad \cdots \quad (3)$$

The frequency at which the magnitude of α has decreased by 3 dB compared with its low-frequency value is called the α–cutoff frequency f_α. From Equ. (3) one finds:

$$f_\alpha = \frac{1}{2\pi\, C_{b'e}\, r_e} \quad \cdots \quad (4)$$

The representation of the diffusion process in transistors by lumped circuit elements is not quite exact. In a complete equivalent circuit this process would have to be represented by distributed circuit elements, similar to a transmission line. The difference between the α versus frequency curve calculated from the exact equivalent circuit with distributed elements and from the simplified lumped circuit according to Fig. 2(d) is represented in Fig. 2(e). The agreement of the two curves is satisfactory up to f/f_α ratios of about 2.

The capacitance $C_{b'e}$ may be evaluated by integration of the total minority-carrier charge stored in the base region, when a direct voltage $v_{b'e}$ is applied between intrinsic base and emitter. From this charge Q, the capacitance $C_{b'e}$ is calculated by differentiation: $C_{b'e} = dQ/dv_{b'e}$. According to Ref. 5, the value of $C_{b'e}$ is:

$$C_{b'c} = \frac{dQ}{dv_{b'e}} = \frac{eI_e w^2}{2kTD_p} \quad \cdots \quad (5)$$

In this equation w is the base width and D_p the diffusion constant of the holes in the base region of a p-n-p

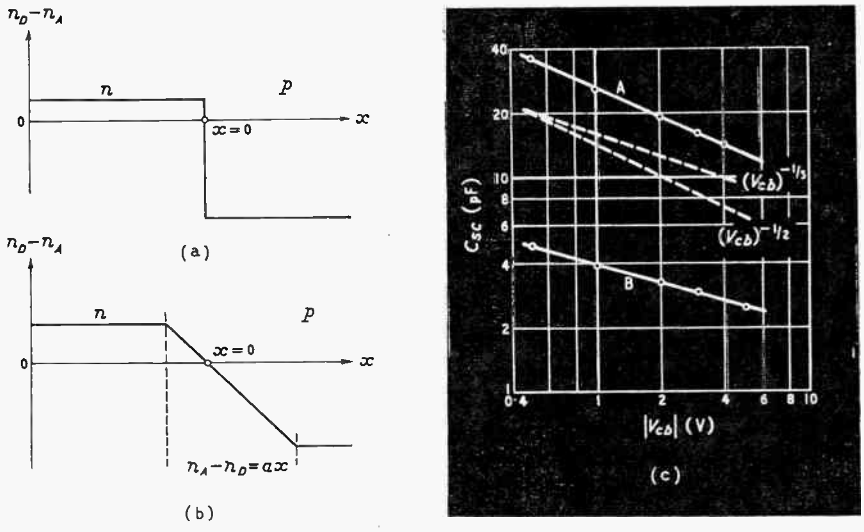

Fig. 3. (*a*) *Density of* n_D–n_A *(schematic) as a function of linear distance in an abrupt p-n junction (step-junction)* n_D = *density of donors,* n_A = *density of acceptors.* (*b*) *Density* n_D–n_A *in a graded p-n junction with linear transition from p- to n-material.* (*c*) *Depletion layer capacitance* C_{sc} *of some transistor collector-junctions as a function of collector voltage* V_{cb}. *Curve A for* 2N137 (*p-n-p alloyed*), $|I_e| = 1$ *mA and curve B for* 2N78 (*n-p-n rate grown*), $|I_e| = 1$ *mA*

transistor. From Equs. (2), (4) and (5) we conclude:

$$f_\alpha = \frac{1}{2\pi} \cdot \frac{2D_p}{w^2} \qquad \text{.. .. .. ..} \qquad (6)$$

where f_α is the α–cutoff frequency. Since D_p is a physical constant, f_α can only be improved by decreasing the base width of the transistor.

1.2. *Depletion Layer Capacitance of the Collector Junction*

In the theory of diffusion transistors*[4], it is stated that there is no electric field in the homogenous regions of the semiconductors (emitter, base and collector regions). The total potential drops corresponding to the applied terminal voltages are located in the depletion layers (i.e., in the direct neighbourhood of the junctions between the n- and p-materials). It has been shown that in these regions of high electric-field strength the neutrality condition for the electric charges is not satisfied. The depletion layers contain only a few mobile carriers and the donors and acceptors fixed in the crystal lattice produce space-charge regions. The thickness of these regions is altered by a variation of the applied terminal voltages; i.e., mobile carriers are supplied to the junctions to neutralize part of the space charge or they are extracted from the junctions so as to extend the depletion layers. This storage effect may again be represented in the equivalent circuit by a capacitance, the so-called depletion-layer capacitance across the junction under consideration. Since the charge associated with this storage effect is much smaller than the stored charge in the base region mentioned in Section 1.1, only the depletion-layer capacitance of the collector junction need be considered in the equivalent circuit. The magnitude of this capacitance is dependent on the type of transition of the impurity concentration from p- to n-material. With a good approximation an alloyed junction can be described by a step junction [abrupt transition from p- to n-material, see Fig. 3(a)]. The depletion layer capacitance of a step junction is given by:

$$C_{se} = A\frac{1}{2}\sqrt{\frac{2\,\epsilon\, e\, n_D}{V'}} \qquad \text{.. .. ..} \qquad (7)$$

In this equation A is the contact area, ϵ the dielectric constant, n_D the concentration of donor atoms in the base region of a p–n–p transistor, V' is a voltage defined by Equ. (8):

$$V' = V_D - V_{cb'} \qquad \text{.. .. .. ..} \qquad (8)$$

Here V'_{cb} is the voltage between collector and base and V_D the so-called 'diffusion voltage' (see Ref. No. 3). Since V_D is some tenths of a volt, the equation $V' \approx V_{cb'}$ is valid for collector voltages of some volts. Equ. (7) is only valid for contacts with high dotation† content at

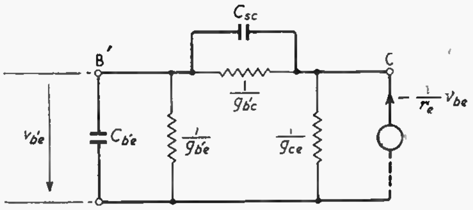

Fig. 4. *Equivalent circuit of Fig.* 2 (*d*) *with additional elements* C_{sc}, $1/g_{b'c}$, $1/g_{ce}$ $1/g_{b'e}$. C_{sc} = *collector depletion layer capacitance.* $1/g_{b'c}$, $1/g_{ce}$ *are due to the modulation of the base layer thickness. The resistance* $1/g_{b'e}$ *is due to the recombination of carrier pairs in the base region and to the majority carrier content of the emitter current*

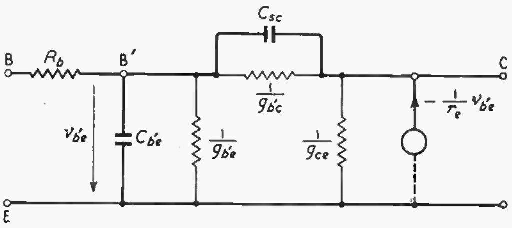

Fig. 5. *Fig.* 4 *with an added base lead resistance* R_b

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* (i.e., transistors in which carriers move through the base layer exclusively by diffusion)

† The degree of doping of germanium or silicon with acceptor or donor atoms.

one side and relatively few doping atoms at the other side of the junction. This condition is normally satisfied with the collector junctions of alloyed p–n–p transistors.

A graded transition from p– to n–material is often preferred with grown junctions. Lower capacitance per unit area is attained with this junction type than with an abrupt transition if suitable constants are chosen. According to W. Shockley's theory[4], the depletion-layer capacitance of a junction with linear transition from p– to n–material [see Fig. 3(b)] is given by

$$C_{sc} = A\frac{\epsilon}{2}\left(\frac{2\,e\,a}{3\epsilon}\right)^{1/3}\cdot\frac{1}{(V')^{1/3}} \quad \cdot\cdot \quad \cdot\cdot \quad (9)$$

Here a denotes the slope of the concentration distribution in the transition region according to Fig. 3(b). V' is again defined by Equ. (8). The different types of dotation transitions may be clearly distinguished by the dependence of the depletion-layer capacitance on the applied collector voltage. Some experimental curves are presented in Fig. 3(c).

If the depletion layer capacitance C_{sc} of the collector junction is added to the equivalent circuit of Fig. 2(d) between collector and intrinsic base, an equivalent circuit denoted by heavy lines in Fig. 4 results. In this diagram some additional resistances incorporating second-order effects have been added with thin lines. Recombination in the base region and the majority-carrier content of the emitter current (electrons in a p–n–p transistor) have been represented by the resistance $1/g_{b'e}$. These two parts of emitter current are not useful for amplifier purposes. The two remaining resistances of Fig. 4 (an output conductance g_{ce} and a feedback conductance $g_{b'c}$) represent the effects of the modulation of the base layer thickness by the collector voltage. Some further second-order effects have been omitted in the circuit of Fig. 4.

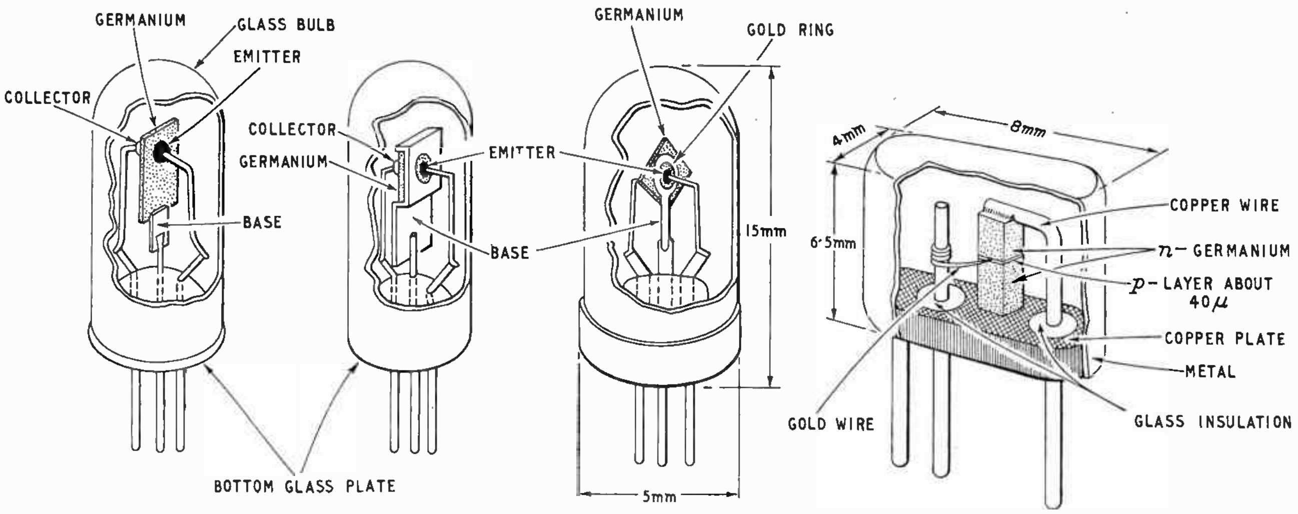
1.3. *Effect of Base Lead Resistance*

In the equivalent circuit of Fig. 4 it would be possible to tune out the capacitances by suitable load and source impedances. Therefore, in a selective amplifier, it would be possible to arrive nearly at the low-frequency power gain by suitable attached circuits. However, in a real transistor, the so-called 'intrinsic base' B′ is not accessible because of the base-lead resistance R_b. In the equivalent circuit of Fig. 4 this resistance has to be connected in series with the intrinsic base point B′. From the more complete equivalent circuit of Fig. 5 it can be seen that exact tuning of the capacitances $C_{b'e}$ and C_{sc} is now impossible.

The magnitude of the base-lead resistance is dependent on the construction of the transistor. In Fig. 6 some commercially available transistors are represented. An early construction of an alloyed transistor is shown in Fig. 6(a). The base contact is connected to one side of the base wafer and there is a relatively long distance between the intrinsic base (between the junctions) and the base terminal, resulting in a base lead resistance of 250 to 600 ohms. Newer construction principles with a ring contact [Fig. 6(b), (c)] have reduced this critical distance and decreased also the base-lead resistance R_b to 70 to 250 ohms.

The representation of the base-lead resistance by a lumped ohmic resistance in the equivalent circuit is valid for alloyed-junction transistors only. A grown-junction transistor is shown in Fig. 6(d). It is easily recognized that there is no simple distance between base terminal and intrinsic base. It is more appropriate to describe this transistor by a circuit with distributed impedances ; i.e., the transistor is sliced into parts in parallel with each other. Due to the asymmetrical base terminal which is attached to one side of the base layer, these partial transistors have different base resistances. It has been shown[7,8] that the effect of these distributed base lead resistances can be represented by a lumped impedance Z_b in series with the intrinsic base in the equivalent circuit (see Fig. 7).

Up to medium frequencies this impedance Z_b can be replaced by an ohmic resistance which is, however,



(a) (b) (c) (d)

Fig. 6. *Practical designs of some commercially available junction transistors. (a) Single side-base contact, (b) and (c) ring-base contact, all with alloyed junctions; (d) grown junction transistor.*

TABLE 1

	L.F. Transistor	H.F. Transistor
f_α	470 kc/s	4·5 Mc/s
R_b	200–400 Ω	100 Ω
$1/g_{b'e}$	2·1 kΩ	2·0 kΩ
$C_{b'e}$	7,000 pF	800 pF
$1/g_{b'c}$	5 MΩ	7 MΩ
C_{sc}	35 pF	10 pF
$1/g_{ce}$	500 kΩ	180 kΩ
$1/r_e$	20 mA/V	20 mA/V

At $I_e = 0{\cdot}5$ mA, $V_{ce} = -6$ V.

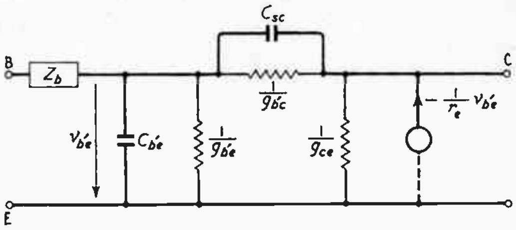
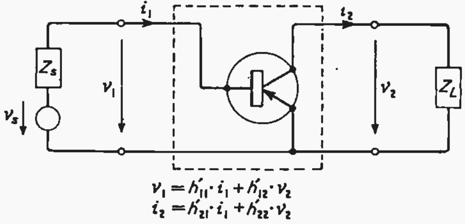


Fig. 7. *Equivalent lumped circuit of a grown junction transistor in earthed-emitter connection*

Fig. 8. *Transistor quadripole in earthed-emitter connection with attached circuits. Voltage source v_s with source impedance Z_s at the input, load impedance Z_L at the output of the amplifier stage*



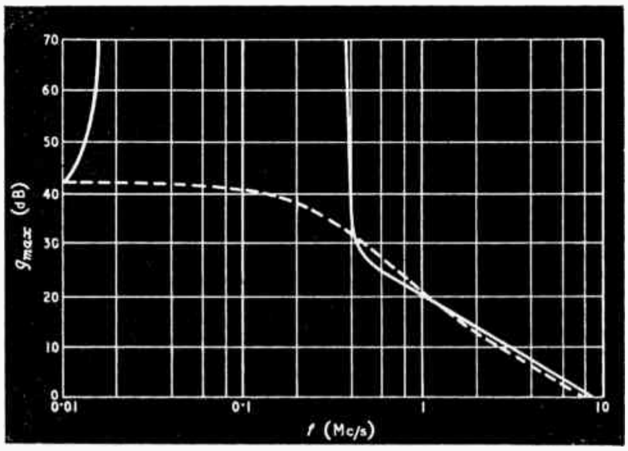


Fig. 9. *Calculated curve of optimal power gain g_{max} versus frequency f of a junction transistor in earthed-emitter connection at matched impedance conditions of input and output (full curve). The dashed curve results from similar calculations for a neutralized (unilateralized) earthed-emitter stage ($h'_{12} = 0$) according to Ref.* 9

dependent on the emitter current. In Table 1 typical values for the elements of Fig. 5 are listed.

2. Figure of Merit for H.F. Transistor Performance

From the circuits of Figs. 5 or 7 it is possible to calculate all interesting data of a high-frequency amplifier stage (input resistance, output resistance, power gain). In practical cases, this method requires extensive calculations and it leads to formulae which are not easy to survey. For instance, if power gain must be calculated, the equivalent circuit has first to be transformed into a matrix system ; e.g., with h'-parameters defined in Fig. 8. These parameters have then to be applied to Equ. (10) for the power gain.

$$g = 4 \text{ Re } (Z_s) \text{ Re } (Z_L) \times \left| \frac{h'_{21}/Z_L}{(Z_s + h'_{11}) \left(\frac{1}{Z_L} - h'_{22}\right) + h'_{12} \cdot h'_{21}} \right|^2 \quad (10)$$

Obviously it is hardly possible to survey these complicated formulae completely.

It has been shown, however, by several authors[5, 8], that a universal formula for the maximum-available power gain of a junction transistor exists, which is valid for a great part of the region of decreasing power gain with increasing frequency. It is applicable to usual transistors at normal operating currents. If the transistor under consideration has a lumped ohmic base-lead resistance (alloyed transistor) one finds for the maximum power gain :

$$g_{max} \approx \frac{1}{f^2} \cdot \frac{f_\alpha}{25 \, R_b \, C_{sc}} \quad .. \quad .. \quad .. \quad (11)$$

Here, f_α, R_b, C_{sc} have been defined in Section 1. The validity of this equation is restricted to the frequency region :

$$0{\cdot}05\text{–}0{\cdot}1 < f/f_\alpha < 2. \quad .. \quad .. \quad .. \quad (12)$$

In this frequency range, power gain decreases at a rate of 20 dB/octave [see Equ. (11)]. It is equal to unity at a frequency :

$$f_0 = \sqrt{\frac{f_\alpha}{25 \, R_b \, C_{sc}}} \quad .. \quad .. \quad .. \quad .. \quad (13)$$

(limit of oscillation).

It has been shown[8] that Equ. (11) must be replaced by Equ. (14) for grown junctions :

$$g_{max} \approx \frac{1}{f^{3/2}} \cdot \frac{f_\alpha^{1/2}}{30 \, C_{sc} \, (R_b \cdot r_e)^{1/2}} \quad .. \quad .. \quad (14)$$

Range : $0{\cdot}05 < f/f_\alpha < 2$. The factors of Equ. (14) have been defined in Section 1. Experimental values for the optimal power gain of grown junction transistors are about 3·5 dB below the values given by Equ. (14); however, Equ. (14) seems to characterize the frequency dependence (15 dB/octave) of power gain of grown junction transistors better than does Equ. (11). The same transistor constants f_α, R_b, C_{sc} (R_b = low-frequency value of impedance Z_b) characterize the high-frequency behaviour of grown transistors, which are also important for the frequency dependence of alloyed transistors. The value :

$$G = \frac{f_\alpha}{25 \, R_b \, C_{sc}}$$

has been defined as a figure of merit for the high-frequency behaviour of junction transistors. The values for G are tabulated for some typical transistors in Table 2.

Normally, the optimal power gain of Equs. (11) or (14) is attained only with selective amplifiers if exact matching of the input and output circuits is possible. A sacrifice in gain is often necessary in broadband amplifiers to get a flat frequency response curve.

TABLE I

Figures of merit G (Equ. 14) of some modern junction transistors. Values of C_{sc} at $|V_{cb}| = 6$ V.

Type	Construction	f_α	C_{sc} (pF)	R_b (Ω)	G $(\text{sec})^{-2}$
OC71	Ge alloyed single-side base contact	0·5 Mc/s	55	400	$9{\cdot}1\times10^{11}$
OC604	Ge alloyed ring base contact	0·6 Mc/s	20	200	$4{\cdot}3\times10^{12}$
TF65	Ge alloyed ring base contact	1·0 Mc/s	25	120	$1{\cdot}6\times10^{13}$
OC612	Ge alloyed h.f. type	6·0 Mc/s	10	100	$2{\cdot}4\times10^{14}$
2N137	,, ,, ,, ,,	6·0 Mc/s	12	100	$2{\cdot}0\times10^{14}$
2N113	,, ,, ,, ,,	9·0 Mc/s	14	80	$3{\cdot}2\times10^{14}$
OC440	Si ,, ,, ,,	1·8 Mc/s	25	100	$2{\cdot}9\times10^{13}$
SB100	Ge surface barrier	35 Mc/s	3·5	200	$2{\cdot}0\times10^{15}$
3N23B	Ge tetrode ..	5·0 Mc/s	9·0	20	$1{\cdot}1\times10^{15}$
p-n-i-p	Ge intrinsic-barrier	170 Mc/s	0·4	96	$1{\cdot}7\times10^{17}$

The transistors are from the following firms: OC71 Philips, OC604 Telefunken, TF65 Siemens, OC612 Telefunken, 2N137 General Electric, 2N113 Raytheon, OC440 Intermetall, SB100 Philco, 3N23B Germanium Products, p-n-i-p Bell Telephone Laboratories.

3. Stability of H.F. Stages

Equs. (11) and (14) do not show whether optimal gain is obtainable for any frequency, nor whether the stage will show self-oscillation in certain frequency ranges. Experiments show that such frequency ranges actually occur within the range of applicability of these equations. These experiments are confirmed by calculations of gain as dependent on frequency pertaining to earthed-emitter stages, matched at both input and output. The results of such a calculation are shown in Fig. 9 according to Ref. 9. It is seen that the gain approaches infinity at relatively low frequencies, meaning self-oscillation. The cause of this self-oscillation may easily be seen. It is similar to the situation in triode amplifying stages. At suitable output and input impedances, the feedback impedance between output and the input has magnitude and phase values appropriate for the generation of oscillations. Calculations by L. J. Giacoletto[9] have shown that earthed-base and earthed-collector stages, optimally matched at input and output, are also unstable in certain frequency ranges (see Figs. 10 and 11).

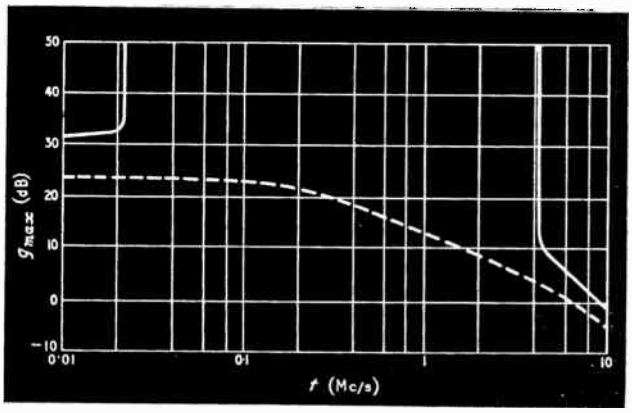


Fig. 10. *Similar curves to Fig. 9, but for an earthed-base junction transistor circuit according to Ref.* 9

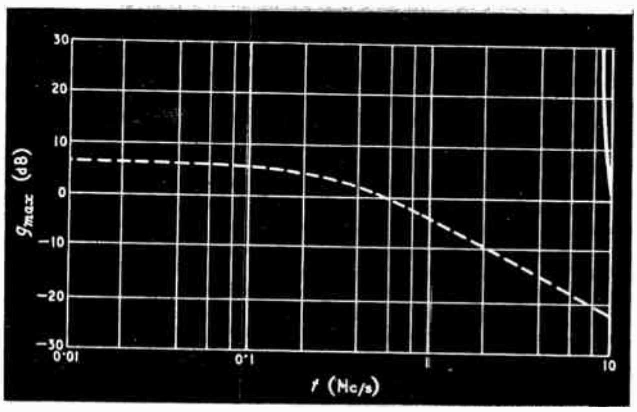


Fig. 11. *Similar curves to Fig. 9, but for an earthed-collector junction transistor circuit. The non-neutralized stage oscillates in the range from 9·7 kc/s to 9 Mc/s, according to Ref.* 9

From Figs. 9–11 it is seen that h.f. earthed-emitter stages are best for gain, as was also found for l.f. stages. The gain of earthed-base stages is lower and that of earthed-collector stages still lower; indeed, for the last the gain is so low that these stages are scarcely used at high frequencies.

It might be thought that Equs. (11) and (14) are of illusory application as to the evaluation of optimal gain, in view of the occurring self-oscillation. By the application of proper stabilizing circuits, however, oscillation may be avoided and the gain is only slightly less than would follow from Equs. (11) and (14) for the earthed-emitter stage (compare the dotted curve of Fig. 9, which pertains to the stabilized amplifier stage).

The conditions of stability of transistor circuits have been investigated by A. P. Stern[10, 11]. If a four-pole circuit is required to be stable under all conditions [i.e. for all possible source and load impedances (absolute stability)], the equation

$$|h_{12}\,h_{21}| - \text{Re}\,(h_{12}\,h_{21}) \leqslant -2\,\text{Re}\,(h_{11}) \cdot \text{Re}\,(h_{22}) \quad (15)$$

must be satisfied[11]. From Equ. (15) the limits of potential oscillation zones of any four-pole circuit may be determined. In the earthed-emitter case A. P. Stern[11] finds an upper frequency limit of the potential oscillation zone, given by:

$$f_s \approx \frac{r_e}{2\,R_b} \cdot f_\alpha \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

The quantities r_e, R_b and f_α were defined in Section 1.1. If an amplifier has to be used in a zone of potential instability (i.e. $f < f_s$ for the earthed-emitter case),

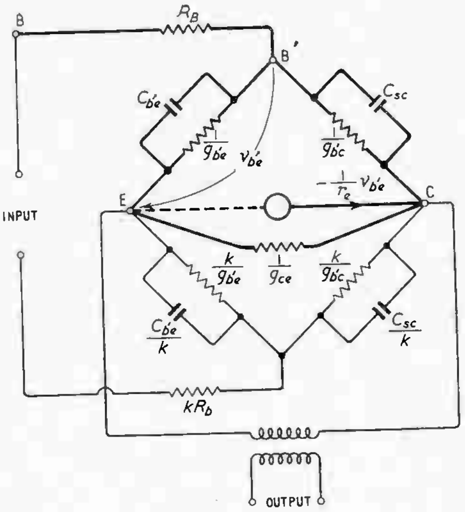


Fig. 12. *Earthed-emitter junction transistor circuit, neutralized over a wide frequency range. The complete circuit resembles a bridge circuit. The equivalent circuit of the transistor is shown by heavy lines*

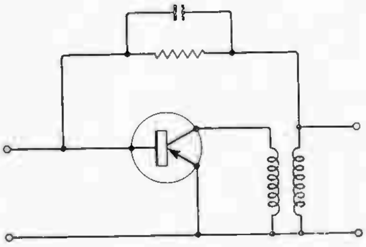


Fig. 13. *Simple neutralizing circuit*

oscillations may be avoided by a proper choice of the load and source impedance. The corresponding impedance values may easily be calculated[11].

The best means of avoiding instability is by neutralization[2, 10, 12, 13]. This neutralization means the elimination of feedback from the output to the input. In the above h-matrix notation this means $h_{12}' = 0$. In Equ. (15) the right-hand side is always of positive sign. Hence the stability condition according to Equ. (15) is always satisfied, if $h_{12} = 0$. Besides this compliance with the stability condition, neutralization also leads to a very marked simplification of the calculation of amplifiers, as each neutralized stage may be considered by itself, neglecting the influence of the other stages.

Neutralizing circuits may be obtained by similar means to those employed with high-vacuum triodes. The circuits differ, however, in that they often contain resistances. If the transistor in question is considered as one branch of a bridge circuit, the neutralizing network must be such that a voltage fed to the output terminals does not result in a voltage across the input terminals. A corresponding bridge circuit is shown in Fig. 12. The bridge ratio k may be chosen so that the gain is optimal. In most cases, a simple neutralizing circuit proves satisfactory. In i.f. amplifier stages the circuit of Fig. 13 is often applied.

As in l.f. amplifiers, stage coupling must be so adjusted as to obtain optimal matching condition. Stabilization of d.c. operating points of transistors in h.f. stages may be obtained similarly to l.f. cases[29].

5. Noise of H.F. Stages

In the input stages of h.f. amplifiers the inherent noise fixes a lower limit for the input signals which may be usefully applied. The noise behaviour of linear four-pole circuits is characterized by their noise figure F, which need not be defined here[1]. In earthed-emitter and in earthed-base stages F is given by[14,15].

$$F = \frac{2\,e\,I_c \left| \dfrac{R_b + h_{11i} + Z_s}{\alpha} \right|^2 - 2\,e\,I_e \left| R_b + Z_s \right|^2}{4\,k\,T\,R_s} \tag{17}$$

for small values of I_e and I_c. In this equation Z_s is the source impedance (at the input), h_{11i} is the h_{11} value of the corresponding intrinsic transistor (base resistance R_b zero) of the earthed-base circuit, I_c is the collector and I_e the emitter current. R_s is the real part of Z_s. Experimental evidence supports Equ. (17) satisfactorily at small values of I_c and I_e (usually up to about 1 mA) for all transistor types under observation[14,15]. From Fig. 14 it is seen that the increase of F at higher frequencies corresponds to a decrease of α. This experimental and theoretical fact gives rise to a simple rule for the construction of low-noise h.f. stages. In the critical input stage of an amplifier the transistor should have a high cut-off frequency f_α, such that α shows no conspicuous decrease in the frequency range under consideration. We may then be sure that F is still in

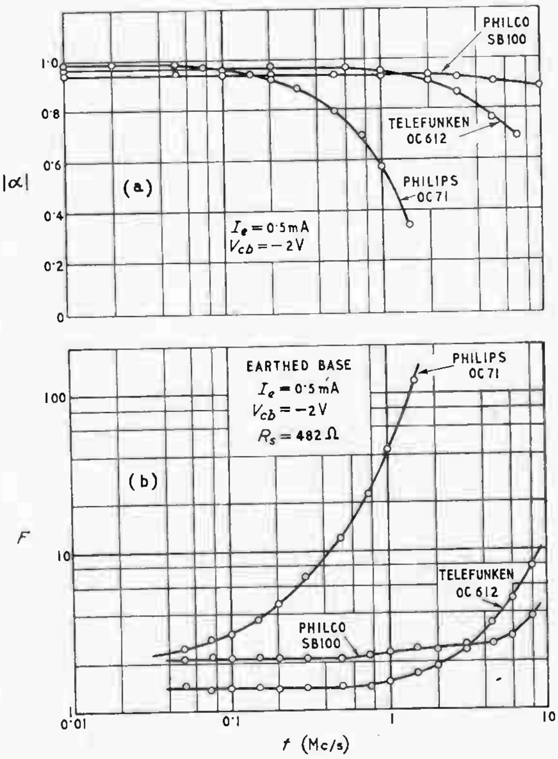


Fig. 14. (*a*) *Current amplification factor* |α| *of junction transistors versus frequency f.* (*b*) *Noise figure F versus frequency f for the same transistors according to Refs.* 14 *and* 15

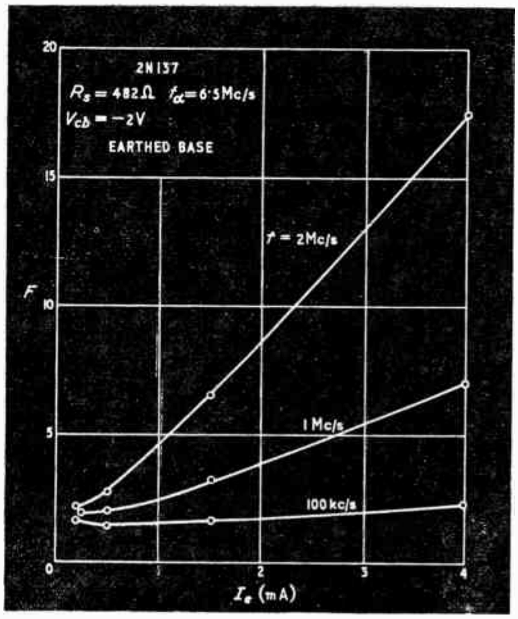


Fig. 15. *Noise figure F of a junction transistor* 2N137 *versus emitter current I_e at several values of frequency f, according to Ref.* 15

the "white noise" frequency range, and the noise conditions are the same as in l.f. amplifier stages[1]. The value of F shows a minimum dependent on source resistance R_s and also dependent on emitter current I_e. The earthed-emitter circuit is rather favourable, as the optimal R_s value for minimal noise is about equal to the value corresponding to optimal matching at the input.

If it is necessary to use an amplifier stage in the frequency range of increasing F, the above optimal conditions are somewhat altered[15]. In order to obtain a low F-value, small currents I_e are favourable (see Fig. 15). The optimal value of R_s is smaller at higher frequencies (see Fig. 16). In the present case, the earthed-emitter circuit remains the most favourable one.

If stage gain is very low ($g < 10$), the amplifier behaviour is not exclusively characterized by the noise figure F of the input stage, as the subsequent stages also contribute to overall noise. In these cases a better figure of merit is[17].

$$M = \frac{F - 1}{1 - 1/g_v} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (18)$$

containing F and also the available stage gain g_v at the given input source. This modified figure of merit takes into account the fact that a low value of F alone at low gain figures would not be favourable. In such cases a higher F-value at higher gains would often be preferable. This modified figure of merit should be applied to low-gain transistor stages; i.e., at high frequencies or with strong negative feedback.

6. Means of Obtaining Increased Frequency Limits

These considerations may start from Equ. (11). A high-frequency limit corresponds to a high value of f_α and to low values of R_b and of C_{sc}. It may be shown that improvement of one of these quantities in the indicated direction has always an unfavourable influence on the other two. For instance, a decrease of the base-layer thickness w causes an increase of f_α, but at the same time an increase of R_b. An increase of the dotation n_D of donors to the base layer causes a decrease of R_b but at the same time an increase of C_{sc} according to Equ. (7). Furthermore, it causes a decrease of admissable voltage across the collector depletion layer and hence a decrease of upper power limit of the transistor.

A decrease of cross section A of the transistor causes a decrease of C_{sc}, but also a decrease of admissable current of the transistor and hence of its admissible power. The base layer thickness cannot be decreased indefinitely, as it should remain two or three times the thickness of the collector depletion layer. If this condition is neglected, the collector voltage could punch through the base layer to the emitter, due to inhomogenities. The lower limit of depletion-layer thickness is determined by its ability to withstand the collector voltage, avoiding breakdown.

From this it is seen, that optimal transistor dimensions can only be fixed on the basis of a compromise, depending on the material and on the basic geometry[8, 18, 19]. Technological difficulties in producing semiconductor parts of minute dimensions should also be taken into account in fixing the compromise data. Extremely thin base layers of some microns thickness have been produced by Philco by the application of electrolytic processes (surface-barrier transistors; e.g., type SB100). With present transistors, in which the carriers are moving through the base region by diffusion, the higher limit of oscillation frequency is about 50 to 100 Mc/s. Collector supply voltage should be as high as possible, in order to decrease C_{sc} according to Equ. (7), due regard being given to the breakdown limit of the collector depletion layer.

An increase of this upper frequency limit may be obtained by a modification of the functioning of the

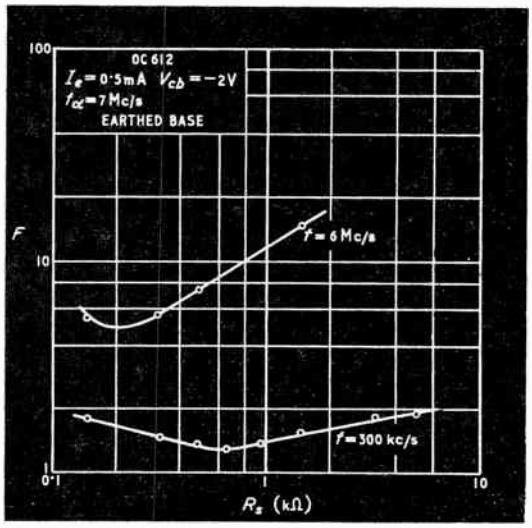


Fig. 16. *Noise figure of a junction transistor* OC612 *versus source resistance R_s, at several values of frequency f, according to Ref.* 15

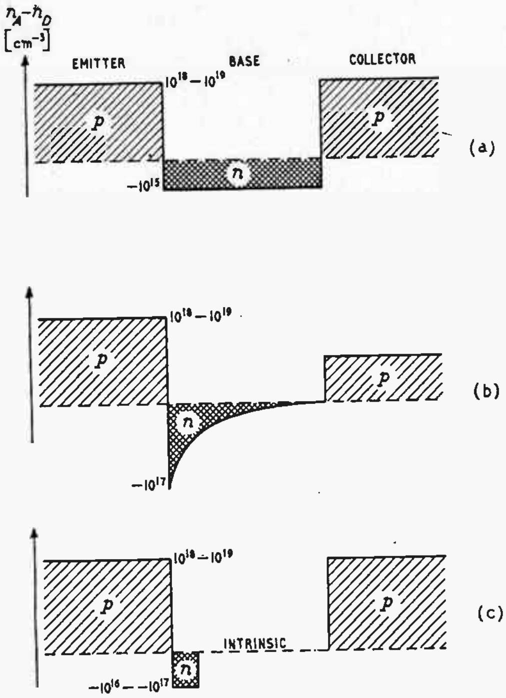


Fig. 17. *(a) Concentration $n_A - n_D$ in a junction transistor, functioning by carrier diffusion, produced by the normal alloy process. The concentration in the base layer is approximately constant. (b) Concentration $n_A - n_D$ versus linear distance in a drift transistor. The exponential concentration distribution in the base layer results in an electric field acting on the minority carriers. (c) Concentration $n_A - n_D$ versus linear distance in a p-n-i-p junction transistor according to Ref. 21. All curves are approximate*

base layer. The capacity $C_{b'e}$ in Fig. 7, and hence the limiting frequency f_α, are preponderantly determined by the carrier velocities in the base layer. In pure diffusion processes, as considered hitherto for the base layer, the carrier velocities can only be increased by increasing the concentration gradient in the base layer, which may be effected by decreasing its thickness. However, the carrier velocities obtained thus are much smaller than those which could be obtained under similar geometrical conditions by the application of electric fields.

H. Kroemer[20] has pointed out that a suitable accelerating electric field may be obtained in the base layer of a transistor by the application of a variable dotation throughout this layer. A favourable variation of this kind would involve an exponential decreasing dotation from emitter to collector. A corresponding dotation is shown in Fig. 17 in comparison with normal dotation. By the application of a dotation according to Fig. 17 (b) the limiting frequency f_α is increased while R_b and C_{sc} are decreased. The decrease of R_b is caused by the high concentration of donors at the emitter side of the base layer. The decrease of C_{sc} is based on Equ. (7), as the donor concentration at the collector side of the base layer is small in the present case and this concentration enters into Equ. (7). H. Kroemer estimates that the upper frequency limit of oscillation according to Equ. (12) with drift-transistors of this type is some kilomegacycles.

A different proposal for increasing the upper frequency limit of transistors is due to J. M. Early[21]. This also involves a modification of the base layer, which is composed of two different layers. The first one, on the emitter side, has normal donor concentration, whereas the second one, on the collector side, consists of intrinsic material (no donors or acceptors). The first layer may be very thin (f_α high) and its donor concentration may be such, that R_b is small. The second layer results in a small value of C_{sc} and also causes an increase of breakdown voltage of the transistor in question. The dotation curve of a p-n-i-p transistor of the present type is shown in Fig. 17 (c). Experimental values[22] are: $f_\alpha = 160$ Mc/s, $C_{sc} = 0{\cdot}4$ pF, $R_b = 96$ ohms. The value f_0 according to Equ. (12) is 410 Mc/s.

H. Kroemer's proposal was realized by the application of a new production process. The donor atoms diffuse into the semiconductor out of the surrounding gas atmosphere. This diffusion process results in a donor concentration, which decreases from the semiconductor surface inwards according to an error function (see Fig. 18), approximately as is required for Kroemer's drift transistors. The third layer (i.e., the emitter) is produced at the same time, also by diffusion out of a gas atmosphere, or by alloying in the usual way. It is by this means that the so-called diffused transistors are produced[23,24]. The resulting base layers are very thin and the donor concentration in them corresponds nearly to the requirements for drift-transistors. With silicon transistors of this type values f_α of about 120 Mc/s and with germanium types even of about 500 Mc/s were obtained experimentally[23,24]. The h.f. behaviour of these types cannot be described by Equ. (11) in all cases. The lead resistance to the collector has a marked influence on the h.f. properties of the types produced so far. Transistors with variable dotation in the base region are now available commercially.

Various other solutions have been proposed for the problems of h.f. transistors. By the application of a fourth contact to grown transistors, their h.f. behaviour may be improved[25]. The fourth contact is applied as a second contact to the base layer (Fig. 19). The electrode

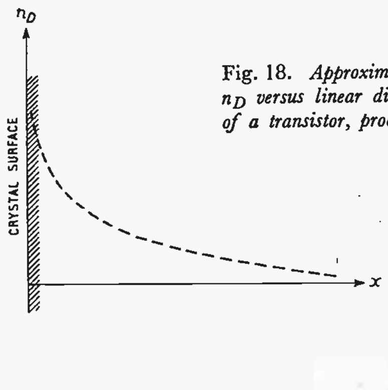


Fig. 18. *Approximate concentration n_D of donors n_D versus linear distance x from crystal surface of a transistor, produced by the diffusion process*

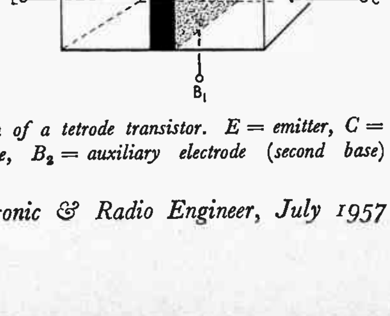


Fig. 19. *Approximate design of a tetrode transistor. E = emitter, C = collector, B_1 = normal base, B_2 = auxiliary electrode (second base)*

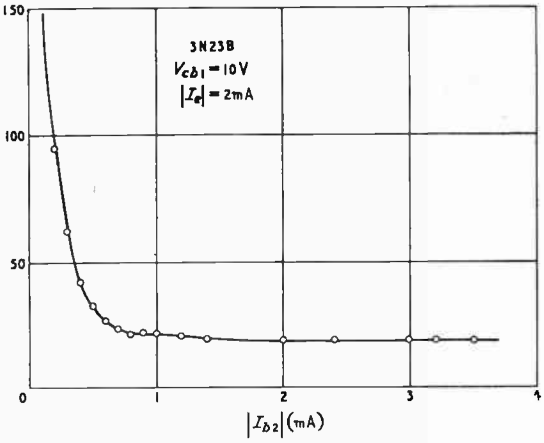


Fig. 20. *Base lead resistance* R_b *of a tetrode transistor* 3N23B *versus auxiliary electrode current* I_{b2}. *Operational data:* $V_{cb1} = 10$ *V,* $I_e = -2$ *mA,* $f = 135$ *c/s*

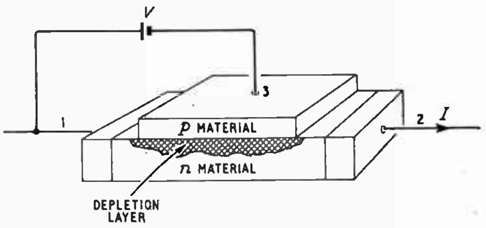


Fig. 21. *Approximate picture of a field effect transistor. The voltage V between* 1 *and* 3 *controls the thickness of the depletion layer* (*hatched surface*) *and thereby it controls also the resistance of the path* 1-2

B_2 may be biased so that only part of the base-layer cross-sectional area is active. It is possible to concentrate the entire base current in the vicinity of B_1 thus lowering R_b considerably (Fig. 20). Furthermore, C_{sc} is also decreased. Characteristic values for a commercial tetrode type are shown in Table 2. Some published upper-frequency limits[26, 27] are even considerably higher than the value quoted in Table 2.

An h.f. transistor of different type has been tried out[28]. The action of this type may be explained by Fig. 21. Between the contacts 1 and 3 a voltage is applied of such sign that a depletion layer is created at the boundary between the p- and n-semiconductors. The thickness of this layer may be varied by variation of the amount of the applied tension. Thus the cross section of the conducting semiconductor path between the electrodes 1 and 2 of Fig. 21 may be varied by variation of the said tension between 1 and 3. The current passing from 1 to 2 is caused by an electric field (not by diffusion as in junction transistors of common type). Hence h.f. properties are comparatively favourable with this new type. Experimental evidence[28] indicates an upper frequency limit of about 50 Mc/s. By decreasing the geometrical dimensions, this figure might be increased.

Practical production facilities will ultimately determine the type, out of the above possibilities, which will be successful.

Acknowledgement

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REFERENCES

[1] W. Guggenbuhl & M. J. O. Strutt, "Transistoren in Niederfrequenz—Anfangsstufen", *Scientia Electrica*, 1956, Vol. 2, pp. 2–12.

[2] W. Moortgat-Pick, "Hochfrequenzverstarkung mit Transistoren", *Nachrichtentechn. Fachber. Beiheft der FTZ*, 1956, Vo. 5, pp. 40–44.

[3] E. Spenke, "Elektronische Halbleiter", Springer, Berlin, 1955.

[4] W. Shockley, "The Theory of p–n Junctions in Semi-Conductors and p–n Junction Transistors", *Bell Syst. techn. J.*, 1949, Vol. 28, pp. 435–489.

[5] L. J. Giacoletto, "Study of p–n–p Alloy Junction Transistor from d-c through Medium Frequencies", *R.C.A. Review*, 1954, Vol. 15, pp. 506–562.

[6] W. Schottky, "Vereinfachte und erweiterte Theorie der Randschichtgleichrichter", *Z.f. Physik*, 1942, Vol. 118, p. 539–592.

[7] R. L. Pritchard & W. N. Coffey, "Small-Signal Parameters of Grown-Junction Transistors at High Frequencies", *I.R.E. Conv. Rec.*, 1954, Part 3, pp. 90–98.

[8] R. L. Pritchard, "High-Frequency Power Gain of Junction Transistors", *Proc. Inst. Radio Engrs*, 1955, Vol. 43, pp. 1075–1085.

[9] L. J. Giacoletto, "Performance of a Radio-Frequency Alloy Junction Transistor in Different Circuits". Transistors I, R.C.A. Laboratories, Princeton, 1956, pp. 431–457.

[10] A. P. Stern, C.A. Aldridge & W. F. Chow, "Internal Feedback and Neutralisation of Transistor Amplifiers", *Proc. Inst. Radio Engrs*, 1955, Vol. 43, pp. 838–847.

[11] A. P. Stern, "Considerations on the Stability of Active Elements and Applications to Transistors", *I.R.E. Conv. Rec.*, 1956, Part 2, pp. 46–52.

[12] G. Y. Chu, "Unilaterlization of Junction-Transistor Amplifiers at High Frequencies", *Proc. Inst. Radio Engrs*, 1955, Vol. 43, pp. 1001–1006.

[13] G. Meyer-Brotz, "Die Neutralisierung im selektiven Transistor-verstarker", *Arch. Elektr. Uebertragung*, 1956, Vol. 10, pp. 391–397.

[14] W. Guggenbuhl, B. Schneider & M. J. O. Strutt, "Messungen uber das Hochfrequenzrauschen von Transistoren", *Nachrichtentechn. Fachber., Beiheft der NTZ*, 1956, Vol. 5, pp. 34–37.

[15] W. Guggenbuhl & M. J. O. Strutt, "Theory and Experiments on Shot Noise in Semiconductor Diodes and Transistors", *Proc. Inst. Radio Engrs*, Vol. 45, June 1957.

[16] H. Rothe & W. Dahlke, "Theorie rauschender Vierpole", *Arch. elektr. Uebertragung*, 1955, Vol. 9, pp. 117–121.

[17] H. A. Haus & R. B. Adler, "Invariants of Linear Noisy Networks", *I.R.E. Conv. Rec.*, 1956, Part 2, pp. 53–67.

[18] H. Statz, E. A. Guillemin & R. A. Pucel, "Design Considerations of Junction Transistors at Higher Frequencies", *Proc. Inst. Radio Engrs*, 1954, Vol. 42, pp. 1620–1628.

[19] L. J. Giacoletto, "Comparative High-Frequency Operations of Junction Transistors Made of Different Semiconductor Materials", *I.R.E. Conv. Rec.*, 1955, Part 3, pp. 133–137.

[20] H. Kromer, "Zur Theorie des Diffusions-und Drifttransistors", *Arch. elekt. Uebertragung*, 1954, Vol. 8, pp. 223–228, 363–369, 499–504.

[21] J. M. Early, "PNIP and NPIN Junction Transistor Triodes", *Bell Syst. techn. J.*, 1954, Vol. 33, pp. 517–533.

[22] R. M. J. Warner & W. C. Hittinger, "A Developmental Intrinsic-Barrier Transistor", *Trans. Inst. Radio Engrs*, 1956, Vol. ED3, pp. 157–160.

[23] M. Tanenbaum & D. E. Thomas, "Diffused Emitter and Base Silicon Transistors", *Bell Syst. techn. J.*, 1956, Vol. 35, pp. 1–22.

[24] C. A. Lee, "A High-Frequency Diffused Base Germanium Transistor", *Bell Syst. techn. J.*, 1956, Vol. 35, pp. 23–34.

[25] R. L. Wallace, L. G. Schimpf & E. Dickten' "A Junction Transistor Tetrode for High Frequency Use", *Proc. Inst. Radio Engrs*, 1952, Vol. 40, pp. 1395–1400.

[26] D. W. Baker, "High Frequency Germanium n–p–n Tetrode", *I.R.E. Conv. Rec.*, 1956, Part 3, pp. 143–147.

[27] R. F. Stewart, B. Cornelison & W. A. Adcock, "High Frequency Tetrodes", *I.R.E. Conv. Rec.*, 1956, Part 3, pp. 166–171.

[28] G. C. Dacey & I. M. Ross, "The Field Effect Transistor", *Bell Syst. techn. J.*, 1955, Vol. 34, pp. 1149–1189.

[29] W. Guggenbuhl & B. Schneider, "Zur Stabilisierung des Gleichstromarbeitspunktes von Flachentransistoren", *Archiv elekt. Uebertragung*, 1956, Vol. 10, pp. 361–375.

BRITISH PLASTICS EXHIBITION

The British Plastics Exhibition and Convention opens at Olympia on 10th July. Seventeen papers will be given at the Convention, many by visitors from overseas, in keeping with the international character of this year's show. The exhibition ends on 20th July.

INSTITUTION OF ELECTRONICS EXHIBITION

The Northern Division of the Institution of Electronics will hold its twelfth annual Exhibition and Convention at the College of Technology, Manchester, 11th–17th July. Applications for tickets, enclosing a stamped addressed envelope, should be made to Mr. W. Birtwistle, 78 Shaw Road, Rochdale, Lancs.

By Computer

Determination of Stability and Damping : Algebraic Criteria

The response of an electrical system with only lumped elements to a transient disturbance can be correctly expressed as a linear combination of several terms of the form

$$Ae^{\alpha t}, \quad e^{\gamma t}\,(C \cos \omega t + D \sin \omega t)$$

Occasionally, transient terms may also occur in which the above expressions are multiplied by a power of t. Now, if the system is stable, the response must die away with time and this will happen if all the α and γ terms which occur are negative, whether powers of t are present or not.

If we know the magnitudes of the elements of the electrical system, we can determine the 'characteristic equation', whose roots are the various quantities α and $\gamma \pm j\omega$ mentioned above, and we thus see that stability is associated with the condition for a certain equation to have all its roots negative if they are real, or with negative real parts if they are complex. We therefore now consider the condition for an algebraic equation to have roots of this nature.

Suppose first that the equation is of degree 5, namely

$$a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 + a_5x^5 = 0 \quad .. \quad (1)$$

Now separate the terms of even degree from those of odd degree, and suppose that

$$a_0 - a_2y + a_4y^2 = 0 \text{ has roots } y = \alpha_1, y = \alpha_2$$
$$a_1 - a_3y + a_5y^2 = 0 \text{ has roots } y = \beta_1, y = \beta_2$$

Then the original equation in x has no roots with positive real parts, and can be the characteristic equation of a stable system if, and only if

(i) All the a-terms in the original equation (1) (in x) have the same sign

(ii) α_1, α_2, β_1 and β_2 are all real

(iii) $\alpha_1 < \beta_1 < \alpha_2 < \beta_2$

We shall not attempt to prove this result here ; it is a result which, once understood, is easily applied and, in the form given above, can be generalized to equations of any degree. The only difference is that there are then more of the quantities we have called α and β ; all of these quantities must be real for stability and, if arranged in ascending order, the α and β terms must occur alternately with the smallest α less than the smallest β. Thus, for example, the equation

$$1 + 4x + 5x^2 + ax^3 + 4x^4 + x^5 = 0 \quad .. \quad (2)$$

has its α terms given by

$$1 - 5y + 4y^2 = 0 \quad .. \quad .. \quad .. \quad .. \quad (3)$$

so that $\alpha_1 = 0{\cdot}25$ and $\alpha_2 = 1$, while β_1 and β_2 are the roots of

$$4 - ay + y^2 = 0 \quad .. \quad .. \quad .. \quad .. \quad (4)$$

If $a < 4$, this last equation has no real roots and, therefore, the original equation (2) cannot possibly be associated with a stable system. When $a = 4$, β_1 and β_2 are both 2 so that the associated system is still unstable. As a increases above 4, β_1 decreases and β_2 increases, until when $a = 5$, β_1 is 1 and β_2 is 4, so that this is the borderline case when $\beta_1 = \alpha_2$. If $a > 5$, β_1 is less than $\alpha_2 = 1$, so the associated system is stable until a increases so much that β_1 falls to $\alpha_1 = 0{\cdot}25$; this happens when $a = 16{\cdot}25$. For greater values of a, the associated system is again unstable, since β_1 is now less than α_1.

For equations of degree less than 5, the above procedure could still be carried out, but there are now fewer of the quantities we have called α and β. In such cases, however, it is possible to express the 'stability condition' directly in terms of the coefficients of the original equation. Again, we shall confine ourselves to stating the results ; namely, that for the equation

$$a_0 + a_1x + a_2x^2 + a_3x^3 + a_4x^4 = 0$$

(a) if the equation is quadratic ($a_3 = a_4 = 0$) it is sufficient that a_0, a_1 and a_2 all have the same sign)

(b) if the equation is cubic ($a_4 = 0$) a_0, a_1, a_2 and a_3 must all have the same sign and

$$a_1a_2 > a_0a_3$$

(c) if the equation is quartic, a_0, a_1, a_2, a_3 and a_4 must all have the same sign and if they are positive

$$a_1a_2a_3 > a_4a_1{}^2 + a_0a_3{}^2$$

Finally, we may sometimes be in no doubt that a system is stable, but we may want a more stringent condition than this ; namely, that every term in the transient response be damped at least as rapidly as e^{-kt}. This means that our characteristic equation must not merely be free from roots with positive real parts, but the real parts of the roots must all be less than $-k$ and, therefore, if we put $x + k = z$, the resulting equation in z must be free from roots with positive real parts. Now, $x = z - k$ so, if we put $(z - k)$ instead of x in the original equation [for example, the fifth-degree equation (1) first discussed] we find that

$$a_0 + a_1\,(z - k) + a_2(z - k)^2 + a_3(z - k)^3 + a_4(z - k)^4$$
$$+ a_5(z - k)^5 = 0,$$

regarded as an equation in z, must be free from roots with positive real parts. The criteria already obtained must therefore be applied to the equation

$$b_0 + b_1z + b_2z^2 + b_3z^3 + b_4z^4 + b_5z^5 = 0$$

where

$b_5 = a_5$; $b_4 = a_4 - 5ka_5$; $b_3 = a_3 - 4ka_4 + 10k^2a_5$;
$b_2 = a_2 - 3ka_3 + 6k^2a_4 - 10k^3a_5$;
$b_1 = a_1 - 2ka_2 + 3k^2a_3 - 4k^3a_4 - 5k^4a_5$
$b_0 = a_0 - ka_1 + k^2a_2 - k^3a_3 + k^4a_4 - k^5a_5$

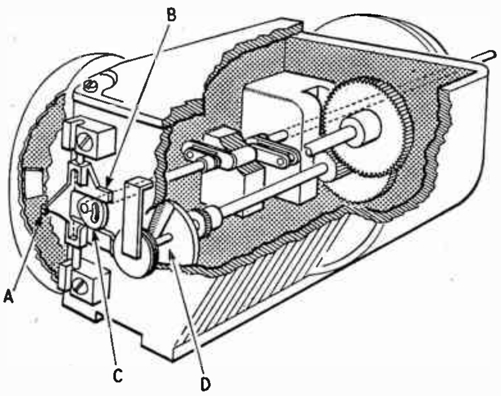
We have thus found a criterion for stability which does not require the drawing of Nyquist diagrams if the characteristic equation is known and, if the characteristic equation has degree not exceeding 5, no mathematical process more complicated than solving a quadratic equation with real roots is involved. The criterion can readily be adapted to securing a minimum damping rate.

Fast Film Pull-down Mechanism For Telerecording

THE most obvious way to record a television programme is to focus a cine camera on the television picture tube screen, open the shutter for two frames (one complete interlaced picture), close the shutter and feed the next section of film into position, photograph the next pair of frames, and so on. Unfortunately the time available for moving the film between exposures is very short, being only the frame blanking period, which is 1·4 msec in the British system. It is difficult to pull down a frame of film into position in such a short period without damaging it. Some alleviation of the difficulty is made possible by sacrificing a few lines at the top and bottom of the picture and so lengthening the time available but, clearly, this process cannot be carried far without serious loss of picture content. Until recently, therefore, this simple arrangement for telerecording has not been employed.

It has now, however, been shown that it is possible, by careful mechanical design, to achieve short enough film pull-down times. A new Marconi 16-mm film telerecording equipment employs a standard pull-down time of 2 msec, and this can be reduced if necessary so that pull-down occurs within the blanking period. The reliability claimed for the system is high ; 2,000 hours of operation without adjustment when using 2 msec pull-down.

The mechanism employed is precise but relatively simple. A synchronous motor controls film feed, shuttering and pull-down. The actual pull-down device is a sapphire-tipped claw which engages in the film sprocket feed holes. The claw is moved up and down by a shuttle driven by a cam rotated by the motor. The shuttle is also moved laterally by another cam, so that the claw engages and disengages with the holes at the appropriate times. Very light pressure is employed in the film gate, and the entire pull-down mechanism takes the form of an easily removable sub-unit which is immersed in an oil bath.

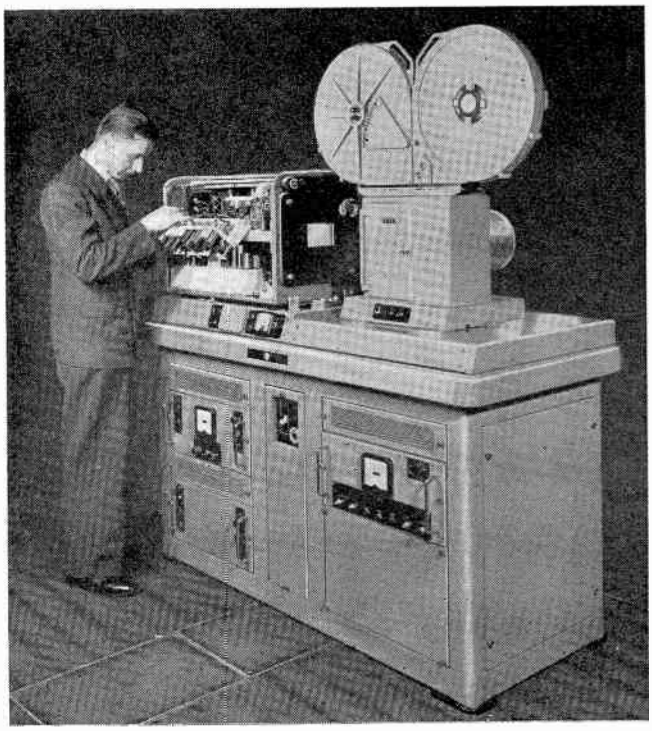


Mechanical details of the new Marconi telerecording system. The film claw (A) is attached to a shuttle (B), which is moved up and down by cam (C), to pull down the film and is engaged and disengaged from the film feed holes by a sideways motion imparted by cam (D)

(This drawing is based on Patent Specification No. 738317)

The use of a fast pull-down system makes for simplicity in the associated optical system and this, in turn, leads to improved picture quality.

The complete telerecording equipment



MANUFACTURERS' LITERATURE

T.C.L. Piezoelectric Ceramics. Barium titanate ceramic materials for ultrasonic transducers operating in the frequency range 15 kc/s–10·4 Mc/s, and for shock and vibration measurements, pickups, filters and oscillators, and surface roughness gauges. Pp. 17.
Technical Ceramics Ltd., Wood Burcote Way, Towcester, Northants.

Brimar Industrial Valves. Pp. 8. List of valves and equivalents.
Standard Telephones & Cables Ltd., Footscray, Sidcup, Kent.

Aero Research Technical Notes. Bulletin No. 168. The extent of Contact between Glue and Adherent. Pp. 12.
Aero Research Ltd., Duxford, Cambridge.

Tinplate Handbook. Pp. 44. Revised edition, with glossary of technical terms in French, German and Spanish.
Tin Research Institute, Fraser Road, Perivale, Greenford, Middx.

Low-Voltage Stabilizers. Pp. 4. Technical Bulletin on cadmium-nickel cells.
Mercia Enterprises Ltd., 30 *Silver Street, Coventry.*

Plessey Aluminium Mk. 4 Plugs and Sockets. Pp. 41.
The Plessey Company Ltd., Wiring and Connector Division, Kembray Street, Swindon, Wilts.

Ketay Precision Components. Pp. 14. Catalogue of servo components.
Ketay Ltd., Eddes House, Eastern Avenue West, Romford, Essex.

GLOSSARY OF ABBREVIATIONS

In this list will be found some of the abbreviations which are frequently met with in the various branches of the electronic and radio fields. The list is not confined to technical terms but includes organizations as well. It does not include algebraic symbols or abbreviations of units. Where the abbreviations refer to expressions in a foreign language only the translation is given.

It is hoped to publish additions to the list from time to time and suggestions for suitable items will be welcomed.

a	anode
a.c.	alternating current
ACE	Automatic Calculating Engine
a.c.r.	approach control radar
A.D.B.M.	Association of Dry Battery Manufacturers
A.E.M.T.	Association of Electrical Machinery Trades
A.E.R.E.	Atomic Energy Research Establishment
a.e.w.	airborne early warning
a.f.	audio frequency
a.f.c.	automatic frequency control
a.g.c.	automatic gain control
a.g.s.	automatic gain stabilization
a.i.	air interception
A.I.D.	Aeronautical Inspection Directorate
A.I.E.E.	American Institute of Electrical Engineers
a.m.	amplitude modulation
A.M.E.W.A.	Associated Manufacturers of Electric Wiring Accessories
A.M.S.S.F.G.	Association of Manufacturers of Small Switch and Fuse Gear
A.P.A.E.	Association of Public Address Engineers
a.ph.c.	automatic phase control
a.q.l.	acceptable quality level
A.R.D.E.	Armament Research and Development Establishment
ARINC	Aeronautical Radio Incorporated
A.R.L.	Admiralty Research Laboratory
a.r.o.	automatic range only
A.R.R.L.	American Radio Relay League
ASA	American Standards Association
A.S.D.I.C.	Allied Submarine Detection and Investigation Committee (name of equipment)
A.S.E.E.	Association of Supervising Electrical Engineers
ASESA	Armed Services Electro-Standards Agency
ASLIB	Association of Special Libraries and Information Bureaux
a.s.m.i.	aerodrome surface movement indicator
A.S.R.E.	Admiralty Signals and Radar Establishment
a.s.v.	air-to-surface vessel
a.t.c.	automatic tuning control
a.t.i.	aerial tuning inductance
a.v.c.	automatic volume control
A.W.R.E.	Atomic Weapons Research Establishment
b	base
B.A.	British Association (and screw threads)
B.A.A.S.	British Association for the Advancement of Science
BARK	Swedish relay-operated computer
B.B.C.	British Broadcasting Corporation
B.C.R.A.	British Ceramic Research Association
B.E.A.	British Engineers Association British European Airways
B.E.A.I.R.A.	British Electrical and Allied Industries Research Association
B.E.A.M.A.	British Electrical and Allied Manufacturers' Association
B.E.D.A.	British Electrical Development Association
B.E.T.R.O.	British Export Trades Research Organization
b.f.o.	beat-frequency oscillator
B.I.F.	British Industries Fair
B.I.M.C.A.M.	British Industrial Measuring and Control Apparatus Manufacturers' Association
BINAC	Binary Automatic Computer
B.N.E.C.	British Nuclear Energy Conference
B.O.A.C.	British Overseas Airways Corporation
B.o.T.	Board of Trade
b.p.	band-pass
B.P.C.	British Productivity Council
B.P.F.	British Plastics Federation
B.R.	British Railways
B.R.C.M.A.	British Radio Cabinet Manufacturers' Association
B.R.E.M.A.	British Radio Equipment Manufacturers' Association
Brit.I.R.E.	British Institution of Radio Engineers
B.R.V.M.A.	British Radio Valve Manufacturers' Association
B.S.F.	British Standard Fine (screw threads)
B.S.I.	British Standards Institution
B.S.I.R.A.	British Scientific Instruments Research Association
B.S.R.A.	British Sound Recording Association
B.S.T.	British Summer Time
B.W.G.	Birmingham Wire Gauge
c	collector
C.B.S.	Columbia Broadcasting System
C.C.I.F.	International Telephone Consultative Committee
C.C.I.R.	International Radio Consultative Committee
C.C.I.T.	International Telegraph Consultative Committee
C.C.I.T.T.	International Telegraph and Telephone Consultative Committee
C.E.A.	Central Electricity Authority
C.E.E.	International Commission for the rules of approval of Electrical Equipment
C.E.I.	International Electrotechnical Commission
c.g.s.	centimetre-gramme-second
C.I.E.	International Committee on Lighting
C.I.R.M.	International Committee on Maritime Radio
C.I.S.P.R.	International Special Committee on Radio Interference
C.I.T.	International Television Committee
C.M.A.	Cable Makers' Association
C.O.D.	Concise Oxford Dictionary
Coho	coherent oscillator
C.O.I.	Central Office of Information
Co.I.D.	Council of Industrial Design
C.S.I.R.O.	Commonwealth Scientific and Industrial Research Organization
c.r.	cathode ray
c.r.o.	cathode - ray oscilloscope (graph)
c.r.t.	cathode-ray tube
c.w.	continuous wave
d.a.p.	double-amplitude peak
dB	decibel
d.c.	direct current
d.c.c.	double cotton covered
DEUCE	Digital Electronic Universal Computing Engine
d.f.	direction finding
DIAD	Drum Information Assembler and Dispatcher
Dina	Direct-noise amplifier
d.m.e.	distance-measuring equipment
d.p.d.t.	double-pole double-throw
d.p.s.t.	double-pole single-throw
d.s.b.	double sideband
d.s.c.	double silk covered
D.S.I.R.	Department of Scientific and Industrial Research
DYSEAC	Second National Bureau of Standards Eastern Automatic Computer
e	emitter
E.A.W.	Electrical Association for Women
E.B.	Electricity Board
E.B.U.	European Broadcasting Union
E.C.A.	Electrical Contractors' Association
ECASS	Electronically Controlled Automatic-Switching System
e.c.g.	electrocardiogram (graph)
E.D.A.	British Electrical Development Association
e.d.p.m.	electronic data-processing machine
EDSAC	Electronic Delayed Storage Automatic Computer
EDVAC	Electronic Discrete Variable Automatic Computer
e.e.g.	electroencephalogram (graph)
E.F.V.A.	Educational Foundation for Visual Aids
E.G.	Engineers' Guild, Ltd.
e.h.t.	extra high tension
e.m.	electromagnetic
e.m.f.	electromotive force
E.M.T.A.	Electro-Medical Trade Association
e.m.u.	electromagnetic unit
en.	enamelled

ENIAC	Electro-Numerical Indicator And Calculator
e.p.r.	equivalent parallel resistance
E.P.U.	European Payments Union
E.R.A.	British Electrical and Allied Industries Research Association
ERNIE	Electronic Random Number Indication Equipment
e.r.p.	effective (equivalent) radiated power
e.s.	electrostatic
e.s.r.	equivalent series resistance
e.s.u.	electrostatic unit
E.T.U.	Electrical Trades Union
F.B.I.	Federation of British Industries
F.C.C.	Federal Communications Commission
f.m.	frequency modulation
f.s.d.	full-scale deflection
f.s.k.	frequency-shift keying
f.t.c.	fast time constant
g	grid
g.b.	grid bias
g.c.a.	ground-controlled approach
g.c.i.	ground-controlled interception
G.M.T.	Greenwich Mean Time
G.P.O.	General Post Office
g.w.	guided weapon
HEC	Hollerith Electronic Computer
h.f.	high frequency (3–30 Mc/s)
H.M.S.O.	Her Majesty's Stationery Office
h.p.	high-pass
h.t.	high tension
h.v.	high voltage
I.A.E.S.T.E.	International Association for the Exchange of Students for Technical Experience
I.A.R.U.	International Amateur Radio Union
I.C.A.O.	International Civil Aviation Organization
I.Chem.E.	Institution of Chemical Engineers
I.C.S.U.	International Council of Scientific Unions
i.c.w.	interrupted carrier wave
I.E.	Institution of Electronics
I.E.C.	International Electrotechnical Commission
I.E.E.	Institution of Electrical Engineers
I.E.S.	Illuminating Engineering Society
i.f.	intermediate frequency
i.f.f.	identification friend or foe
I.F.L.	Institute of Fluorescent Lighting
I.F.R.B.	International Frequency Registration Board
i.f.r.u.	interfering frequency rejection unit
I.G.Y.	International Geophysical Year
ILLIAC	University of Illinois Automatic Computer
I.L.O.	International Labour Organization
i.l.s.	instrument landing system
I.Mar.E.	Institute of Marine Engineers
I.Mech.E.	Institution of Mechanical Engineers
Inst.C.E.	Institution of Civil Engineers
I.Prod.E.	Institution of Production Engineers
I.R.E.	Institute of Radio Engineers
i.s.b.	independent sideband
I.S.F.A.	International Scientific Film Association
I.S.I.	International Statistical Institute
I.S.O.	International Organization for Standardization
I.T.A.	Independent Television Authority
I.T.U.	International Telecommunication Union
I.U.P.A.P.	International Union of Pure and Applied Physics
J.A.N.	Joint Army-Navy
J.E.T.E.C.	Joint Electron Tube Engineering Council
k	cathode
L.C.C.	London Chamber of Commerce London County Council
LEO	Lyons' Electronic Office
l.e.t.	linear energy transfer
l.f.	low-frequency (30–300 kc/s)
l.o.	local oscillator
Loran	Long-range navigation system
l.p.	long-playing low-pass
L.T.E.	London Transport Executive
l.v.	low voltage
l.w.	long wave
MADAM	Manchester Automatic Digital Machine
MANIAC	Mathematical Analyser, Numerical Indicator and Computer
maser	microwave amplification by stimulated emission of radiation
m.c.w.	modulated continuous wave
m.f.	medium frequency (300–3000 kc/s)
MIDAC	Michigan Digital Automatic Computer
MIL	Military (specification)
M.I.T.	Massachusetts Institute of Technology
m.k.s.	metre-kilogramme-second
m.m.f.	magnetomotive force
m.o.	master oscillator
M.o.F.P.	Ministry of Fuel and Power
MONECA	Motor network calculator
M.o.S.	Ministry of Supply
MOSAIC	Ministry of Supply Automatic Integrator and Computer
m.p.d.	maximum permissible dose
MSAC	Moore School Automatic Computer
MSF	Medium Standard Frequency
MUSA	Multiple-Unit Steerable Antenna
m.w.	medium wave
m.u.f.	maximum usable frequency
N.A.T.O.	North Atlantic Treaty Organization
N.B.C.	National Broadcasting Corporation
N.B.S.	National Bureau of Standards
N.C.B.	National Coal Board
N.C.T.	National Chamber of Trade
N.E.T.A.C.	Nuclear Energy Trade Associations' Conference
NORC	Naval Ordnance Research Computer
N.P.L.	National Physical Laboratory
N.R.D.C.	National Research and Development Corporation
n.t.c.	negative temperature coefficient
n.t.r.	noise temperature ratio
N.T.S.C.	National Television System Committee
O.E.E.C.	Organization for European Economic Co-operation
O.I.R.	International Broadcasting Organization
ORACLE	Oak Ridge Automatic Computer and Logical Engine
p.a.	power amplifier public address
p.a.m.	pulse-amplitude modulation
p.a.r.	precision approach radar
p.c.m.	pulse code modulation
p.d.	potential difference
p.d.a.	post-deflection accelerator
p.f.m.	pulse-frequency modulation
ph.m.	phase modulation
p.m.	permanent magnet pulse modulation
P.M.A.	Permanent Magnet Association
P.O.	Post Office
p.ph.m.	pulse phase modulation
p.p.i.	plan position indicator
p.p.m.	pulse position modulation
p.r.f.	pulse recurrence frequency
p.t.f.e.	polytetrafluoroethylene
p.v.c.	polyvinyl chloride
p.w.m.	pulse-width modulation
Q.P.L.	Qualified Products List
R.A.E.	Royal Aircraft Establishment
RASCAL	Royal Aircraft Establishment Sequence Calculator
RAYDAC	Raytheon Digital Computer
r.b.e.	relative biological effectiveness
R.C.E.E.A.	Radio Communication and Electronic Engineering Association
R.E.C.M.F.	Radio and Electronic Component Manufacturers' Federation
R.E.T.M.A.	Radio - Electronics - Television Manufacturers' Association
r.f.	radio frequency
r.h.i.	range-height indicator
R.I.C.	Radio Industry Council
R.I.Club	Radio Industries Club
R.N.S.S.	Royal Naval Scientific Service
r.p.m.	revolutions per minute
R.R.B.	Radio Research Board
R.R.E.	Royal Radar Establishment
R.S.G.B.	Radio Society of Great Britain
r/t	radio telephony
R.T.C.M.A.	Rubber and Thermoplastic Cable Manufacturers' Association
R.T.E.B.	Radio Trades Examination Board
R.T.R.A.	Radio and Television Retailers' Association
SAGE	Semi-Automatic Ground Environment
s.b.a.	standard beam approach
S.B.A.C.	Society of British Aircraft Constructors

S.B.C.	School Broadcasting Council for the United Kingdom
s.c.c.	single cotton covered
SEAC	National Bureau of Standards Eastern Automatic Computer
S.E.A.T.O.	South-East Asia Treaty Organization
SEC	Simple Electronic Computer
S.E.R.L.	Services' Electronics Research Laboratory
s.f.	signal frequency
S.F.A.	Scientific Film Association
s.g.	signal generator screen grid
S.H.A.P.E.	Supreme Headquarters Allied Powers in Europe
Shoran	Short-range navigation system
S.I.M.A.	Scientific Instrument Manufacturers' Association
S.M.P.T.E.	Society of Motion Picture and Television Engineers
s.p.d.t.	single-pole double-throw
s.p.s.t.	single-pole single-throw
S.R.D.E.	Signals Research and Development Establishment
s.r.e.	surveillance radar element
s.s.b.	single sideband
s.s.c.	single silk covered
S.S.Loran	Sky-wave synchronized Loran
stalo	stable local oscillator
s.t.c.	sensitivity time control (swept gain)
s.w.	short wave
SWAC	National Bureau of Standards Western Automatic Computer
s.w.g.	standard wire gauge
s.w.r.	standing-wave ratio
TAC	Tokyo Automatic Computer
TACAN	Tactical Air Navigation System
T.E.M.A.	Telecommunications Engineering and Manufacturing Association
T.I.D.U.	Technical Information Documents Unit
TR	transmit-receive
t.r.f.	tuned radio frequency
TRIDAC	Three-dimensional Analogue Computer
T.S.	Television Society
TV	television
U.D.C.	Universal Decimal Classification
U.E.R.	European Broadcasting Union
u.h.f.	ultra-high frequency (> 300 Mc/s)
U.I.T.	International Telecommunication Union
U.K.A.E.A.	United Kingdom Atomic Energy Authority
U.N.E.S.C.O.	United Nations Educational, Scientific and Cultural Organization
U.N.I.P.E.D.E.	International Union of Producers and Distributors of Electrical Energy
UNIVAC	Universal Automatic Computer
U.R.S.I.	International Scientific Radio Union
U.S.A.E.C.	United States Atomic Energy Commission
u.s.w.	ultra-short wave
U.T.	Universal Time
V.A.R.	visual-aural range
v.f.	video frequency voice frequency
v.f.o.	variable-frequency oscillator
v.h.f.	very high frequency (30–300 Mc/s)
v.i.r.	vulcanized india rubber
v.l.f.	very low frequency (< 30 kc/s)
v.m.	velocity modulation
V.O.R.	V.h.f. Omni-Range
VORTAC	V.O.R. and TACAN
v.s.w.r.	voltage standing-wave ratio
v.t.v.m.	vacuum-tube voltmeter
v.v.	valve voltmeter
w/t	wireless telegraphy

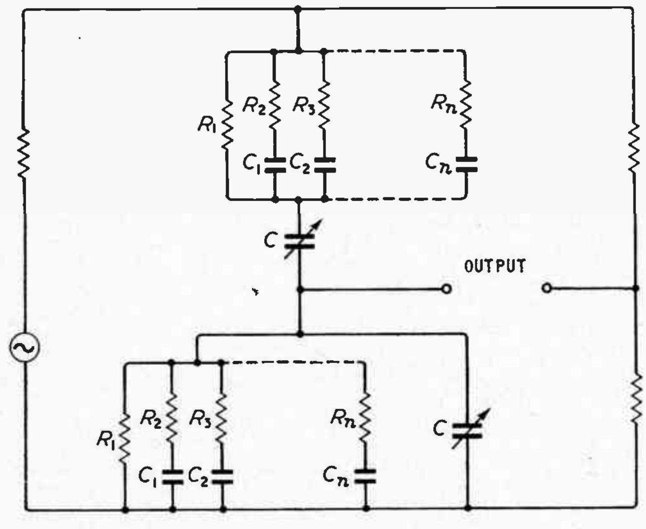
Very-Wide-Range Audio Oscillator

It is often convenient, when making frequency-response measurements at low frequencies, to explore the entire region of interest rapidly in one sweep.

The RC oscillator is an attractive proposition but for such applications, in the past, the frequency ratio has usually been limited to about 10 to 1. If the usual Wien-bridge type of tuning network is employed, with C variable, this is about the limit which can be achieved using normal components. Much greater ratios appear to be possible with variable R but, here again, practical components impose limits. In an oscillator with any pretence to precision and permanence of calibration, R will be wire-wound. Its maximum value will then be limited to about 100 kΩ. If 100 : 1 range is required, the minimum value is 1 kΩ. The resulting low impedance of the tuning network will often impose too great a load on the generator and cause the amplitude of oscillation to fall off severely. Further reduction of R will aggravate the effect. In practice, therefore, the frequency sweep is still limited to about 10 to 1, if good amplitude stability is to be obtained.

An oscillator using variable C, with a frequency sweep of 1,000 to 1, has recently been described[1].

Instead of switching $R_1 \ldots\ldots R_n$, these are connected permanently, the lower values by series capacitors. If the frequency is very high, so that all the added capacitors have negligible reactance in comparison with the values of their associated resistors, each resistance arm obviously behaves like a single resistor equal to $R_1 \ldots R_n$ in parallel. If the frequency is very low, so that $X_{c1} \gg R_2$, etc., the resistance arm reduces to R_1. By suitably staggering the values of C_1, R_2, C_2, R_3, etc., a smooth transition of impedance over the frequency range of interest can be obtained so that, as the size of the tuning capacitors C is increased, the effective size of the tuning resistors is increased, and the frequency is reduced faster than would be the case with one fixed value of R. In effect, the network behaves somewhat as if C and R were both variable, the main difference being that the impedance presented by the resistance arms no longer has a phase angle of zero.



Tuning Network

REFERENCE

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[1] Nicholas Kovalevski and B. M. Oliver, "An RC Oscillator that Covers the 20 cps—20 kc Range in a Single Dial Sweep", *Hewlett-Packard Journal*, January 1957.

Laboratory Chassis Elements

VERSATILE UNITS FOR 'BREADBOARD' EQUIPMENT

IN a production equipment, the metal chassis is generally in the form of an inverted tray with the valves on top and the small components beneath. This is convenient in practice, since it renders the valves (the components most likely to need changing) accessible, and provides some measure of protection against dust to the small components. In the laboratory, however, this form of chassis is inconvenient. During the breadboard stage of an equipment, one wants to be able to change components easily and to get at all points in the circuit for the purpose of making measurements. The valves are, in this case, the least important components. It is logical, therefore, to reverse the usual order of things and put the valves under the chassis and the rest of the components on top. This arrangement is catered for in the new Mullard 'Labix' breadboard chassis elements, shown in the accompanying pictures. These units also have sloping sides, which is a further aid to accessibility.

Basically, one unit is employed for each stage, or pair of stages, a variety of top panels being available to suit different valve bases.

Although described here as breadboard chassis, the units are obviously suitable for permanent use in 'one-off' equipments.

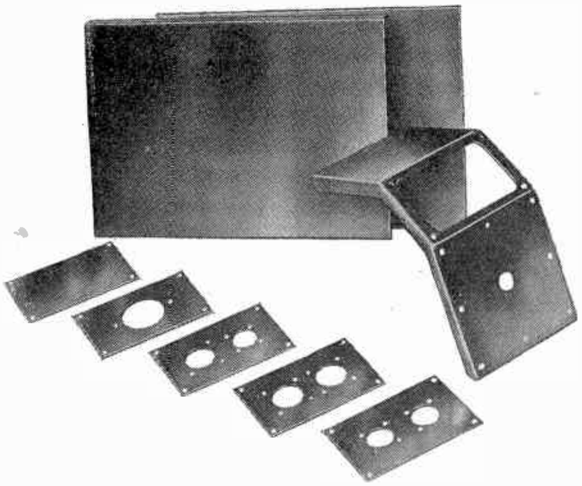


Fig. 1. *There are seven sub-units to the 'Labix' chassis. The basic chassis has sloping sides and a valve platform consisting of a series of interchangeable units. End plates are also available*

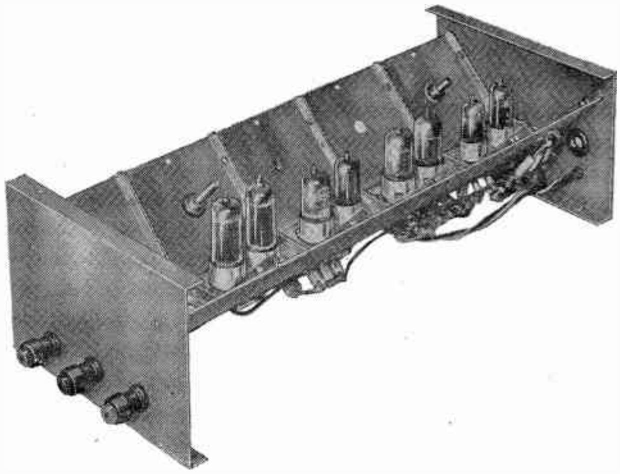


Fig. 3. *The finished equipment can be mounted with valves upright by means of end plates*

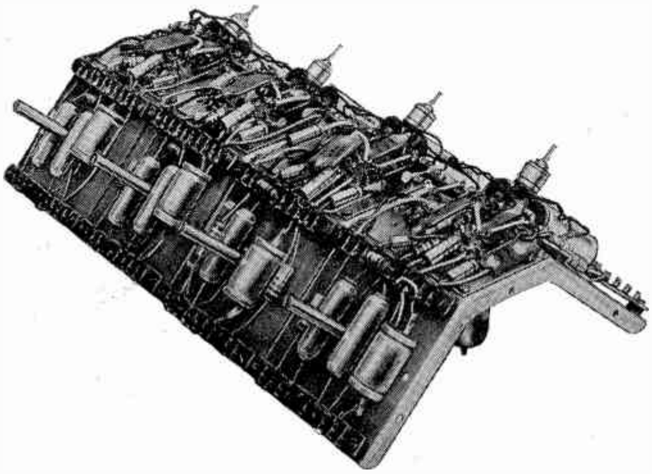


Fig. 2. *A typical prototype chassis using four 'Labix' units. Components and controls are readily accessible*

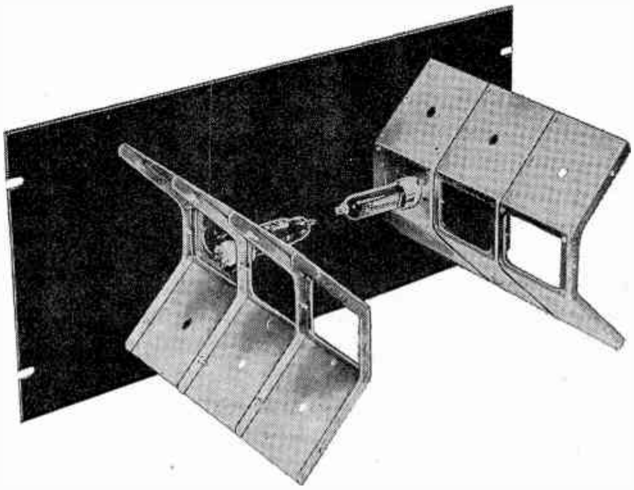


Fig. 4. *Two sets of chassis units can be conveniently accommodated on a 19-inch panel. In the example shown, the valves are in a 'heat chimney'*

Correspondence

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

Microwave Dissipative Material

SIR,—Further to the article in your March issue, we have used ratios of about 3 : 1 by weight (iron powder to resin) in order to get sufficient attenuation for short waveguide terminations at frequencies from S to Q Band.

For a ratio of $2\frac{1}{2}$: 1 we obtained in W.G.15 filled with the material

$$\begin{aligned} \lambda_a &= 3 \cdot 2 \text{ cm} \\ \lambda_d &= 0 \cdot 77 \text{ cm} \\ |\epsilon| &= 11 \cdot 7 \\ |\mu| &= 1 \cdot 6 \\ \text{dB/cm} &= 20 \end{aligned}$$

These figures tie up with extrapolations of the published curves quite well. The author comments that the attenuation constant for these mixing ratios is too high for accurate measurements by Birks' method, but we have found a reasonable measure of consistency by a simple extension of this method. This consists of taking readings for other piston positions in addition to the short-circuit and open-circuit positions to obtain points on a circle on a Smith Chart. The closeness to a circle is a measure of the precision of the results, and also from the size and position of the circle it is simple to calculate the dissipative loss of the sample under test. This may be used as a check on the attenuation coefficient calculated from the short-circuit open-circuit measurements. Also the insertion loss of different samples was measured directly as a further comparison.

Sample Thickness (in.)	dB/cm from s.c. and o.c. points	dB/cm from circle plot
0·100	19·4	18·0
0·150	20·4	20·2
0·200	20·0	19·5

From direct measurements of loss for samples up to 0·600-in. thick a mean slope of 20·5 dB/cm was deduced.

Measurements were also done with samples 3 : 1 and $3\frac{1}{2}$: 1, the latter giving 32 dB/cm. With one of these a sample 0·06-in. thick gave a Smith Chart circle going through the matched condition when the piston was 0·016 in. from the sample. This gave a very short waveguide termination, suitable for narrow-band applications (±2%) where space is severely limited.

Terminations for bands of the order of ±10% have been made from conical tapers approximately one and a half air wavelengths long. These have a v.s.w.r. of better than 0·98. Also shorter three-eighths wavelength, stepped cylindrical terminations have been made to have a v.s.w.r. better than 0·93 over a 5% band. Patent applications for these have been filed.

Araldite D has been used instead of Marco as the moulding resin. This change was found to give better consistency, to ease machining troubles, and to facilitate casting.

P. HUMPHREYS
J. BREWSTER

Microwave Division, E.M.I. Electronics Ltd.,
Feltham, Middx.
15th May 1957.

Dr. M. Y. El-Ibiary replies :

The agreement between the figures given by Messrs. Humphreys and Brewster and extrapolations of my results illustrates the consistency in the properties of the material. It is not clear, however, how their method would overcome the difficulties in measuring the properties of highly attenuating samples though, by using a greater number of experimental points, it may smooth out random errors. The s.c. and o.c. method determines two diametrically-opposite points on the Smith Chart and thus completely determines its position and size. The difficulty with highly attenuating samples is to obtain a circle of reasonable size. For this, the sample has to be very thin and machining tolerances become more severe. Further, the support of the sample in the waveguide with its faces normal to the axis requires an elaborate arrangement. The fact that the results obtained by moving the piston behind the sample are very nearly a circle on the Smith Chart does not indicate the absence of high-order modes excited at the faces of the sample due to imperfect geometry.

The waveguide terminations described by Messrs. Humphreys and Brewster are quite interesting, but they seem to have taken no advantage of the possibility of using more than one section of the material with different iron to resin ratios. This provides more freedom in design and may well lead to greater bandwidths.

[On page 106 of the original article, the words Fig. 5 and Fig. 6 in lines 7 and 9 (left-hand column) should be interchanged.]

Magnetic Amplifiers

SIR,—Your article in the April issue of *Electronic and Radio Engineer* gave a survey of magnetic amplifiers which was admirable within the limits of space available, but there are two points which I think worth enlarging on even for the non-specialist reader.

You said that "The response time of a non-feedback magnetic amplifier is of the order of 10 cycles of the energizing frequency". This is no doubt quantitatively true, but it is worth knowing that the magnetic amplifier conforms to the general principle that for a given type of amplifier the time-constant is proportional to the power gain[1]. The theoretical relationship as quoted by Storm[2] is

$$T = \frac{1}{4f} \cdot \frac{W_{out}}{W_{in}}$$

(Note that *power gain* is the relevant factor, not current amplification.) A response time of 10 cycles would then correspond to a power gain of about 40, which is perhaps reasonable for a simple amplifier without self-excitation (positive feedback). In theory, the use of feedback cannot change the overall gain-bandwidth of an amplifier. But the time-constants of control and load circuits of a practical magnetic amplifier differ so widely that the ratio of gain in the useful frequency range to time-constant may be improved by self-excitation. Storm[2] gives specimen figures for the "dynamic gain"; i.e., ratio of power gain to number of supply cycles in the response time, and in amplifiers with self-excitation this can be around 65 to 115. (One figure as high as 202 is cited.)

The other issue is the comparison of magnetic amplifier against transistor in terms of temperature effects. Since the majority of magnetic amplifiers employ semi-conducting devices as rectifiers, they are to that extent just as temperature-dependent as amplifiers which depend directly on the properties of semi-conductors.

D. A. BELL

Electrical Engineering Department,
University of Birmingham.
31st May 1957.

REFERENCES

[1] D. A. Bell, "General Theory of Electromagnetic Amplifiers", *Wireless Engr*, Vol. 31, December 1954, p. 310.

[2] H. F. Storm, "Magnetic Amplifiers", John Wiley, New York, 1955.

Uncorrelated Grid Noise

SIR,—In Dr. Bell's reply in the May issue to the points I raised in connection with his letter in your January issue, there are several questions requiring answers.

It is agreed that electron transits are mutually independent everywhere except (in a space-charge limited diode) near the potential minimum, but in common with others, I am of the opinion that interaction at the latter place is of importance in determining the magnitude of fluctuations in space-charge limited currents. When a potential minimum is present, the 'total-emission' damping and noise of the electrons that return to the cathode are likely to be very much less than those of a simple retarding field diode because, at frequencies below the electron plasma frequency at the potential minimum [$f = 7 \cdot 1 \times 10^7 i^{\frac{1}{2}}$ (c/s) where i is the current density in A/m² and the cathode temperature is 1000 °K], the dense space-charge near the cathode reduces the ripple on the electric field there to a negligibly small value.

The uncorrelated noise from the elastic reflection of some electrons at the anode is a partition noise, arising because the reflection of a given electron is a random event. The mean square current fluctuation is proportional to $r(1 - r)$ but since $r \ll 1$, it is taken to be proportional to r. Of course, there is also a smaller noise component, correlated with and in proportion to the noise in the primary stream.

The suitable tuning of the input circuit to which I referred was for minimum noise factor. The presence of terms in r (the fraction of the primary stream reflected) does in fact make the theoretical increase in tuning capacitance (required to go from maximum gain to minimum noise factor) progressively less as the frequency is increased. Quantitative comparison with the experimental results of Houlding and Glennie cannot be made with the present analysis which includes only powers of ωT_1 up to the second. For a proper comparison, all terms in $(\omega T_1)^3$ would have to be retained in the analysis, and this has not yet been done.

Elastically reflected electrons are certainly present in a valve and whether there are apparent discrepancies between theory and experiment or not, their effects at high frequencies must be accounted for. A calculation using the accepted transit time theory shows *inter alia* that they have a major effect on the noise performance of a triode. The sole assumption made is that because the paths of the reflected electrons will be slightly deflected when penetrating the grid, the mean time spent on their excursion in the cathode–grid space is about $\frac{3}{2}T_1$, T_1 being the transit time of the forward moving primary stream in the same space. The chance of second or multiple reflections of a given electron is considered to be negligible.

Since the above mentioned theory which leads to the results quoted in my letter appearing in your May issue also takes into account the relative timing of grid and anode pulses (through the relative phases of the Fourier components corresponding to ω), I shall be most interested to study Dr. Bell's calculation, when he publishes it.

Princes Risborough, Bucks. I. A. HARRIS

3rd June 1957.

New Books

Voltage Stabilized Supplies

By F. A. BENSON, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E. Pp. 370. Macdonald & Co. (Publishers) Ltd., 16 Maddox Street, London, W.1. Price 50s.

A large part of this book is devoted to glow-discharge tubes for use directly as stabilizers or as a source of reference voltage in more complex stabilizers of the valve type. Chapter 2 deals with stabilizers and Chapter 3 with the characteristics and limitations of the tubes, while Chapter 4 covers their noise and impedance–frequency characteristics. There is then a short chapter on corona and other discharge tubes. With the introduction, all this occupies 140 pages.

Chapter 6, of 43 pages, deals with thermionic-valve stabilizers and the remaining ones are headed: Power supplies for microwave oscillators, Characteristics of some reference elements, Stabilizers employing magnetic saturation, and Miscellaneous circuits. There is a copious bibliography.

A great deal of useful information about glow-discharge tubes and their use is included. The treatment of the basic thermionic-valve stabilizers is very thorough and includes mathematical analyses. The various modifications of them are dealt with only briefly and with frequent references to the literature.

The use of barretters is touched upon and there is a good discussion on the use of batteries to provide a reference voltage in place of the glow-discharge tube.

The book provides most of the information necessary for the understanding of stabilizers and the choice of a suitable type. For the commoner forms, it also gives adequate design information and for others it does tell one where further details can be found.

W.T.C.

Variable Capacitors and Trimmers

By G. W. A. DUMMER, M.B.E., M.I.E.E. Pp. 169. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 32s. 6d.

General information, including properties of some dielectrics and plate shapes for various laws; measurement of capacitance, dielectric loss, '*Q*', temperature coefficient; general-purpose multi-gang capacitors, precision variable capacitors, transmitter variable capacitors, trimmers, special types, faults, and future developments. There is a bibliography and a 36-page list of British-made variable capacitors.

Television Engineering Handbook

Edited by DONALD G. FINK. Pp. 1523 + xiv. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 112s. 6d.

This enormous book is the work of 33 authors and is divided into 20 chapters. Almost everything in the field of monochrome and colour television is mentioned, including transmission and reception, propagation, transmission lines and radiators. The coverage is so great that a detailed recital of the contents is impracticable.

It is essentially a reference book, not a textbook. A good feature is the emphasis on practice, for typical circuit values are frequently quoted. These are, naturally enough, mainly for the American television system, but design equations are usually given in general terms.

As is perhaps inevitable with so many different authors, there is some overlap between the sections and the form of treatment varies. In the case of scanning circuits, for instance, the various design equations are developed from first principles but, with video-coupling circuits, there is no comparable development, the various formulae being merely quoted. W.T.C.

Polythene

Edited by A. RENFREW and PHILLIP MORGAN. Pp. 567 + xiv. Published for *British Plastics* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 126s.

This book deals with the manufacture and properties of polythene, as well as processing techniques, applications and prospects. The 37 authors cover in considerable detail most aspects of the material and the newer developments, such as irradiated polythene, are included.

Induction and Dielectric Heating

Published by The British Electrical Development Association, 2 Savoy Hill, London, W.C.2. Pp. 190. Price 8s. 6d.

A comprehensive book for users of induction-heating equipment. There are 14 chapters and the book is divided into three parts, covering induction melting, induction heating and dielectric heating.

Analog Computer Techniques

By CLARENCE L. JOHNSON. Pp. 264. Published by McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 45s.

"Designed as an aid to those learning to use electronic analog computers, this book will make the transition period from neophyte to experienced computer operator easier for the engineer".

Servicing TV AFC Systems

By JOHN RUSSELL, Jr. Pp. 120. John F. Rider Publisher Inc., 116 West 14th Street, New York 11, U.S.A. Price $2.70.

This small book is intended as an aid to the servicing of American television receivers with 'flywheel' line time-base synchronization.

Les Semiconducteurs

By G. GOUDET and C. MEULEAU. Pp. 435. Editions Eyrolles, 61 Boulevard Saint-Germain, Paris 5e, France. Price Fr. 5720. (Post paid.)

Begins with a discussion of the physics of semiconductors, followed by a section on semiconductor technology and another on applications. Thirteen chapters and a bibliography (up to 1956).

Electronic Components Handbook

Edited by KEITH HENNEY and CRAIG WALSH. Pp. 244. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 67s. 6d.

The aim of this book is to give designers of U.S. military electronic equipment up-to-date information on resistors, capacitors, relays and switches. The book will be of great use to designers who have got a breadboard model of their equipment working satisfactorily and are confronted with the task of transforming this into an acceptable unit capable of reliable operation in the field. Its usefulness to British designers will, unfortunately, be limited by the fact that the JAN and MIL component specifications given may not have counterparts here. On the other hand, a knowledge of these specifications will be of interest to British manufacturers of N.A.T.O. equipment.

In any case, there is much material of general interest, including a brief but useful opening chapter on reliability. The latter is defined as "the probability of a device's performing its purpose adequately for the period of time intended under the operating conditions encountered". It is pointed out that, if an equipment has n parts, each with the same reliability R, the reliability of the equipment is R^n. With the increasing complexity of military equipment, component reliability is therefore extremely important. Some information on the measurement of reliability is given, including hints on the correct duration of a life-test.

The book appears to have been produced photographically from a typewritten original. Within the limitations of the technique, it is a model of neatness and clear presentation. G.W.S.

Frequency Response

Edited by RUFUS OLDENBURGER, Ph.D. Pp. 372. The Macmillan Company, New York. (London Branch, 10 South Audley Street, London, W.1.) Price 52s. 6d.

A collection of papers on the frequency response method of control system design.

An Introduction to Junction Transistor Theory

By R. D. MIDDLEBROOK. Pp. 296. John Wiley, available from Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 68s.

The physics of the device, and equivalent circuits.

The Radio Amateur's Handbook 1957

Pp. 576 (+32 pages of valve data and an index). Published by the American Radio Relay League Inc., West Hartford 7, Connecticut, U.S.A. Price $4.50.

Energy

By SIR OLIVER LODGE. Pp. 54. John F. Rider Publisher Inc., 116 West 14th Street, New York 11, U.S.A. Price $1.25.

A modern edition of Lodge's well-known work.

Notes on D.S.I.R. Grants for Graduate Students and Research Workers

Pp. 20. H.M.S.O., York House, Kingsway, London, W.C.2. Price 1s. 3d. (By post 1s. 5d.)

Television Programming and Production

By RICHARD HUBBELL. 3rd Edition. Pp. 272. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 32s.

This American book contains one chapter on television in England. There are 117 photographs and many drawings.

The Electronic Musical Instrument Manual

By ALAN DOUGLAS, M.I.R.E. Pp. 247. Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price 35s.

A revised and enlarged edition.

Elektronische Rechenmaschinen und Informationsverarbeitung (Electronic Digital Computing and Information Processing) Pp. 229. Published by Friedr. Vieweg & Sohn, Burgplatz 1, Braunschweig (20b), Germany. Price D.M. 26.

A collection of 64 papers, of which 18 are in English, 2 in French and the rest in German.

The Cathode-Ray Oscilloscope

By J. CZECH. Pp. 352. Philips' Technical Library. Distributed by Cleaver Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price 57s. 6d.

Deals with circuitry and applications of general-purpose oscilloscopes. Two complete designs are described.

L-C Oscillators

By ALEXANDER SCHURE, Ph.D., Ed.D. Pp. 72. John F. Rider Publisher Inc., 116 West 14th Street, New York 11, U.S.A. Price $1.25.

Electronic Tubes

By members of Philips' Electron Tube Division. Philips' Technical Library Series. Cleaver Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8.

Book XI. U.H.F. Tubes for Communication and Measuring Equipment.

Pp. 60. Contains valve data and notes on applications for 11 low-power valves and noise sources. Price 9s. 6d.

Book XII. Tubes for Computers.

Pp. 51. Data on 7 valves and cold-cathode tubes, general information on computing and numerous circuits. Price 9s. 6d.

Wall Charts

The price of the wall charts illustrating "The Principles of Radio", mentioned in the April issue, is 9s. for a set of three, not 10s. each.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Deviations from nominal frequency for May* 1957

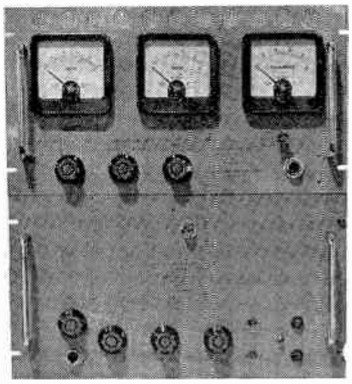
Date 1957 May	MSF 60 kc/s 2030 G.M.T. parts in 10^9	Droitwich 200 kc/s 1030 G.M.T. parts in 10^8
1	+ 5	+ 2
2	+ 4	+ 1
3	+ 4	+ 2
4	+ 4	+ 1
5	+ 4	+ 2
6	+ 4	+ 3
7	+ 5	+ 4
8	+ 5	— 1
9	+ 4	— 1
10	+ 4	— 1
11	+ 4	N.M.
12	+ 4	— 3
13	+ 4	— 2
14	+ 4	— 3
15	+ 5	— 1
16	+ 4	— 1
17	+ 4	— 1
18	+ 4	0
19	+ 5	— 1
20	+ 5	— 1
21	+ 5	— 3
22	— 4	— 3
23	— 2	— 4
24	— 1	— 3
25	0	— 4
26	0	— 3
27	0	— 3
28	0	— 3
29	+ 1	— 3
30	+ 1	— 2
31	+ 1	— 2

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

New Products

400-c/s Power Supply

Small 400-c/s power supplies for testing aircraft equipment, such as gyros, in the workshop are available. That illustrated is the PUM 16, with a three-phase output at 120 V or 40 V, 23 VA and a single-phase output at 10 V, 8 VA. The specified frequency stability is 0·2%, and the voltage stability 0·5%. A 30-V low-power output for use as a phase reference is provided in connection with the single-phase supply. The equipment operates from 50-c/s mains.



Hatfield Instruments Ltd.,
Crawley Road, Horsham, Sussex.

New Variacs

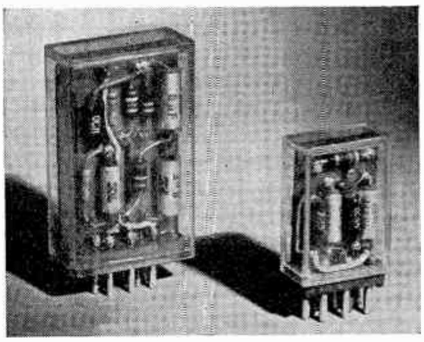
Claude Lyons Ltd. now have a high-power Variac type V-30H-2B with two independently-variable outputs. The total load rating is 4 kVA when the device is operated from a 230-V supply and 2 kVA on 115-V operation. The supply frequency may be 45–65 c/s.

Another new product is a fused Variac for laboratory or school use.

Claude Lyons Ltd.,
Valley Works, Ware Road, Hoddesdon, Herts.

Miniature Transistor Amplifiers

Venner Electronics have produced two types of transistor amplifier. The first, TS3, is intended for industrial applications and the response is said to be within 3 dB from 15 c/s to 125 kc/s; the second, TS4, is intended for frequencies in the audio range and has a response flat within 3 dB from 120 c/s to 10 kc/s. The voltage gains are between 900 and 1,000. Each type consists of two stages which may be used separately or in cascade. The amplifiers are assembled in plastic cases and are mounted on small 8-pin bases with identical pin connections.



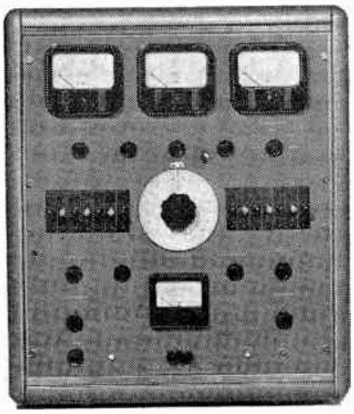
Type TS3 measures 1⅛ in. × 1⅞ in. × ⅝ in. and weighs ¾ oz.; type TS4 measures 1⅝ in. × 2¾ in. × ¾ in. and weighs 1½ ozs.

Both amplifiers are RC coupled and employ temperature-compensation circuits to give satisfactory working from −10°C to +50°C. The amplifiers are designed to work from a nominal 10-V supply but will function with supplies from 1·5 V d.c. to 12 V d.c. With a 10-V supply, the maximum undistorted output is 2 V r.m.s.

Venner Electronics Ltd.,
Kingston By-Pass, New Malden, Surrey.

Transistor Measuring Set

The Microcell transistor measuring set type 107 is described as a laboratory instrument capable of giving full information on the characteristics of p-n-p and n-p-n transistors. Collector and base direct currents are separately metered and continuously variable over a wide range. Small signal measurements are made at 1,000 c/s and include h, T-network, open and closed circuit parameters. Circuit configurations are either common emitter or common base.

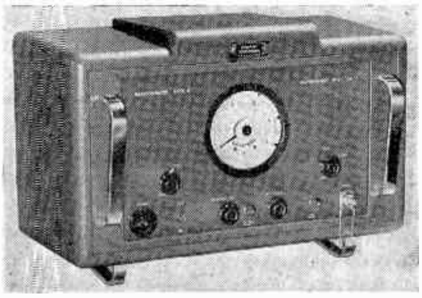


Measurements are claimed to be relatively simple, most being direct readings on a single calibrated dial. Completely matched pairs can be readily selected using this instrument.

Microcell Ltd.,
Imperial Buildings, 56 *Kingsway, London, W.C.*2.

Direct-Reading Magnetometer

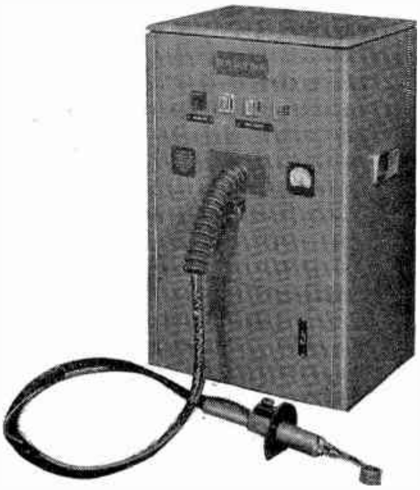
A sensitive direct-reading magnetometer manufactured by Newport Instruments is designed to measure fields of 0·1 to 500 oersteds. In operation, a ferrite torroid is magnetized to saturation by an a.c. field. In the presence of a magnetic field a winding on the ferrite delivers a second-harmonic output to a gain-stabilized amplifier and a valve voltmeter calibrated in oersteds. The short-term accuracy is said to exceed ±1%. A thermometer is provided in the measuring probe so that the necessary temperature-correction factor can be applied.



Newport Instruments (Scientific & Mobile) Ltd.,
Newport Pagnell, Bucks.

Induction Heater

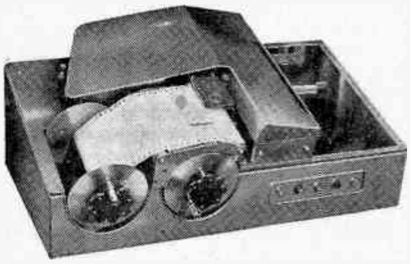
A new 1-kW Radyne induction heater is available in three versions. These are for vacuum-tube outgassing, laboratory work, and soldering and brazing.



Radio Heaters Ltd.,
Wokingham, Berks.

Data Reduction Equipment

Southern Instruments are developing a range of equipment to deal with analogue records on film or paper and provide digital read-out. The device illustrated is the K1015 Digital Trace Reader. This is a manually-operated equipment designed to speed up the analysis of records. The operator positions a cursor over the required part of a trace; this actuates a decoding disc which gives a digital output suitable for operating an electric typewriter. On 6-inch wide records, the maximum reading is 1,000 units.

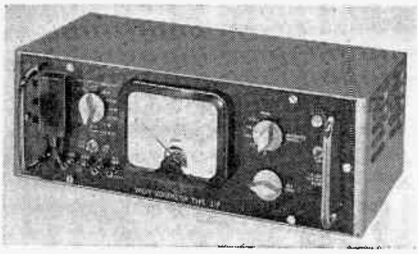


Another similar device gives an analogue voltage output which can be passed through function generators before being converted to digital form. This system enables scale or correction factors to be applied.

Southern Instruments Ltd.,
Frimley Road, Camberley, Surrey.

Valve Voltmeter

A new Airmec valve voltmeter, type 217, is described as an accurate general-purpose instrument. It is suitable for measuring balanced, unbalanced, or differential voltages in the frequency range 10 c/s to 200 Mc/s. In addition, direct voltages up to 500 V, and resistances from 100 ohms to 100 megohms can be measured. The instrument is of the diode-rectifier–d.c.-amplifier type, the rectifier being housed in a probe which can be stowed when not required. Low-frequency measurements can be made with the probe stowed by using terminals on the front panel of the instrument.



The five a.c. ranges cover 1·5 V to 150 V (f.s.d.), and the d.c. ranges 5, 50 or 500 V. The d.c. input resistance is about 40 megohms and the a.c. input is high and the capacitance low. Calibration accuracy is given as ±5% or better below 80 Mc/s. The accuracy of resistance measurements is ±10% and the maximum voltage to appear across the component under test is 5 V.

Airmec Ltd.,
High Wycombe, Bucks.

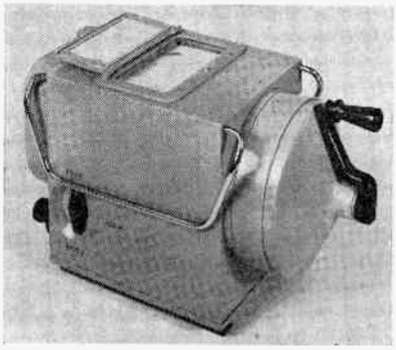
'Teramel' Winding Wires

'Teramel' is the name given to a new synthetic enamelled coil-winding wire which British Insulated Callender's Cables have recently developed. The insulant, which is a polyester-resin-based synthetic enamel, is claimed to possess excellent electrical and mechanical properties and, in particular, a high thermal stability—it may be used continuously at temperatures of up to 130°C. Its thermoplastic flow is negligible and it has a high resistance to abrasion. It is hard and adheres strongly to the copper, yet it is so flexible that the wires can be stretched, twisted and even flattened without damage to the film.

British Insulated Callender's Cables Ltd.,
21 Bloomsbury Street, London, W.C.1.

Insulation Tester

A recent addition to the 'Megger' range of instruments employs three test voltages. These are 1,000, 500 and 250 volts in a 200-megohm instrument. The scale range is the same for each test voltage.



Evershed & Vignoles Ltd.,
Acton Lane Works, Chiswick, London, W.4.

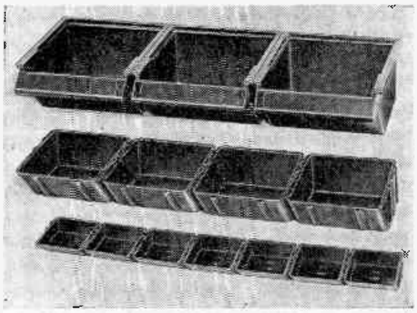
Band III Pre-amplifier

The Labgear type E.5044 Band III television pre-amplifier is a self-contained unit with its own power pack. One stage of amplification is provided, the gain being given as 15 dB and the bandwidth 3·5 Mc/s to −1·5 dB points. The mains supply to the pre-amplifier is intended to be connected via the main receiver's on/off switch. A switch puts the pre-amplifier in or out of circuit. In the out-of-circuit position Band I signals are passed to the receiver without amplification.

Labgear (Cambridge) Ltd.,
Willow Place, Cambridge.

Midget Storage Trays

The photograph shows 'Kabi' midget bench assembly and storage trays. These are made of moulded plastic material and have interlocking sides. The smallest trays measure $2\frac{5}{8}'' \times 2\frac{1}{16}'' \times \frac{3}{4}''$.



Precision Components (Barnet) Ltd.,
13 Byng Road, Barnet, Herts.

Low-Frequency Phasemeter

The requirements of the rapidly-expanding field of servo engineering and the subsequent interest in frequencies below 1 c/s are met by the D-729-B low-frequency phasemeter which has a lower frequency limit of 0·5 c/s. Measurements of the phase-change and gain of passive and active networks and the input/output characteristics of servo systems may be made without imposing an appreciable load. Direct indication of the phase angle and the difference in level between two substantially sinusoidal voltages is made possible by arranging that the two voltages are adjusted to the same predetermined level—the vector sum then becoming a function of phase angle only. Both voltages may be measured and, for distorted waveforms, sockets are provided between which a frequency-selective device may be connected. With this arrangement, the fundamental (or other specific frequency) may be selected and phase, level and voltage measurements may be made using the phasemeter indicator in the normal manner.

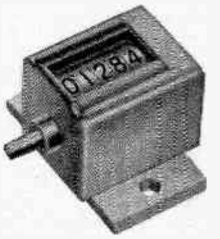
The phase-angle range of the instrument is 0–360°, with an accuracy of ±1° above 2 c/s, decreasing to ±3° at 0·5 c/s. The frequency range is 0·5 c/s to 10 kc/s.

The instrument may also be used as a voltmeter (1 mV to 20 V in eight ranges).

Muirhead & Co. Ltd., Beckenham, Kent.

Mechanical Counters

Small non-resettable mechanical counters are now made by Counting Instruments Ltd. These add one unit for each tenth of a revolution of the spindle. They are available in direct-drive, revolution and ratchet versions. The direct and revolution types subtract when the spindle motion is reversed.



Maximum counting speeds are stated as 500 counts per minute for ratchet types and 1,000 per minute for direct and revolution types.

Counting Instruments Ltd.,
5 Elstree Way, Boreham Wood, Herts.

Abstracts and References

OMPILED BY THE RADIO RESEARCH ORGANIZATION OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND PUBLISHED BY ARRANGEMENT WITH THAT DEPARTMENT

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually ; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses. Copies of articles or journals referred to are not available from Electronic & Radio Engineer. *Application must be made to the individual publishers concerned.*

ACOUSTICS AND AUDIO FREQUENCIES

534.13 : 539.2/.3].083 **1995**

Physical Acoustics and the Properties of Solids.—W. P. Mason. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1197-1206.) Many of the techniques of physical acoustics can be used to study the elastic properties and internal friction of a wide range of materials. Several examples are discussed in detail.

534.2 **1996**

Dispersion Equation for Normal Waves in Stratified Media.—L. M. Brekhovskich. (*Akust. Zh.*, Oct.–Dec. 1956, Vol. 2, No. 4, pp. 341–351.) A simple method of deriving the dispersion equation is shown and some particular cases are considered.

534.2 **1997**

Comparison of Methods of Calculating Pressure Fluctuations at a Diaphragm.—H. Jung. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 37–41.) The derivation of pressure conditions based either on considerations of the statistical distribution of molecular impacts or on the natural frequencies in a one- or three-dimensional model leads to an equivalent result only if isothermal conditions are assumed.

534.2-14 **1998**

On the Pressure Dependence of Sound Absorption in Liquids.—L. Liebermann. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1253–1255.) The absorption depends not only on the familiar shear viscosity but also on bulk viscosity which relates to the dilation or compression of the liquid. The analysis is applied to water and ethyl alcohol.

534.2-8 **1999**

Attenuation of Ultrasonic Waves of Finite Amplitude in Liquids.—V. Narasimhan & R. T. Beyer. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1233–1236.) The attenuation was measured in water and in aqueous solutions of acetic acid and manganous sulphate. In contrast to the results of Towle and Lindsay (2809 of 1955), the results indicate that for water the rate of increase of α/ν^2 with pressure decreases with increasing frequency.

534.21-14 **2000**

The Effect of Gas Bubbles on Sound Propagation in Water.—J. D. Macpherson. (*Proc. phys. Soc.*, 1st Jan. 1957, Vol. 70, No. 445B, pp. 85–92, plate.) An investigation in the frequency range 15–100 kc/s.

534.22-14 **2001**

Rao's Rule and its Basis.—B. B. Kudryavtsev. (*Akust. Zh.*, Oct.–Dec. 1956, Vol. 2, No. 4, pp. 331–340.) Rao's empirical relation connecting the velocity of sound in liquids and molecular volume (*Indian J. Phys.*, April 1940, Vol. 14, pp. 109–116) is discussed. 38 references including eleven to Russian literature.

534.232 : 538.65 : 621.318.134 **2002**

Performance of Ceramic Ferrite Resonators as Transducers and Filter Elements.—van der Burgt. (See 2232.)

534.232 : 546.431.824-31 **2003**

Vibrations in Long Rods of Barium Titanate with Electric Field Parallel to the Length.—C. V. Stephenson. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1192–1194.) The fundamental resonant and antiresonant frequencies are related to physical properties of the material. The theory was verified by experiment.

534.26 **2004**

Theory of Scattering of Sound by a Thin Rod.—L. M. Lyamshev. (*Akust. Zh.*, Oct.–Dec. 1956, Vol. 2, No. 4, pp. 358–365.) An expression is derived for the sound pressure in the scatter field of a thin, infinitely long, elastic rod with circular cross-section, taking into account the longitudinal and flexural vibrations.

534.26 **2005**

Some Results of the Theory of Diffraction of Sound at an Elastic Sphere.—S. N. Rzhevkin. (*Akust. Zh.*, Oct.–Dec. 1956, Vol. 2, No. 4, pp. 366–371.)

534.26-14 : 534.88 **2006**

Theory of the Shadow Zone Diffraction of Underwater Sound.—W. J. Noble. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1247–1252.) The theory of diffraction by a dark half-plane and an asymptotic expansion of the edge wave are used to calculate transmission anomalies. The dependence of the calculated values on range, wavelength and depth agrees with observations.

534.613 **2007**

The Possibility of an Absolute Calibration of Emitters and Receivers of Sound by Radiation Pressure with-

out the Use of a Radiometer.—V. A. Zverev. (*Akust. Zh.*, Oct.–Dec. 1956, Vol. 2, No. 4, pp. 378–379.) Absolute calibration by a modulation method is outlined.

534.78 **2008**

Electronic Binary Selection System for Phoneme Classification.—J. Wiren & H. L. Stubbs. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1082–1091.) A system for automatic classification of spoken English into several groups of phonemes is described.

534.78 **2009**

Note on Pitch-Synchronous Processing of Speech.—E. E. David, Jr, & H. S. McDonald. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1261–1266.) A gating system for reducing channel capacity based on the quasi-periodic nature of speech waveforms.

534.78 **2010**

Determination of the Speech Spectrum through Measurements of Superposed Samples.—T. H. Tarnóczy. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1270–1275.) The application of a magnetic-recording technique to Hungarian speech is reported.

534.78 : 621.391 **2011**

The Information Content of Noise Sounds.—F. Enkel. (*Nachrichtentech. Z.*, Nov. 1956, Vol. 9, No. 11, pp. 493–498.) Analytical tests using logatoms were made to assess the importance of the continuous noise spectrum above 4 500 c/s and the dynamic structure of consonant sounds. Redundancy in normal speech is also discussed.

534.79 **2012**

The Curves of Constant Loudness for Continuous Tones and for Single Pressure Impulses.—R. Feldtkeller. (*Frequenz*, Nov. 1956, Vol. 10, No. 11, pp. 356–358.) Brief discussion of a comparison of the curves. The impulses considered are of Gaussian shape, and their loudness is determined with reference to a 1-kc/s tone.

534.833.4 **2013**

Reactive Components in Sound Absorber Construction.—C. Becker. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1068–1071.)

534.84 **2014**

The Development of Equipment for Measuring Intelligibility Ratio.—W. Erler. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 53–59.) The apparatus described is used for the experimental determination of the ratio defined by Thiele (311 of 1954); it is suitable for direct tests or for tests on models to a scale of 1 : 20.

534.843 **2015**

Methods for Evaluating and Measuring the Diffusion of the Acoustic Field in Closed Rooms.—W. W. Furdujew (Furduev). (*NachrTech.*, Oct. 1956, Vol. 6, No. 10, pp. 448–454.) Critical survey and discussion of definitions and methods proposed by various authors. A measurement based on the correlation coefficient and taking account of the composition of the sound appears to be the most suitable and convenient method [see also 2973 of 1952 (Gershman)]. 21 references.

534.845 **2016**

The Dynamic Flow Parameter (Flow Resistance) of Circular Short Ducts.—W. Kraak. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 46–49.) The flow conditions in the short ducts of perforated sound-absorbing panels are calculated and a correction factor allowing for the length of the ducts is determined experimentally. Test results confirm the validity of the formulae given.

534.846 **2017**

Acoustics of Large Orchestral Studios and Concert Halls.—T. Somerville & C. L. S. Gilford. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 85–97.) A comparison between the acoustic properties of old-style concert halls and studios with more modern designs having fan-shaped plans and reflecting surfaces. The modern practice of directing sound to the back of the hall by reflection may improve speech audibility but reduces musical quality.

621.395.61/.62 **2018**

Speech Communications in Noise: some Equipment Problems.—M. E. Hawley. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1256–1260.) The paper includes discussions on the merits of pressure gradient microphones which discriminate against sound from distant sources, a.v.c. and peak clipping, and the use of headsets and earplugs.

621.395.623.7 **2019**

Investigation of the Reproduction of Audio Frequencies by a Cone-Type Loudspeaker.—F. Valentin. (*C. R. Acad. Sci., Paris*, 4th Feb. 1957, Vol. 244, No. 6, pp. 735–737.) Theory and experiment indicate that for true response above the resonance frequency a loudspeaker should be operated with constant-current rather than constant-voltage excitation.

621.395.625.3 **2020**

A Survey of Factors Limiting the Performance of Magnetic Recording Systems.—E. D. Daniel, P. E. Axon & W. T. Frost. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 158–168.) The nature and magnitude of departures from ideal performance of the various system elements are examined together with the element properties required for improved performance.

AERIALS AND TRANSMISSION LINES

621.372.2 **2021**

A Theoretical Study of Propagation along Tape Ladder Lines.—P. N. Butcher. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 169–176.) Dispersion curves are calculated for single-ridge, double-ridge, single T-section and double T-section ladder lines in which the rungs of the ladder are thin tapes. Qualitative predictions are confirmed.

621.372.2 **2022**

The Coupling Impedance of Tape Structures.—P. N. Butcher. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 177–187.) The exact solution to the problem of TEM wave propagation along a periodic array of parallel straight tapes is applicable to the determination of coupling impedances and dispersion curves of a variety of tape structures.

621.372.2 : 621.318.134 **2023**

Design Considerations for Broad-Band Ferrite Coaxial-Line Isolators.—J. Duncan, L. Swern, K. Tomiyasu & J. Hannwacker. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 483–490.) Circular polarization of the *H*-vector is produced by partially filling the coaxial line with a low-loss dielectric. Results are given for isolators of this type having an octave bandwidth.

621.372.2 : 621.318.134 **2024**

Analysis of Nonreciprocal Effects in an *N*-Wire Ferrite-Loaded Transmission Line.—H. Boyet & H. Seidel. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 491–495.) An analysis for a structure of *N* wires surrounding a thin ferrite pencil magnetized longitudinally.

621.372.43 : 621.317.3.029.64 **2025**

An S-Band Coaxial Load.—L. W. Shawe. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 191–192.)

621.372.8 **2026**

Propagation of Radio Waves in Slightly Curved Waveguides.—A. G. Sveshnikov. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1222–1229.) An approximate method of calculating e.m. wave propagation in slightly irregular waveguides is presented and the general formulae obtained are applied to the calculation of propagation in circular-cross-section waveguides with (*a*) circular and (*b*) sinusoidal curvature.

621.372.8 **2027**

Gyrotropic Infinitely Long Cylindrical Waveguide.—R. G. Mirimanov & L. G. Lomize. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1195–1221.) Review of theory of e.m. wave propagation in cylindrical waveguides, completely filled with ferrite, in the presence of longitudinal and transverse magnetizing fields. 19 references, including six to Russian literature.

621.372.8 **2028**

Calculation of Losses in Smooth Walls of Circular Waveguides on the Basis of Maxwell's Equations.—A. Turski. (*Archiwum Elektrotech.*, 1956, Vol. 5, No. 3, pp. 567–587. English summary, pp. 588–589.) The basic approach used is similar to that made by Sommerfeld in calculating the propagation of guided waves along a single solid conductor. By this approach, the field can be determined without assuming that the walls are perfectly conducting. A transcendental equation, which arises from the boundary conditions, is solved approximately giving the propagation constant and the damping factor. The errors introduced by other approximate methods for calculating the damping of various modes in circular waveguides are estimated.

621.372.8 **2029**

H-Guide—a New Microwave Concept.—F. J. Tischer. (*Electronic Ind. Tele-Tech*, Nov. 1956, Vol. 15, No. 11, pp. 50–51 . . 136.) The waveguide described consists of a dielectric slab of H-shaped cross-section with flat metallized outer vertical surfaces. Its attenuation is lower than that of rectangular guides and decreases continuously with increasing frequency. Junctions can be made without special connectors and the construction of microwave systems is simplified.

621.372.8 : 621.316.727.029.6 **2030**

A Microwave Waveguide Trombone Phase Shifter.—A. W. Adey & J. Britton. (*Canad. J. Phys.*, Nov. 1956, Vol. 34, No. 11, pp. 1112–1118.) "A microwave phase shifter is described which is based on the sliding principle of the trombone and which involves the telescoping together of two snugly-fitting sections of rectangular waveguide of different cross-sectional dimensions. $\lambda/2$ transformers are used to reduce the reflection at the change of waveguide cross-section. An attempt is made to increase the bandwidth of the instrument by making the transformers of different lengths. A phase change of several wavelengths is possible with an error of approximately ± one degree."

621.372.8 : 621.318.134 **2031**

The Character of Waveguide Modes in Gyromagnetic Media.—H. Seidel. (*Bell Syst. tech. J.*, March 1957, Vol. 36, No. 2, pp. 409–426.) "The effect of birefringence is studied in rectangular and circular waveguides with special attention paid to propagation characteristics in guides of arbitrarily small cross-section. Propagating, small-size structures are found in certain ranges of magnetization for both types of guide." See also 19 of January.

621.396.677.029.64 : 621.372.8 **2032**

An Experimental Dual-Polarization Antenna Feed for Three Radio Relay Bands.—R. W. Dawson. (*Bell Syst. tech. J.*, March 1957, Vol. 36, No. 2, pp. 391–408.) "The fundamental problems associated with coupled-wave transducers which operate over a 3-to-1 frequency band have been explored and usable solutions found. The experimental models described are directed toward the broad objectives of feeding the horn-reflector antenna with two polarizations of waves in the 4-, 6- and 11-kMc/s radio relay bands."

AUTOMATIC COMPUTERS

681.142 **2033**

The Wisconsin Integrally Synchronized Computer—a University Research Project.—J. L. Asmuth, C. H. Davidson, J. B. Miller, D. S. Noble & A. K. Scidmore. (*Commun. & Electronics*, July 1956, No. 25, pp. 330–338.)

681.142 **2034**

Approximate Solution of Differential Equations with Partial Derivatives using Electrical Analogues.—E. S. Kozlov & N. S. Nikolaev. (*Avtomatika i Telemekhanika*, Oct. 1956, Vol. 17, No. 10, pp. 890–896.) Analogues for solving Laplace, Poisson and Fourier-type equations are briefly discussed.

681.142 **2035**

A New Analogue Computer using Matrix Iteration for Determining the Roots of Algebraic Equations.—J. Miroux. (*Ann. Télécommun.*, Nov. 1956, Vol. 11, No. 11, pp. 226–232.) The mathematical principles underlying an experimental computer are detailed. Its application and possible development are discussed.

681.142 : 621.314.7 **2036**

The Junction Transistor as a Computing Element.—E. Wolfendale, L. P. Morgan & W. L. Stephenson. (*Electronic Engng*, Jan.–March 1957, Vol. 29, Nos. 347–349, pp. 2–7, 83–87 & 136–139.) The small-signal and transient characteristics of the transistor and their application to the design of basic circuits are described and examples of computer elements using transistors given.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.011.6 **2037**

Time Constants.—(*Wireless World*, May 1957, Vol. 63, No. 5, pp. 218–223.) A discussion of the rise and fall of voltage in *RC* and *RL* circuits with particular reference to blocking oscillators.

621.3.011.6 : 621.374 **2038**

Choice of Optimum Time Constants for Sections of Complex Pulse Systems.—S. N. Krize. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1255–1257.) A method of selecting the time constants so as to obtain a maximally steep pulse front of the output voltage is discussed.

621.3.012 **2039**

The Approximate Representation of Attenuation Curves by Straight Lines.—M. Gosewinkel. (*Frequenz*, Nov. 1956, Vol. 10, No. 11, pp. 348–356.) The method described is simpler, but less accurate, than others previously known [e.g. 2869 of 1955 (Kaufmann)]. It is particularly useful for evaluating the equivalent circuits of electro-acoustic systems.

621.316.726.078.3 **2040**

Phase-Lock A.F.C. Loop.—R. Leek. (*Electronic Radio Engr*, April & May 1957, Vol. 34, Nos. 4 & 5, pp. 141–146 & 177–183.) A detailed analysis is made of a system for tracking the rate of change of frequency (approximately 10 kc/s per second) of an input signal. Sources of error are discussed.

621.316.86 : 537.312.6 **2041**

Industrial Types of Thermistors and their Field of Application.—B. T. Kolomiets, I. T. Sheftel', E. V. Kurlina & G. I. Pavlova. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1177–1185.) The characteristics of Russian thermistors are tabulated and presented graphically and section drawings showing the construction of various types are given.

621.318.43 : 538.221 **2042**

Analysis of Instability and Response of Reactors with Rectangular-Hysteresis-Loop Core Material in Series with Capacitors.—J. T. Salihi. (*Commun. & Electronics*, July 1956, No. 25, pp. 296–305. Discussion, pp. 305–307.)

621.318.57 : 621.314.7 **2043**

The Symmetrical Transistor as a Bilateral Switching Element.—R. B. Trousdale. (*Commun. & Electronics*, Sept. 1956, No. 26, pp. 400–403.) The application of a Ge alloy-junction transistor in switching circuits is described. Signal attenuation greater than 100 dB in the 'off' position and insertion loss less than 0·2 dB in the 'on' position can be obtained. Possible improvements are discussed.

621.319.4 : 537.311.33 **2044**

A Metal-Semiconductor Capacitor.—R. L. Taylor & H. E. Haring. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 611–613.) A porous Ta/Ta$_2$O$_5$/MnO$_2$ capacitor is described. The characteristics are similar to those of wet electrolytic capacitors.

621.319.43 **2045**

Decade Air Condenser.—W. H. F. Griffiths. (*Engineer, Lond.*, 16th & 23rd Nov. 1956, Vol. 202, Nos. 5260 & 5261, pp. 691–693 & 728–731.) A detailed illustrated description is given of the design of a variable capacitor in which setting and reading errors are minimized. The moving plates, each comprising ten 'fingers', are located by a click mechanism to give the required capacitance increments. Fixed plates are suitably slotted to compensate for edge capacitances. An instrument consisting of two decade units with increments 1 000 and 100 pF and a continuously variable element is illustrated.

621.319.45 **2046**

On the Residual Voltage with Electrolytic Capacitors.—W. C. van Geel & C. A. Pistorius. (*Philips Res. Rep.*, Dec. 1956, Vol. 11, No. 6, pp. 471–478.) The residual voltage occurring in the electrolytic system Al/Al_2O_3/electrolyte is examined experimentally and the effect is explained on the assumption of a displacement of Al^{3+} ions in the Al_2O_3 lattice.

621.372.4+621.372.5 **2047**

Contribution to the Synthesis of Two-Terminal and Four-Terminal Reactance Networks.—W. Saraga. (*Nachrichtentech. Z.*, Nov. 1956, Vol. 9, No. 11, pp. 519–532.) The method of synthesis discussed uses as primary design parameters the points at which suitably chosen rational functions become unity. The application of this method, although very restricted, permits the realization of networks with a minimum of calculation; analysis based on these 'unity points' is much more widely applicable. 22 references.

621.372.412 : 537.228.1 **2048**

The Concept of Resonance of Piezoelectric Crystal Resonators.—G. Becker. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 467–477.) The relation between the equivalent series and parallel resonance and the physical resonances is discussed and the definition of the concepts is extended. Criteria are given for differentiating between the two types of crystal oscillator.

621.372.413 **2049**

On the Coupling between Two Cavities.—R. N. Gould & A. Cunliffe. (*Phil. Mag.*, Dec. 1956, Vol. 1, No. 12, pp. 1126–1129.) A general method of calculating the electric and magnetic field configurations and associated eigenvalues is derived in terms of orthogonal functions for two electromagnetic cavity resonators which are coupled through an iris closed by a thin partition.

621.372.5 **2050**

General Theory of Circuits with Nonlinear Magnetic Elements.—S. A. Ginzburg. (*Avtomatika i Telemekhanika*, Sept. 1956, Vol. 17, No. 9, pp. 799–810.)

621.372.54 **2051**

Catalogued Filters.—E. Glowatzki. (*Nachrichtentech. Z.*, Nov. 1956, Vol. 9, No. 11, pp. 508–513.) Report on systematic filter calculations carried out with the aid of the electronic computer G1 at Göttingen. A survey of data already tabulated is illustrated by examples from the catalogue. See also 351 of 1956.

621.372.54 **2052**

Frequency Transformations and Dissipative Effects in Electric Wave Filters.—D. J. H. Maclean. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 108–114.) The relevant frequency transformation, e.g. low-pass to band-pass, is applied to the root positions of the low-pass equivalent network; the resulting pattern is used in a graphical estimation of the effects of dissipation.

621.372.54 **2053**

Synthesis of Tchebycheff Parameter Symmetrical Filters.—A. J. Grossman. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 454–473.) A discussion of the earlier work of Darlington (1361 of 1940) on reactive Tchebycheff-type filters, with details of their design.

621.372.543 **2054**

Synchronous Filter-Oscillator for Frequency [-controlled] **Equipment in Telemechanics.**—V. L. Inosov & A. M. Luchuk. (*Avtomatika i Telemekhanika*, Oct. 1956, Vol. 17, No. 10, pp. 936–940.) The operation of this relay filter circuit is based on synchronism of the local-oscillator frequency with the input signal. The capture of the local-oscillator frequency by signals within a narrow band about the natural frequency of the oscillator results in an effective narrow-band filter. A suitable circuit is described.

621.372.543.2 : 538.652 **2055**

Equivalent Circuit of a Resonant, Finite, Isotropic, Elastic Circular Disk.—R. L. Sharma. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1153–1158.) The analysis applies to the first three symmetrical flexural modes. The results are in fair agreement with experimental data on mechanical filters.

621.372.543.2 : 621.372.413 **2056**

A Resonant-Cavity Filter for the S-Band.—A. A. L. Browne. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 193–195.) A tunable filter terminated with coaxial couplings has a second-harmonic rejection of more than 30 dB.

621.372.55 : 534.861.3 **2057**

Correct Low- and High- [frequency] **Compensation of Sound Distortion.**—H. Völz. (*Funk-Technik, Berlin*, Nov. 1956, Vol. 11, No. 21, pp. 628–630.) The development of a tone-compensated volume control in the form of a *RC* network is described.

621.372.56.029.6 **2058**

Methods of Vapour Deposition and Measurement for the Manufacture and Calibration of Strip Attenuators for the Microwave Region.—M. Bonitz. (*NachrTech.*, Oct. 1956, Vol. 6, No. 10, pp. 443–448.) Brief outline of method ensuring uniform deposition by using a plane source of evaporation, and description of a method of reasonable accuracy based on v.s.w.r. for use where standard attenuators are not available.

621.372.6 **2059**

The Admittance Matrix of Passive and Active Networks.—H. Pecher. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 494–498.) General rules for the formation of the matrix are derived and applied to known valve and transistor circuits.

621.373.4 **2060**

Nonlinear Coupled Systems.—L. Sideriades. (*J. Phys. Radium*, Nov. 1956, Vol. 17, Supplement to No. 11, *Phys. appl.*, pp. 159A–175A.) See also 2339 and 2666 of 1956.

621.373.4 **2061**

Fluctuations in a Valve Oscillator in the Presence of Grid Current.—L. I. Gudzenko. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1240–1254.) Phase and amplitude fluctuations in tuned-anode and tuned-grid oscillators due to the thermal noise of the resistance in the tuned circuit and the shot noise in the anode and grid currents are considered; the depression of the shot noise by the space charge is neglected. Fluctuations in a tuned-grid oscillator with automatic cathode bias are also discussed.

621.373.4.029.6 **2062**

Influence of the Transit Angle of Electrons in a [reflex-klystron] **Valve on the Synchronizing Action of an External Signal.**—F. M. Klement'ev. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1284–1287.) Theoretical discussion. Conditions for the stability of synchronization are derived.

621.373.421.11 **2063**

The Fluctuation-Type Nature of the Establishment of Oscillation Amplitude in an Oscillator.—V. I. Tikhonov. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1262–1267.) A quantitative estimate is made of the effect of initial conditions on the variance of the times required to reach a given amplitude of oscillations.

621.373.421.13 : 621.372.412 **2064**

The Performance of Crystal Oscillators.—R. A. Spears. (*A.T.E. J.*, Oct. 1956, Vol. 12, No. 4, pp. 234–240.) The effects of variations in circuit constants and parameters are described with particular reference to temperature effects.

621.373.43 **2065**

Experiments with Pulse Generators with High Pulse Repetition Frequency.—R. Gerharz. (*Z. angew. Phys.*, Nov. 1956, Vol. 8, No. 11, pp. 531–535.) The apparatus investigated consists, basically, of a single-stage electron multiplier and a coaxial delay line; it produces pulses of consistent shape, at a maximum frequency of 40 Mc/s, 2-mμs rise time and peak amplitude of about 5 V. Modifications to obtain frequency multiplication and division are also discussed.

621.373.43 : 621.383.27 : 535.376 **2066**

An Electron Multiplier as a Pulsed Light Source.—Gerharz. (See 2309.)

621.373.431.1 : 621.318.57 : 621.373.52 **2067**

Power Transistor Switching Circuit.—C. Huang & E. Slobodzinski. (*Commun. & Electronics*, July 1956, No. 25, pp. 290–296.) Methods and results of measurements of the d.c. parameters of the Type-2N68 transistor are discussed. Bistable transistor circuits with temperature compensation are described.

621.373.442 : 621.372.543.2 **2068**

Application of Underexcited *RC* Oscillators as Band [-pass] **Filters.**—L. N. Kaptsov. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1258–1261.)

621.373.52 **2069**

A Single-Transistor Magnetic-Coupled Oscillator.—Kan Chen & A. J. Schiewe. (*Commun. & Electronics*, Sept. 1956, No. 26, pp. 396–399. Discussion p. 400.) The oscillator circuit developed by Van Allen (*Trans. Amer. Inst. elect. Engrs*, July 1955, Vol. 74, Part 1, pp. 356–361) is discussed. This consists of two magnetic cores with two junction transistors acting as switches and produces a square wave of frequency proportional to the d.c. input voltage. From this circuit a single-core, single-transistor oscillator has been derived which has good frequency stability with temperature when a Si transistor is used.

621.373.52 **2070**

Field-Effect-Transistor Applications.—C. Huang, M. Marshall & B. H. White. (*Commun. & Electronics*, July 1956, No. 25, pp. 323–329.) Parameters of a Ge transistor are measured with reference to an a.c. equivalent circuit. The design of some suitable switching and oscillator circuits is outlined.

621.374.4 : 621.385.029.6 **2071**

Frequency Multiplication with a Reflex Klystron.—E. N. Bazarov & M. E. Zhabotinski. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, p. 1292.) Brief note on conversion efficiency obtained with a klystron, the resonator of which was tuned to the second harmonic. The theory was discussed earlier (1375 of May).

621.375.2 : 621.3.08.015.3 **2072**

Periodic Sampling Logarithmic Amplifier.—S. J. Nettel. (*Rev. sci. Instrum.*, Jan. 1957, Vol. 28, No. 1, pp. 37–40.) This amplifier gives a logarithmic output over four decades, derived from the time taken for the voltage across a parallel *RC* combination to decay to a fixed value.

621.375.2.029.3 **2073**

Inexpensive Pre-amplifier.—P. J. Baxandall. (*Wireless World*, May 1957, Vol. 63, No. 5, pp. 209–212.) Description of a unit with negative-feedback tone control suitable for use with a crystal pickup and the high-quality amplifier described earlier (1706 of June), or for a.f. tuning in an f.m. receiver.

621.375.23 **2074**

The Interaction Concept in Feedback Design.—N. H. Crowhurst. (*Audio*, Oct. & Nov. 1956, Vol. 40, Nos. 10 & 11, pp. 38 . . 85 & 32 . . 81.) A method of analysing feedback amplifiers is presented which enables the effect of closing the feedback loop to be considered in isolation.

621.375.3 **2075**

Bibliography of Magnetic Amplifiers for 1955.—G. V. Subbotina. (*Avtomatika i Telemekhanika*, Sept. 1956, Vol. 17, No. 9, pp. 858–864.) Over 130 references, including over 30 to Russian papers, dissertations and patents, are listed.

621.375.3 **2076**

The Pulse-Stretch Coupling Circuit.—H. W. Patton. (*Commun. & Electronics*, Sept. 1956, No. 26, pp. 377–379.) The circuit described is for use on half-wave and full-wave magnetic amplifiers where fast response and high power gain are required. A biasing pulse is used to block the power winding of the reactor thus facilitating reset.

621.375.4 **2077**

The Design of Wide-Band Transistor Amplifiers.—G. Meyer-Brötz & K. Felle. (*Nachrichtentech. Z.*, Nov. 1956, Vol. 9, No. 11, pp. 498–503.) Formulae are derived for calculating the approximate frequency characteristics of multistage amplifiers.

621.375.4 **2078**

Temperature Stabilization of Transistor Amplifiers.—L. M. Vallese. (*Commun. & Electronics*, Sept. 1956, No. 26, pp. 379–384.) Design formulae, particularly for thermistor compensation, are derived from an analysis of the thermal behaviour of the amplifier.

621.375.5 : 546.42/431].824-31 **2079**

Hysteresis Loops in Dielectric Amplifiers.—E. Wingrove, L. Depian & W. L. Shevel. (*Commun. & Electronics*, July 1956, No. 25, pp. 283–288. Discussion, pp. 288–289.) The behaviour of nonlinear capacitors used in dielectric amplifiers was investigated experimentally. The ceramic material examined consisted of sintered (Ba,Sr)TiO$_3$ crystals formed into 0·007 in. thick sheets silvered on both sides. Amplifier analysis is simplified by representing the nonlinear capacitor by equivalent linear circuit elements.

621.376.222.029.63 **2080**

Minimizing Incidental Frequency Modulation in Amplitude-Modulated U.H.F. Oscillators.—G. Schaffner. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 524–530.) Compensation for changes in cathode-grid transit time is obtained by adjustment of the feedback and cathode lines.

621.376.23 : 621.375.4 : 621.314.7 **2081**

A Transistor Demodulator.—H. Sutcliffe. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 140–141.) The junction-type transistors provide linear signal amplification besides rectification.

621.376.54 **2082**

Pulse-Width-Modulation Unit for Investigating Pulse Control Systems by means of an Electronic Analogue.—M. A. Shnaidman. (*Avtomatika i Telemekhanika*, Oct. 1956, Vol. 17, No. 10, pp. 910–920.)

GENERAL PHYSICS

535.215+537.37 **2083**

New Views on the Mechanism of Photoconductivity and Phosphorescence.—N. A. Tolstoi. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1135–1143.) Discussion of the 'two-step' excitation mechanism. This theory is contrasted with the 'bimolecular' theory.

537.226.1 **2084**

Remark on the Calculation of the Static Dielectric Constant.—H. Fröhlich. (*Physica*, Oct. 1956, Vol. 22, No. 10, pp. 898–904.) "Macroscopic relations are derived between the dielectric constant and the fluctuations of the dipole moment of a substance. They can be used as a basis for a microscopic calculation of the dielectric constant."

537.226.2 : 537.311.33 **2085**

Measurement of the Permittivity of High-Conductivity Materials (Semiconductors).—F. M. Popov. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1268–1271.) Results are tabulated of an experimental investigation of the validity of four different formulae for calculating the permittivity of a semiconductor by measurement of the dielectric constant of a mixture of the semiconductor and a dielectric with known permittivity.

537.226.2 : 537.311.62 **2086**

The Introduction of an Effective Dielectric Constant at High Frequencies.—E. A. Kaner & M. I. Kaganov. (*Zh. eksp. teor. Fiz.*, Sept. 1956, Vol. 31, No. 3(9), pp. 459–461.) An effective dielectric constant given by the relation $\epsilon_{\mathrm{eff}} = (4\pi/cZ)^2$, where Z is the surface impedance of the metal, is shown to apply under anomalous as well as normal skin-effect conditions.

537.226.3 : 621.317.335.029.63 **2087**

The Association of Dipole Molecules [determined] **from an Investigation of the Dispersion and Absorption of their Solutions in the dm-Wave Region.**—E. Fischer & N. Zengin. (*Z. Phys.*, 27th Nov. 1956, Vol. 147, No. 1, pp. 113–124.)

537.3 **2088**

Proceedings of the International Conference on Electron Transport in Metals and Solids.—(*Canad. J. Phys.*, Dec. 1956, Vol. 34, No. 12A, pp. 1171–1423.) A special issue containing the papers presented at the conference held in Ottawa in September 1956, including the following:

Interaction between Electrons and Lattice Vibrations.—J. Bardeen (pp. 1171–1186).

On the Electrical Resistivity of Stacking Faults in Monovalent Metals.—A. Seeger (pp. 1219–1234).

The General Variational Principle of Transport Theory.—J. M. Ziman (pp. 1256–1273).

Remarks on the Anomalous Behaviour of Alloys Containing Traces of Manganese or Similar Elements.—C. J. Gorter, G. J. van den Berg & J. de Nobel (pp. 1281–1284).

Magnetization and Magnetoresistance of some Dilute Alloys of Mn in Cu.—R. W. Schmitt & I. S. Jacobs (pp. 1285–1289).

On the Resistivity Anomalies in some Diluted Alloys.—J. Korringa (pp. 1290–1291).

Heat Transfer in Semiconductors.— A. F. Joffé (pp. 1342–1353).

On the Transition to Metallic Conduction in Semiconductors.—N. F. Mott (pp. 1356–1367).

The Chemical Bond in Semiconductors. The Group VB to VIIB Elements and Compounds Formed Between Them.—E. Mooser & W. B. Pearson (pp. 1369–1376).

Our Knowledge of the Fermi Surface.—R. G. Chambers (pp. 1395–1420).

Discussion on the papers is also included.

537.311.1 **2089**

Phenomenological Theory of Conductivity.—G. Beck. (*Nuovo Cim.*, 1st Nov. 1956, Vol. 4, No. 5, pp. 1190–1191. In English.)

537.323.08 **2090**

Methods of Precision Measurement of the Peltier Effect and Thermoelectromotive Forces.—M. Shtenbek & P. I. Baranski. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1373–1388.) The methods used in an experimental investigation into the fundamental thermoelectric relation in single crystals of germanium are described in detail, and the possible errors are analysed.

537.5 **2091**

Radiation Temperature of a Plasma.—F. Bitter & J. F. Waymouth. (*J. opt. Soc. Amer.*, Oct. 1956, Vol. 46, No. 10, pp. 882–884.)

537.533 **2092**

Electron Emission from Solids after Mechanical Work or Irradiation: Exoelectrons and Photoelectrons.—E. L. Huguenin & J. G. Valat. (*J. Phys. Radium*, Nov. 1956, Vol. 17, No. 11, pp. 965–975.) Survey of theoretical work and experimental investigations of this effect. Nassenstein's theory (see 87 of 1955) appears to be the most generally applicable of those noted. 49 references.

537.533 : 537.58 **2093**

Investigation of Thermionic Emission during the Transition from the Solid into the Liquid State.—V. G. Bol'shov. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1150–1162.) Measurements on Cu, Ag and Ge are reported. Results show that at the melting point (*a*) the thermionic current does not change sharply and (*b*) the slope of the log $(I/T^2)/(I/T)$ curve changes.

537.533 : 539.211 **2094**

The Surface Migration of Tungsten Atoms in an Electric Field.—I. L. Sokol'skaya. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1177–1184.) The temperature dependence of the time for a change of shape of a fine tungsten point in a field-emission microscope was investigated experimentally. The activation energies for the build-up and smoothing processes were 2·36 and 3·2 eV respectively.

537.533.8 : 546.561-31 **2095**

Investigation of the Angular Distribution of Secondary Electrons from Cuprous Oxide and their Energy Distribution.—N. B. Gornyi. (*Zh. eksp. teor. Fiz.*, Sept. 1956, Vol. 31, No. 3(9), pp. 386–392.) Experimental results, corrected for the effect of tertiary electrons, confirm the cosine-law angular distribution of secondary electrons. The energy distribution at various angles was also investigated and the effect of tertiary electrons on the experimental results is discussed.

537.56 **2096**

The Dissipation of Magnetic Energy in an Ionized Gas.—T. G. Cowling. (*Mon. Not. R. astr. Soc.*, Nov. 1956, Vol. 116, No. 1, pp. 114–124.) Piddington's theory (3578 and 3579 of 1955) is discussed with reference to the general formula derived; the application of the results to magnetic fields in interstellar clouds is considered.

537.56 **2097**

Kinetic Theory of Weakly Ionized Homogeneous Plasmas: Part 3.—M. Bayet, J. L. Delcroix & J. F. Denisse. (*J. Phys. Radium*, Nov. 1956, Vol. 17, No. 11, pp. 923–930.) This continuation of previous work (see 1624 and 2915 of 1955) deals with the investigation of an imperfect Lorentz-type gas where account is taken of the energy exchange between electrons and molecules. A collision operator is defined and associated functions and values are calculated.

537.56 **2098**

Study of Plasmas under Transient Conditions.—J. Salmon. (*J. Phys. Radium*, Nov. 1956, Vol. 17, No. 11, pp. 931–933.) A formula is derived to represent the conditions in an imperfect Lorentz-type gas after the removal of the electric field. A comparison shows that results agree with those obtained by the method of Bayet et al. (see 2097 above).

537.56 : 538.566 **2099**

Microwave Conductivity of an Ionized Decaying Plasma at Low Pressures.—A. L. Gilardini & S. C. Brown. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 25–30.) The microwave conductivity of a bounded plasma in a slightly nonuniform field is calculated. The analysis is applied to two particular cases in the theory of the late afterglow of a diffusion-controlled decaying plasma, inelastic collisions being neglected.

537.56 : 538.6 **2100**

Experimental Investigations of the Motion of Plasma Projected from a Button Source across Magnetic Fields.—E. G. Harris, R. B. Theus & W. H. Bostick. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 46–50.) The velocity with which the front 'blob' of plasma moves across a magnetic field has been measured under various conditions; it was found to vary slowly with the field strength above 1 kG and to increase monotonically with the source voltage. See also 1057 of April (Bostick).

537.564 : 538.566 **2101**

Microwave Determination of the Probability of Collision of Electrons in Neon.—A. L. Gilardini & S. C. Brown. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 31–34.) Theory (2099 above) is used to determine the collision probability for momentum transfer of slow electrons.

538.2 **2102**

Magnetic Hysteresis Losses.—K. M. Koch & K. Strnat. (*Elektrotech. u. Maschinenb.*, 1st Nov. 1956, Vol. 73, No. 21, pp. 493–497.) A preliminary report on an experimental investigation of the mechanism of remagnetization processes.

538.221 **2103**

Magnetic After-Effect: Part 2.—T. Huzimura. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, Aug. 1956, Vol. 8, No. 4, pp. 313–318.) Theory based on exhaustion phenomena yields results similar to those derived from previous theoretical investigations establishing a logarithmic time variation of the after-effect (*ibid.*, April 1956, Vol. 8, No. 2, pp. 87–94).

538.23 **2104**

A Relation between the Hysteresis Coefficient and Coercivity.—M. Kornetzki. (*Z. angew. Phys.*, Nov. 1956, Vol. 8, No. 11, pp. 536–538.) The quantitative relation found on the basis of theoretical assumptions agrees with the mean value derived from previous measurements (see e.g. 3123 of 1956).

538.249 **2105**

On the Determination of the Time Constants of the Magnetic Diffusion After-Effect.—P. Brissonneau. (*C. R. Acad. Sci., Paris*, 25th Feb. 1957, Vol. 244, No. 9, pp. 1174–1177.)

538.3 : 52 **2106**

Some Aspects of Magnetohydrodynamics.—G. H. A. Cole. (*Advances Phys.*, Oct. 1956, Vol. 5, No. 20, pp. 452–497.) A survey. The effects of small and of shock disturbances are discussed.

538.56 **2107**

On the Presence and Conservation of Reactive Power in a Radiation Phenomenon.—C. Budeanu. (*C. R. Acad. Sci., Paris*, 25th Feb. 1957, Vol. 244, No. 9, pp. 1171–1174.) Application of the complex form of the Poynting vector to a medium containing 'regions of excitation'.

538.561.029.6 : 621.373 **2108**

Operation of a Solid-State Maser.—H. E. D. Scovil, G. Feher & H. Seidel. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 762–763.) Details of the operation at 9 kMc/s of a maser oscillator of the type proposed by Bloembergen (1062 of April).

538.566.029.6 : 548.73 : 001.57 **2109**

Microwave Model Crystallography.—J. F. Ramsay & S. C. Snook. (*Electronic Radio Engr*, May 1957, Vol. 34, No. 5, pp. 165–169.) A general account is given of the problem of X-ray diffraction simulation at millimetre wavelengths, together with the experimental equipment used and the nature of the phenomena.

538.569.4 : 538.221 **2110**

Ferromagnetic Resonance Phenomena.—S. A. Ahern. (*Research, Lond.*, Jan. 1957, Vol. 10, No. 1, pp. 15–22.) Theoretical and experimental aspects of ferromagnetic resonance phenomena are described with particular reference to applications in ferrite microwave circuit elements.

538.569.4 : 538.221 2111

Magnetostatic Modes in Ferromagnetic Resonance.—L. R. Walker. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 390–399.) A sample placed in an inhomogeneous r.f. field of fixed frequency may absorb power at a number of magnetic fields. Theoretical analysis is presented to account for the case where exchange and e.m. propagation can be ignored simultaneously.

538.569.4.029.6 : 53.08 2112

Sensitivity Considerations in Microwave Paramagnetic Resonance Absorption Techniques.—G. Feher. (*Bell Syst. tech. J.*, March 1957, Vol. 36, No. 2, pp. 449–484.) Problems of setting up a high-sensitivity spectrometer are discussed, including coupling to resonant cavities for maximum output, the minimum detectable signal under ideal conditions, the optimum amount of sample to be used, noise due to frequency instabilities and to cavity vibrations, klystron noise, and signal/noise ratio for specific systems. Experimental results, using a 3-cm wavelength, are compared with theory. A detailed description of a superheterodyne spectrometer is given.

538.569.4.029.6 : 547 2113

Paramagnetic Resonance of Free Radicals at Millimetre-Wave Frequencies.—A. van Roggen, L. van Roggen & W. Gordy. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 50–55.) Experimental results are given for three radicals measured as single crystals and in solution at 36 and 75 kMc/s. The magnetic resonance spectrometer used is described.

539.11 2114

Theory of Local Electron States in an Isotropic Homopolar Crystal.—M. F. Deigen. (*Zh. eksp. teor. Fiz.*, Sept. 1956, Vol. 31, No. 3(9), pp. 504–511.)

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 2115

Intensity of the Radio Line of Galactic Deuterium.—R. L. Adgie & J. S. Hey. (*Nature, Lond.*, 16th Feb. 1957, Vol. 179, No. 4555, pp. 370–371.)

523.16 2116

Radio Star Scintillations and Interstellar Hydrogen.—G. A. Harrower. (*Nature, Lond.*, 23rd March 1956, Vol. 179, No. 4560, pp. 608–610.) Continuous records of 50-Mc/s radiation from Cassiopeia during 1954 have been analysed. An interpretation of the scintillation effects is discussed, based on the capture of interstellar particles by the sun's gravitational field.

523.16 : 523.3 2117

Reflexion of Radio Waves from the Moon.—F. J. Kerr & C. A. Shain: J. D. Kraus. (*Nature, Lond.*, 23rd Feb. 1957, Vol. 179, No. 4556, p. 433.) Comment on 3358 of 1956 and author's reply. See also 2118 below.

523.16 : 523.75 2118

Relation of 11-Metre Solar System Phenomena to Solar Disturbances.—J. D. Kraus. (*Nature, Lond.*, 16th Feb. 1957, Vol. 179, No. 4555, pp. 371–372.) The reception of radio signals associated with Venus and the moon (3357 and 3358 of 1956) is discussed in relation to solar disturbances during that period and the presence of a large cloud of charged particles near the moon.

523.5 : 621.396.9 2119

A Radio Echo Survey of Sporadic Meteor Radiants.—G. S. Hawkins. (*Mon. Not. R. astr. Soc.*, Nov. 1956, Vol. 116, No. 1, pp. 92–104.) An analysis of observations made at Jodrell Bank with two narrow-beam aerials over the period October 1949–September 1951. For a description of the equipment, see 3003 of 1951 (Aspinall et al.).

523.5 : 621.396.9 2120

A Radio Echo Method of Meteor Orbit Determination.—J. C. Gill & J. G. Davies. (*Mon. Not. R. astr. Soc.*, Nov. 1956, Vol. 116, No. 1, pp. 105–113.) The equipment used consists of a pulse transmitter operating at 36·3 Mc/s and three receivers spaced at 3·5 km. The accuracy attainable is limited to ± 2 km/s in velocity and ± 3° in radiant position.

550.385 : 523.78 2121

Geomagnetic Variation due to the Solar Eclipse of June 20th 1955.—M. Ota & S. Hashizume. (*J. Geomag. Geoelect.*, June 1956, Vol. 8, No. 2, pp. 76–80.) Vector diagrams of the magnetic variation observed at four Japanese stations and the S_q-field chart for the day are briefly analysed.

551.510.53 : 551.594.6 2122

A Method to Detect the Presence of Ionized Hydrogen in the Outer Atmosphere.—L. R. O. Storey. (*Canad. J. Phys.*, Nov. 1956, Vol. 34, No. 11, pp. 1153–1163.) The proposed method is based on the observation of the relation between frequency and time in a whistler. The ionized hydrogen should cause a departure of the relation at low frequencies from the form observed at high frequencies. At magnetic latitude 45° the effect should be detectable at frequencies below about 2 kc/s.

551.510.535 2123

Night-Time Ionization in the Lower Ionosphere: Part 1—Recombination Processes. Part 2—Distribution of Electrons and Negative Ions.—A. P. Mitra. (*J. atmos. terr. Phys.*, March 1957, Vol. 10, No. 3, pp. 140–162.) From various ionospheric data, the variation of recombination coefficient with height, near 80 km, and time during the night is obtained. Interpretation of the results is based on the recent suggestion that positive atomic ions of low ionization potential are present. The distribution of electrons, negative ions (O^-,O_2^-), positive molecular (YZ^+) and positive atomic ions of low ionization potential (X^+) are deduced from the observational results.

551.510.535 2124

Lunar Effects on the Equatorial E_s.—S. Matsushita. (*J. atmos. terr. Phys.*, March 1957, Vol. 10, No. 3, pp. 163–165.) The time of disappearance of equatorial E_s at Huancayo is shown to be earlier at times of full and new moon. This gives support to the author's theory that equatorial E_s is formed by the agency of the eastward electric current jet.

551.510.535 2125

The Characteristics of the F_2 Regions as deduced from the Daily Variations in the Ionospheric Layer.—T. Shimazaki. (*Rep. Ionosphere Res. Japan*, Sept. 1956, Vol. 10, No. 3, pp. 124–142.) Summary and discussion of previous work (3050 of 1956) amplified by results of subsequent study.

551.510.535 : 523.7 : 518.3 2126

The Calculation of the Sunrise at the Altitudes of the Ionospheric Layers.—H. Kautzleben. (*Z. Met.*, Nov. 1956, Vol. 10, No. 11, pp. 337–341.) A nomogram is derived which gives the true local time of sunrise or sunset at altitudes up to 500 km for any locality or date. It can also be used to determine the true local time at which the sun reaches any given height above the horizon. The presence of an atmospheric layer absorbing ultraviolet radiation necessitates the use of correction data so that the time of the effective sunrise can be found.

551.510.535 : 523.75 2127

Sweep-Frequency *ft* and *h't* Records of the Ionosphere at the Time of Solar Flares on February 14 and 23, 1956.—Y. Nakata. (*Rep. Ionosphere Res. Japan*, Sept. 1956, Vol. 10, No. 3, pp. 149–151.) The records obtained in Japan are reproduced and briefly discussed.

551.510.535 : 523.75 : 621.396.11 2128

Some Effects of Intense Solar Activity on Radio Propagation.—R. E. Houston, Jr, W. J. Ross & E. R. Schmerling. (*J. atmos. terr. Phys.*, March 1957, Vol. 10, No. 3, pp. 136–139.) Records are given showing the effects of a solar flare (observed at Tokyo) on night-time measurements in Pennsylvania, U.S.A., of 75-kc/s pulsed vertical-incidence transmissions. A drop in phase height and increase in absorption occurred 15 min after the flare, while the group height remained unaltered.

551.510.535 : 550.38 2129

Relation between Noon F_2-Layer Ionization and Magnetic Dip.—J. N. Bhar. (*J. atmos. terr. Phys.*, March 1957, Vol. 10, No. 3, pp. 168–172.) The relations are studied for constant values of χ rather than constant L.M.T.

2130

551.510.535 : 551.55 : 523.5 : 621.396.96

The Height Variation of Upper Atmospheric Winds.—J. S. Greenhow & E. L. Neufeld. (*Phil. Mag.*, Dec. 1956, Vol. 1, No. 12, pp. 1157–1171.) The results of an investigation by the meteor radio-echo technique of variations between 80 and 100 km for the year ending August 1955 are given in graphical form and discussed. For earlier results, also obtained at Jodrell Bank, see 3259 of 1955.

551.594.6 **2131**

A Theoretical Investigation on the Propagation Path of the Whistling Atmospherics.—K. Maeda & I. Kimura. (*Rep. Ionosphere Res. Japan*, Sept. 1956, Vol. 10, No. 3, pp. 105–123.) Formulae are derived for the exact calculation of whistler paths by applying Fermat's principle, and are used to determine the ray paths for various geomagnetic latitudes. The paths do not generally follow the lines of magnetic force and in lower latitudes the paths are not symmetrical relative to the magnetic equator. The theory explains a number of observational results.

551.594.6 **2132**

On the Direction of Arrival and the Polarization of Whistling Atmospherics.—J. Delloue. (*C. R. Acad. Sci., Paris*, 4th Feb. 1957, Vol. 244, No. 6, pp. 797–799.) Measurements at 5·5 kc/s show the direction of arrival to be always close to that of the local geomagnetic field and to vary, for the same whistler, at the same time as the polarization.

551.594.6 **2133**

Waveguide Interpretation of Atmospheric Waveforms.—F. Hepburn. (*J. atmos. terr. Phys.*, March 1957, Vol. 10, No. 3, pp. 121–135.) Discusses atmospheric waveforms received by low-frequency propagation. A graphical construction is given for deducing received waveforms, assuming a modified current/time relationship for lightning return strokes and using waveguide propagation theory. The types of waveform encountered are qualitatively explained by the theory, and a directional dependence is reported.

551.594.6 : 621.396.11.029.45 **2134**

Lightning and the Propagation of Audio - Frequency Electromagnetic Waves.—Ya. L. Al'pert. (*Uspekhi fiz. Nauk*, Nov. 1956, Vol. 60, No. 3, pp. 369–389.) See 919 and 920 of March (Al'pert & Borodina).

LOCATION AND AIDS TO NAVIGATION

621.396.93 **2135**

Some Developments of the Decca Navigator System.—(*J. Inst. Nav.*, Oct. 1956, Vol. 9, No. 4, pp. 385–405.)

Part 1—Decca for Helicopter Operations.—J. G. Adam (pp. 385–389).

Part 2—The Use of the Flight Log.—E. R. Wright (pp. 389–393).

Part 3—Dectra [Decca track/range].—G. Hawker (pp. 394–403).

Discussion, pp. 403–405.

621.396.93 **2136**

The Total Error in an Adcock Goniometer System.—K. Baur. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 491–493.) The calculation presented takes into consideration the interrelation between the goniometer and aerial errors and thus accounts for the discrepancy between theory and practice at the higher frequencies. See also 451 of February and 781 of March.

621.396.933.1 **2137**

Airborne Doppler Navigation.—G. E. Beck. (*Wireless World*, May 1957, Vol. 63, No. 5, pp. 225–227.) A note on the principles and requirements of a Doppler system.

621.396.933.2 : 551.594.6 **2138**
: 621.396.11.029.45

Very-Low-Frequency Propagation and Direction-Finding.—Horner. (See 2272.)

621.396.963.325 **2139**

Detection of Separations between Adjacent Signals on a Simulated P.P.I. Radar Scope.—R. M. Herrick, H. E. Adler, J. E. Coulson & G. L. Howett. (*J. opt. Soc. Amer.*, Oct. 1956, Vol. 46, No. 10, pp. 861–866.) Experiments indicate that background luminance is the most important factor affecting the threshold at which signals can be detected as separate; the influence of phosphorescence decay rate and scan rate is relatively small.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.583 : 621.385 **2140**

Barium Getters and Oxygen.—R. N. Bloomer. (*Brit. J. appl. Phys.*, Jan. 1957, Vol. 8, No. 1, pp. 40–43.) Speed of gettering and film capacity are studied under various conditions. Films deposited under a very good vacuum are initially inert towards oxygen, even in the presence of an ionizing electron discharge or of incandescent filaments.

533.583 : 621.385 **2141**

Performance Characteristics of Barium Getters.—P. della Porta. (*Vacuum*, July 1954, Vol. 4, No. 3, pp. 284–302.) Report of performance tests carried out on pure Ba getter material by means of an improved capillary method in which the pressure in the getter chamber is kept constant. Curves of the instantaneous absorption capacity and of the gettering rate are given for various gases and conditions.

535.215 **2142**

Spectral Distribution of the Internal Photoeffect in some Systems of Sulphides and Tellurides.—N. A. Goryunova & B. T. Kolomiets. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1155–1161.) Experimental results are presented graphically of an investigation of the internal photoeffect in complex semiconducting systems of binary compounds. In all graphs the photocurrent per unit of incident energy is plotted in arbitrary units along the y axis, and the wavelength in μ along the x axis.

535.215 : 539.23 : 546.817.231 **2143**

Photoconductivity in Lead Selenide. Experimental.—J. N. Humphrey & W. W. Scanlon. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 469–476.) The effects of oxygen, sulphur, selenium and the halogens on the photoconductive and electrical properties of thin evaporated films have been investigated. Each of the above sensitizers acts as an acceptor impurity.

535.215 : 546.482.21 **2144**

Internal Photoelectric Effect in Polycrystalline Cadmium Sulphide.—B. T. Kolomiets, A. O. Olesk & S. G. Pratusevich. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1162–1166.) Report on experimental investigation of the effect of Cu impurity on the photoelectric properties of CdS, and of the quenching effect of Fe on photoconductivity in CdS containing 0·01% Cu activator. Results are presented graphically.

535.215 : 546.482.21 **2145**

The Kinetics of the Growth of Photocurrent and the Phenomenon of Quenching of Photoconductivity in Cadmium Sulphide.—A. D. Shneider. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1428–1432.) The kinetic characteristics of the photoresistors were investigated experimentally at low intensities of illumination. Measurements also showed the absence of a 'photo-rectifying effect'.

535.215 : 546.482.31 **2146**

Cadmium Selenide Photoresistors.—B. T. Kolomiets & S. G. Pratusevich. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1174–1176.) Preliminary results of an experimental investigation of the spectral and integral sensitivity, current/voltage and current/wavelength characteristics of polycrystalline-CdSe photoresistors are presented graphically and are briefly discussed.

535.215 : 546.492.221 **2147**

Quenching of Photoconductivity in Mercuric Sulphide.—A. D. Shneider. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1433–1436.) An experimental investigation of infrared quenching at and below room temperature is reported. A theoretical interpretation of the results obtained is given.

535.215 : 546.561-31 **2148**

Properties of the Long-Period Component of Photoconductivity of Cuprous Oxide.—Yu. I. Gritsenko & V. E. Lashkarev. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1167–1173.)

535.215 : 546.817.221 : 539.23 **2149**

Noise, Time-Constant, and Hall Studies on Lead Sulphide Photoconductive Films.—F. L. Lummis & R. L. Petritz. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 502–508.) Measurements at frequencies from 20 to 16 000 c/s showed a $1/f$ component of noise below 100 c/s, a generation-recombination component between 100 and 10 000 c/s, and a Nyquist component at higher frequencies. In conjunction with the time-constant and

Hall measurements, the results confirm the theory of photoconductivity in semiconductor films [1774 of June (Petritz)].

535.215 : 547 **2150**

Photoelectronics of Organic Compounds.—A. N. Terenin. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1127–1134.) Survey of data on photoionization of organic dyes. The nature of photoconductivity of the dyes is discussed. 30 references.

535.37 **2151**

The Emission Spectrum of an Exciton.—E. F. Gross & M. A. Yakobson. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1369–1371.) Experimental results indicate that the 'blue' luminescence of CdS may be considered as the emission by excitons during their annihilation in the lattice.

535.37 **2152**

Exciton Absorption and Emission Spectra for Cadmium Selenide Crystal. E. F. Gross & V. V. Sobolev. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1622–1624.)

535.37 **2153**

Photoluminescence of Thallous Chloride.—A. S. Vysochanski. (*C. R. Acad. Sci. U.R.S.S.*, 11th Jan. 1957, Vol. 112, No. 2, pp. 228–231. In Russian.) An experimental investigation of the absorption, excitation and luminescence spectra of TlCl is reported. Results indicate that TlCl is a typical crystal phosphor in which the excess Tl atoms perform the function of an activator and are both the absorption and luminescence centres; absorption leads to the internal photoeffect, and luminescence is preceded by recombination of a conduction-zone electron with an excess Tl ion.

535.37 **2154**

Influence of the Adsorption of Gases on the Luminescence of Zinc Oxide.—K. V. Tagantsev & A. N. Terenin. (*C. R. Acad. Sci. U.R.S.S.*, 11th Jan. 1957, Vol. 112, No. 2, pp. 241–244. In Russian.) An experimental investigation is reported of the effect of water vapour, oxygen and ozone on the luminescence of ZnO illuminated (*a*) continuously, and (*b*) for 10-sec periods at intervals of not less than 5 min.

535.37 **2155**

Photofluorescence Decay Times of Organic Phosphors.—T. D. S. Hamilton. (*Proc. phys. Soc.*, 1st Jan. 1957, Vol. 70, No. 445B, pp. 144–145.) Decay times for thick crystals and microcrystals of seven phosphors are given.

535.376 **2156**

Influence of Charge-Carrier Injection on Alternating-Field Luminescence.—D. Hahn & F. W. Seeman. (*Z. Phys.*, 13th Nov. 1956, Vol. 146, No. 5, pp. 644–654.) Additional luminescence observed in alternating-field excitation of ZnS-based phosphors was investigated. The phosphor, in powder form embedded in a dielectric, was excited at frequencies between 50 c/s and 10 kc/s and field strengths of 10^4–10^5 V/cm. The additional luminescence is probably due to a charge transfer at the phosphor/electrode interface.

535.376 **2157**

The Energy Dependence of the Fluorescence of Polycrystalline Phosphors Excited by Electron Beams and X-rays.—D. Messner. (*Z. Phys.*, 27th Nov. 1956, Vol. 147, No. 1, pp. 24–42.) Analysis of results of investigations carried out for an electron-beam energy range of 5 to 45 keV and with X-rays of λ from about 0·08 to 0·4 Å. 33 references.

537.226/.228.1 : 536.7 **2158**

Thermodynamic Theory of Ferroelectric Ceramics.—H. G. Baerwald. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 480–486.) A new small-signal theory is developed. An elastic and a piezoelectric relation are given which are in agreement with experimental data.

537.226/.227 **2159**

New Ferroelectric Crystal Containing No Oxygen.—R. Pepinsky & F. Jona. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 344–345.) Measurements of ferroelectric behaviour in crystals of $(NH_4)_2BeF_4$ are reported at temperatures below −94·7°C.

537.226.33 : 546.431.824-31 **2160**

Investigations concerning Polarization in Barium Titanate Ceramics.—G. W. Marks, D. L. Waidelich & L. A. Monson. (*Commun. & Electronics*, Sept. 1956, No. 26, pp. 469–477.) The results of Fourier analyses of symmetrical and unsymmetrical hysteresis loops are presented. For a $BaTiO_3$ disk the second-harmonic content and the electromechanical coupling coefficient reach a maximum at a polarizing voltage of 15 kV d.c. per cm.

537.227/.228.1 : 546.431.824-31 **2161**

Effect of Pressure on the Curie Temperature of Polycrystalline Ceramic Barium Titanate.—H. Jaffe, D. Berlincourt & J. M. McKee. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 57–58.) The Curie point is found to increase as the square of the applied stress.

537.227 **2162**

The Effect of a Unilateral Mechanical Pressure on the Permittivity of Ceramic Ferroelectrics.—M. S. Lur'e & A. I. Medovoi. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1437–1442.) Under pressures of the order of 10 kg/cm^2, the dependence of permittivity on pressure is non-stationary for temperatures below the Curie point and stationary above the Curie point. The non-stationary variation of permittivity under pressure becomes stationary when the a.c. field exceeds a certain critical value. The orientation of the domains by polarization and an additional d.c. field results in the appearance of a stationary dependence together with the remnants of the non-stationary process. It is suggested that the non-stationary dependence of permittivity observed is a result of the orientation processes of the domain structure of polycrystalline ferroelectrics.

537.227 : 547.476.3 **2163**

On the Upper Curie Point of Rochelle Salt.—M. S. Kosman & A. N. Shevardin. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1443–1450.) Hysteresis loops of Rochelle salt specimens were studied over a temperature range from 18 to 40°C at a frequency of 50 c/s. Results show that in strong fields the ferroelectric properties do not disappear at higher temperatures. Although this investigation was carried out for the upper Curie point, there are good grounds for supposing that similar phenomena also occur at the lower Curie point.

537.228.1 : 546.431.824-31 **2164**

Dependence of the Ratio of Piezoelectric Coefficients on Density and Composition of Barium Titanate Ceramics.—D. Berlincourt & H. H. A. Krueger. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 56–57.)

537.3 **2165**

Proceedings of the International Conference on Electron Transport in Metals and Solids.—(See 2088.)

537.31 : [546.56 + 546.883 **2166**

The Reflection of Slow Electrons from Tantalum and Copper.—J. P. Hobson. (*Canad. J. Phys.*, Nov. 1956, Vol. 34, No. 11, pp. 1089–1096.)

537.311.3 : 539.23 : 621.396.822 **2167**

Measurement of the Deviations from Ohm's Law and of Flicker Effect Shown by Very Thin Films of Silver, Gold and Aluminium.—C. Uny & N. Nifontoff. (*C. R. Acad. Sci., Paris*, 4th Feb. 1957, Vol. 244, No. 6, pp. 729–732.) Simultaneous measurements of resistance variation and flicker effect, the latter at 1 and 5 kc/s, are reported. Additional irregular fluctuations distinct from the flicker effect were observed, particularly with Ag films on glass. See also 3291 of 1955 (Nifontoff).

537.311.33 **2168**

Contemporary Semiconductor Materials.—D. A. Petrov. (*Bull. Acad. Sci. U.R.S.S., tech. Sci.*, Nov. 1956, No. 11, pp. 82–95. In Russian.) A survey, with particular reference to the metallurgy and preparation of semiconductor materials.

537.311.33 **2169**

Spontaneous Radiative Recombination in Semiconductors.—W. P. Dumke. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 139–144.) Expressions are derived for the radiative recombination lifetimes due to direct and indirect transitions. For intrinsic Ge at room temperature the calculated lifetimes for both direct and indirect transitions are of the order of a second. For intrinsic Si the lifetimes are much higher.

537.311.33 **2170**

Carrier Lifetime in Semiconductors for Transient Conditions.—D. J. Sandiford. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, p. 524.) The solution for recombination under transient conditions contains a time constant associated with the readjustment in concentration of the recombination centres, in addition to that of the main recombination term.

537.311.33 **2171**

Surface Recombination and its Influence on the Characteristics of Semiconductor Devices.—A. V. Rzhanov. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1086–1092.) A discussion.

537.311.33 **2172**

Behaviour of Semiconductors in Strong Electric Fields.—Yu. K. Pozhela. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1106–1112.) Continuation of work reported in 471 of 1957.

537.311.33 **2173**

On Surface Recombination.—V. L. Bonch-Bruevich. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1137–1140.)

537.311.33 **2174**

The Diffusion of Current Carriers in a Semiconductor in the Presence of an External Electric Field.—E. I. Rashba. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1415–1418.) Exact expressions are derived for determining the distribution of photo-holes in a bar or plate in the presence of an external electric field and illumination by a filament or point light probe.

537.311.33 : 535.21 : 535.8 **2175**

Two Optical Instruments Used in Semiconductor Research.—D. G. Avery. (*J. sci. Instrum.*, Jan. 1957, Vol. 34, No. 1, pp. 16–17.) A single-prism monochromator and a light-spot microscope with reflecting objective are described.

537.311.33 : 537.312.5 **2176**

Bulk Photo-e.m.f. in Semiconductors.—V. E. Lashkarev & V. A. Romanov. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1144–1146.) The theory and the experimental verification of the bulk photovoltaic effect observed in Ge specimens with inhomogeneous resistivity are presented. For another theory of the effect, see *Czech. J. Phys.*, April 1955, Vol. 5, No. 2, pp. 178–192 (Tauc).

537.311.33 : 546.26-1 **2177**

Some Physical Properties of Diamonds.—F. C. Champion. (*Advances Phys.*, Oct. 1956, Vol. 5, No. 20, pp. 383–411.) A survey including (*a*) theory of the properties of a pure diamond, (*b*) physical behaviour of real diamonds, (*c*) applications of defect theory, (*d*) discussion of conducting diamonds, the infrared absorption spectrum and the growth of diamonds, and (*e*) a comparison between the properties of diamonds and of other materials.

537.311.33 : [546.28 + 546.289 **2178**

Electron Self-Energy and Temperature-Dependent Effective Masses in Semiconductors: *n*-Type Ge and Si.—H. D. Vasileff. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 441–446.) A theoretical study of electron self-energy in some homopolar semiconductors from which the temperature dependence of the principal effective masses is deduced. The results are found to substantiate the observations of Macfarlane & Roberts (2656 and 3646 of 1955) but not those of Lax & Mavroides (1759 of 1956).

537.311.33 : [546.28+546.289 **2179**

On the Permeation of Hydrogen and Helium in Single-Crystal Silicon and Germanium at Elevated Temperatures.—A. v. Wieringen & N. Warmoltz. (*Physica*, Oct. 1956, Vol. 22, No. 10, pp. 849–865.) Analysis of mass spectrometer measurements in the temperature range 967°–1 207°C for Si and 766°–930°C for Ge. No evidence of any permanent influence of dissolved H_2 on the electrical properties of Si and Ge was found.

537.311.33 : [546.28+546.289] **2180**
: 537.312.9

Temperature Dependence of the Piezoresistance of High-Purity Silicon and Germanium.—F. J. Morin, T. H. Geballe & C. Herring. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 525–539.) Measurements were made over the temperature (T) ranges 5°–350°K for Ge and 20°–350°K for Si. For *n*-type Ge in the [110] direction, and *n*-type Si in the [100] direction, the piezoresistance is substantially linear in T^{-1}. For *p*-type Ge the results suggest a T^{-1} dependence for pure material, in both [110] and [100] directions. For *p*-type Si no simple temperature dependence is found. The results are discussed in relation to theory.

537.311.33 : 546.28 **2181**

Removal of Boron from Silicon by Hydrogen Water Vapour Treatment.—H. C. Theuerer. (*J. Metals, N.Y.*, Oct. 1956, Vol. 8, No. 10, pp. 1316–1319.) The treatment of liquid silicon with H_2 containing water vapour at various concentrations is investigated with regard to its boron-removal efficiency. In combination with zone refining this method provides silicon of higher purity than otherwise obtainable.

537.311.33 : 546.28 **2182**

Diffusion and Electrical Behaviour of Zinc in Silicon.—C. S. Fuller & F. J. Morin. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 379–384.) The diffusivity and solubility of Zn in Si single crystals were measured. One acceptor level only was found for Zn at 0·31 eV above the valence band.

537.311.33 : 546.28 **2183**

Microplasmas in Silicon.—D. J. Rose. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 413–418.) Discrete current pulses and minute luminous spots are often observed at breakdown of reverse-biased Si junctions. The phenomena are postulated to be similar to the gas discharge cathode fall. The mechanism is illustrated for the case of the *n-i-p* structure, and analysed approximately by using a simple equivalent circuit.

537.311.33 : 546.28 **2184**

Hall and Drift Mobility in High-Resistivity Single-Crystal Silicon.—D. C. Cronemeyer. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 522–523.) Room - temperature measurements on specimens with resistivity ranging from nearly intrinsic down to 10^{-2} Ω.cm indicate that the Hall mobilities for lattice scattering are 1 560 and 345 cm^2/V.sec for electrons and holes respectively, and the drift mobilities are 1 360 and 510 cm^2/V.sec for electrons and holes respectively.

537.311.33 : 546.289 **2185**

Field - Effect Measurements and Application to Semiconductor Surface Studies.—Shyh Wang. (*Sylvania Technologist*, Oct. 1956, Vol. 9, No. 4, pp. 111–114.)

537.311.33 : 546.289 **2186**

Depth of Surface Damage due to Abrasion on Germanium.—T. M. Buck & F. S. McKim. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 593–597.) "The approximate depth of surface damage on Ge as it influences surface recombination velocity has been measured for a variety of abrasive treatments by etching, weighing, and making two types of photomagnetoelectric measurements. Values range from $1\,\mu$ or less for fine polishes to $35\,\mu$ for heavy sandblasting. Close correlation is found with changes in reverse characteristics of grown-junction *p-n* diodes treated in the same manner."

537.311.33 : 546.289 **2187**

A Shot Tower for Producing Germanium Doping Pellets of Uniform Composition.—I. A. Lesk. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 601–603.)

537.311.33 : 546.289 **2188**

Hydrogen and Oxygen in Single-Crystal Germanium as determined by Vacuum Fusion Gas Analysis.—C. D. Thurmond, W. G. Guldner & A. L. Beach. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 603–605.) Concentrations of hydrogen of 3–4 × 10^{18} atoms/cm^3 and of oxygen of 1–2 × 10^{18} atoms/cm^3 were found in three special preparations of Ge obtained by hydrogen reduction of GeO_2 in graphite. The possibility exists that these elements may have been present in these crystals as H_2O. Vacuum crystal growing lowered the hydrogen and oxygen concentrations 20–30-fold.

537.311.33 : 546.289 **2189**

The Crucible Problem in the Prolonged Heat Treatment of Germanium.—W. Bösenberg. (*Z. angew. Phys.*, Nov. 1956, Vol. 8, No. 11, pp. 551–552.) Four different methods of heating Ge crystals are compared. The use of a graphite crucible supporting the induction-heated crystal in a vacuum enclosed by a cold quartz-glass container is the best method for maintaining the purity of the crystal.

537.311.33 : 546.289 **2190**

The Effect of Impurities on the Lifetime of Excess Carriers of Charges in Germanium.—A. V. Rzhanov. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1389–1393.) Results of an experimental investigation of the effect of impurity concentration are reported.

537.311.33 : 546.289 **2191**

Effects of Thick Oxides on Germanium Surface Properties.—M. Lasser, C. Wysocki & B. Bernstein. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 491–494.) Oxides grown on germanium by heating in oxygen are shown to inhibit interaction between the germanium and the ambient atmosphere. The decay time of the d.c. field effect increases with increasing oxide thickness.

537.311.33 : 546.289 **2192**

Triple Acceptors in Germanium.—H. H. Woodbury & W. W. Tyler. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp.

84–92.) Both copper and gold introduce three acceptor levels in the forbidden band. For copper the energy levels are 0·04 and 0·32 eV from the edge of the valence band and 0·26 eV from the edge of the conduction band. For gold they are 0·15 eV from the valence band and 0·04 and 0·20 eV from the conduction band: additionally gold introduces a donor level 0·05 eV from the valence band.

537.311.33 : 546.289 **2193**

Formation of Ion Pairs and Triplets between Lithium and Zinc in Germanium.—F. J. Morin & H. Reiss. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 384–389.) Measurements have been made of carrier mobility, relaxation, and energy levels; the results agree with the idea that zinc provides two energy levels for electrons in the forbidden gap.

537.311.33 : 546.289 : 546.33 **2194**

Adsorption of Sodium Ions by Germanium Surfaces.—S. P. Wolsky, P. M. Rodriguez & W. Waring. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 606–609.)

537.311.33 : 546.289 : 546.811 **2195**

Solid Solubilities and Electrical Properties of Tin in Germanium Single Crystals.—F. A. Trumbore. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 597–600.) An experimental investigation in the temperature range from 400°C to the melting point of Ge is reported. Results of electrical measurements confirm the neutrality of Sn in Ge.

537.311.33 : [546.873.231 + 546.873.241 **2196**

The Electrical Properties of Bismuth Chalkogenides: Part 2—Electrical Properties of Bismuth Selenide ($Bi_2 Se_3$); Part 3—Electrical Properties of Bismuth Telluride ($Bi_2 Te_3$).—P. P. Konorov. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1394–1399 & 1400–1405.) Continuation of experimental investigation reported in 1500 of May. Results are presented graphically showing the temperature dependence of electrical conductivity, the concentration and mobility of current carriers, and the coefficient of thermo-e.m.f. for both Bi_2Se_3 and Bi_2Te_3 and of the Hall constant in Bi_2Te_3; the dependence of the mobility of current carriers in Bi_2Se_3 on their concentration is also shown graphically.

537.311.33 : 546.873.241 **2197**

An Ionization-Method X-Ray Structural Investigation of Bismuth Telluride.—F. I. Vasenin & P. F. Konovalov. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1406–1414.) An investigation of the cause of the inversion of polarity of the thermo-e.m.f. when the composition of the alloy approaches the stoichiometric ratio is reported. Results indicate that the phenomenon is probably due to the existence of two modifications of the alloy.

537.311.33 : 546.3-1-28-289 **2198**

The Electrical Conductivity of Germanium-Silicon Alloys in the Liquid State.—M. S. Ablova, O. D. Elpat'evskaya & A. R. Regel. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1366–1368.) A number of experimental curves are plotted showing the width of the forbidden band, the abrupt change in electrical conductivity during melting, and the maximum electrical conductivity in the liquid state versus the composition of the alloy.

537.311.33 : [546.682.19 + 546.682.86 **2199**

Effective Masses of Electrons in Indium Arsenide and Indium Antimonide.—R. J. Sladek. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 460–464.) Measurements of the electrical conductivity and Hall effect made between 1·5° and 300°K.

537.311.33 : 546.682.86 **2200**

The Dependence of the Hall Coefficient of a Mixed Semiconductor upon Magnetic Induction as Exemplified by Indium Antimonide.—D. J. Howarth, R. H. Jones & E. H. Putley. (*Proc. phys. Soc.*, 1st Jan. 1957, Vol. 70, No. 445B, pp. 124–135.) The Bloch-Wilson theory is discussed and applied to InSb. Good agreement was found between the theory and the observed behaviour of two *p*-type single crystals. Values found for the intrinsic carrier concentration are in good agreement with those found elsewhere.

537.311.33 : 549.351.12 **2201**

New Semiconductors with the Chalcopyrite Structure.—I. G. Austin, C. H. L. Goodman & A. E. Pengelly. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 609–610.) "Compounds of the chalcopyrite group are related to well-known semiconductors such as Ge and the zinc blende compounds. This relationship is discussed briefly and some new data are presented regarding the preparation and properties of five chalcopyrite compounds $AgInS_2$, $AgInSe_2$, $CuInSe_2$, $AgInTe_2$, and $CuInTe_2$."

537.311.33 : 621.314.63 **2202**

Rectifying Semiconductor Contacts.—H. K. Henisch. (*J. electrochem. Soc.*, Nov. 1956, Vol. 103, No. 11, pp. 637–643.) A review of present theory.

537.311.33 : 621.314.632 : 546.561.221 **2203**

Point Contact of Pt and γ-Cu_2S.—S. Miyatani. (*J. phys. Soc. Japan*, Oct. 1956, Vol. 11, No. 10, pp. 1059–1063.) Investigations reveal d.c. characteristics similar to those of other metal/semiconductor rectifiers, but attributed to ionic conduction. Experimental results appear to confirm the theory developed.

537.312.6 + 538.632] : 546.3-1-76-59 **2204**

Hall Effect and Resistance of Dilute Gold-Chromium Alloys at Low Temperatures.—W. B. Teutsch & W. F. Love. (*Phys. Rev.*, 15th Jan. 1957, Vol. 105, No. 2, pp. 487–490.)

537.323 **2205**

Thermoelectric Properties of Bismuth.—G. A. Ivanov & L. I. Mokievski. (*Zh. tekh. Fiz.*, June 1956, Vol. 26, No. 6, pp. 1343–1344.) Contrary to the results obtained by Sato (*J. Phys. Soc. Japan*, March/April 1951, Vol. 6, No. 2, pp. 125–127) it was found that the coefficient of the thermo-e.m.f. of bismuth remains constant for temperature differences across the specimen greater than 0·01°C.

538.2 **2206**

Material of the Conference on Radiospectroscopy (Kazan', 30th May–2nd June 1955).—(*Bull Acad. Sci. U.R.S.S., sér. phys.*, Nov. 1956, Vol. 20, No. 11, pp. 1199–1356. In Russian.) Texts are given of 25 papers presented at the conference. Subjects discussed included paramagnetic and ferromagnetic resonance and the characteristics of ferrites.

538.22 **2207**

On the Magnetic Properties of the System MnSb-CrSb.—T. Hirone, S. Maeda, I. Tsubokawa & N. Tsuya. (*J. phys. Soc. Japan*, Oct. 1956, Vol. 11, No. 10, pp. 1083–1087.)

538.221 **2208**

Surface Structures and Ferromagnetic Domain Sizes.—D. H. Martin. (*Proc. phys. Soc.*, 1st Jan. 1957, Vol. 70, No. 445B, pp. 77–84, plate.) Optimum domain sizes in iron and silicon-iron crystals have been calculated.

538.221 **2209**

An Investigation of the Magnetization of a Structure representing a Model of Magneto-dielectric Material.—M. N. Grigor'ev & I. M. Kirko. (*Zh. tekh. Fiz.*, July 1956, Vol. 26, No. 7, pp. 1501–1508.) A report is presented on an experimental investigation into the magnetization of mixtures of spherical or cylindrical magnetic particles and quartz sand, in d.c. and a.c. fields (from 0·1 to 20 kc/s). A number of experimental curves are shown, and, using the formulae given, magnetic characteristics can be derived for other frequencies and packing factors.

538.221 **2210**

An Analysis of the Magnetization Processes in Iron Single Crystals by an Electrical Method.—R. Parker. (*Phil. Mag.*, Dec. 1956, Vol. 1, No. 12, pp. 1133–1146.)

538.221 **2211**

Hysteresis-Relaxation and Permeability of Carbon-Containing Silicon-Iron.—F. Schreiber. (*Z. angew. Phys.*, Nov. 1956, Vol. 8, No. 11, pp. 539–551.) Results of tests carried out at low field strengths on two types of Si-Fe laminations are given in graphical form and are analysed with reference to the existing theory of magnetic after-effects and previous investigations.

538.221 **2212**

Study of Ferrous Ternary Diagrams in relation to Magnetic Interactions: Fe-Ni-Al System.—U. H. Roesler. (*J. Metals, N.Y.*, Oct. 1956, Vol. 8, No. 10, pp. 1285–1289.) From a thermodynamic analysis of the γ-loop in iron alloys it appears that Al raises the temperature range in which atomic spins in iron become uncoupled from one another; this disagrees with Curie temperature data for Fe-Al alloys. The anomaly is interpreted by assuming that for alloys short-range magnetic order above the Curie point is maintained to higher temperatures than for pure Fe.

538.221 **2213**

The Influence of Heat Treatment on the Magnetic Properties of Face-Centred Cubic Nickel-Cobalt Alloys.—M. Yamamoto & S. Taniguchi. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, Aug. 1956, Vol. 8, No. 4, pp. 280–292.) The anomalous magnetic behaviour is explained in terms of domain-wall stabilization by induced uniaxial anisotropy [1827 of June (Taniguchi)]. This provides a satisfactory interpretation of the sensitivity to heat treatment of simple ferromagnetic solid solutions.

538.221 **2214**

Ferromagnetic Domain Patterns on Nickel Crystals: Part 2—Domain Patterns on General Surfaces of Unmagnetized Crystals.—T. Iwata & M. Yamamoto. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, Aug. 1956, Vol. 8, No. 4, pp. 293–312.) A magnetic colloid technique is used to photograph domain patterns of various types. A detailed interpretation of the complicated patterns is based on previous investigations (*ibid.*, Oct. 1953, Vol. 5, No. 5, pp. 433–459).

538.221 **2215**

The Influence of Plastic Deformation on the Magnetic Properties of Nickel Single Crystals.—H. Dietrich & E. Kneller. (*Z. Metallkde*, Oct. & Nov. 1956, Vol. 47, Nos. 10 & 11, pp. 672–684 & 716–728. English summaries, pp. 683–684 & 728.) The influence of plastic deformation on the law of approach to magnetic saturation and on coercivity is investigated.

538.221 : 537.311 **2216**

Properties of the Temperature Dependence of the Electrical Resistance of Ferromagnetic Metals at Low Temperatures.—A. I. Sudovtsov & E. E. Semenenko. (*Zh. eksp. teor. Fiz.*, Sept. 1956, Vol. 31, No. 3(9), pp. 525–526.) Experimentally determined resistance/temperature characteristics are presented graphically for iron and nickel for the temperature range 1·23–4·2° K.

538.221 : 538.249 **2217**

Anomalies in Hysteresis Cycles due to Diffusion After-Effect.—P. Brissonneau. (*C. R. Acad. Sci., Paris*, 11th Feb. 1957, Vol. 244, No. 7, pp. 868–870.) Results of measurements made on armco iron at −21·3°C, which are similar to those of Feldtkeller (126 of 1953) for an Si-Fe alloy, are interpreted in terms of Néel's theory.

538.221 : 538.569.4.029.6 **2218**

A Note on the Ferromagnetic Resonance in α-Fe_2O_3.—M. Shimizu. (*J. phys. Soc. Japan*, Oct. 1956, Vol. 11, No. 10, pp. 1078–1083.) Microwave resonance formulae are derived for a ferromagnet with hexagonal and uniaxial anisotropy. Results are compared with published experimental data.

538.221 : 621.318.12 **2219**

Magnetic Properties of Magnet Alloys of Iron, Wolfram [tungsten] **and Molybdenum.**—H. Masumoto & Y. Shirakawa. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, Aug. 1956, Vol. 8, No. 4, pp. 319–324.) Results are given of a series of measurements on alloys of different composition. The best characteristics were obtained with a heat-treated alloy containing 15% W and 15% Mo.

538.221 : 621.318.132 : 538.569.4 **2220**

Ferromagnetic Resonance in Metal Single Crystals.—J. O. Artman. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 74–84.) The microwave susceptibility tensor components are calculated for single crystals with uniaxial or cubic magnetic symmetry, and the resonance relations derived. For a simple multi-domain structure, two resonance conditions are found, depending on whether the microwave and static fields are parallel or orthogonal. These conditions involve the static field, saturation magnetization, anisotropy parameter and ratio of skin depth to domain width; thus domain spacings can be inferred from microwave measurements.

538.221 : 621.318.134 **2221**

Observation of Magnetic Viscosity of Ferrites at Low Temperatures.—R. V. Telesnin & I. A. Lednev. (*C. R. Acad. Sci. U.R.S.S.*, 1st Jan. 1957, Vol. 112, No. 1, p. 48. In Russian.) Brief note. The experimental results show that the magnetic induction at 78° K is lower than at 293° K and the hysteresis loop is broader.

538.221 : 621.318.134 **2222**

Magnetic Viscosity of Nickel-Zinc Ferrites.—I. A. Lednev & R. V. Telesnin. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1186–1192.) A systematic experimental investigation of a series of Ni-Zn ferrites at temperatures between 78° K and the Curie point is reported. The special circuit used in conjunction with a pulse oscillograph is described.

538.221 : 621.375.3 **2223**

Flux Reversal in Magnetic Amplifier Cores.—F. J. Friedlaender. (*Commun. & Electronics*, July 1956, No. 25, pp. 268–276. Discussion, pp. 277–278.) A model describing magnetization processes in grain-oriented 50% Ni-Fe alloy tapes is developed. Results of tests made on eleven toroidal cores are compared with theoretical predictions.

538.221 : 621.318.134 : 538.569.4 **2224**

Microwave Resonance Relations in Anisotropic Single-Crystal Ferrites.—J. O. Artman. (*Phys. Rev.*, 1st Jan. 1957, Vol. 105, No. 1, pp. 62–73.) Detailed analyses are given for spherical specimens possessing only first-order anisotropy. The resonance frequency for single-domain crystals is related to the anisotropy parameter, which may be positive or negative, and the magnitude and direction of the static field H, which is taken to lie in a (110) crystal plane. The case of a simple multi-domain structure, appropriate below saturation conditions, is also treated. It is assumed that the domains are lamellae of equal volume, their planes being normal to H and their magnetizations being oriented in two directions which alternate in sequence. Two resonance frequencies are found for a given H, depending on whether it is parallel or normal to the microwave field. The theory agrees with recent experimental data.

539.23 : 546.87 **2225**

Preparation and Electrical Properties of Thin Films of Bismuth.—A. Colombani & P. Huet. (*C. R. Acad. Sci., Paris*, 4th Feb. 1957, Vol. 244, No. 6, pp. 755–758.)

539.23 : 546.87 : 537.312.6 **2226**

Thermal Development of the Electrical Resistance of Thin Films of Bismuth.—P. Huet & A. Colombani. (*C. R. Acad. Sci., Paris*, 11th Feb. 1957, Vol. 244, No. 7, pp. 865–868.) Resistance/temperature characteristics between 0°C and 320°C are shown for three ranges of film thickness.

549.514.51 **2227**

Crystal Defects in Y-Cut Quartz and their Effect on the Equivalent Resistance.—H. Iwasaki. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 259–264.) The nature of etch patterns is investigated. Plates exhibiting a crevice pattern, which is due to crystal imperfections, have a high equivalent resistance.

549.514.51 : 534.133-8 **2228**

The Role of Internal Friction in Piezoelectric Quartz Crystals.—A. G. Smagin. (*C. R. Acad. Sci. U.R.S.S.*, 21st Jan. 1957, Vol. 112, No. 3, pp. 425–426. In Russian.) Experimental results indicate that internal friction is negligible in comparison with the surface-layer friction.

621.315.612.6.017.143 **2229**

Further Experimental Investigation of the Dielectric Losses of Various Glasses at Low Temperatures.—J. Volger & J. M. Stevels. (*Philips Res. Rep.*, Dec. 1956, Vol. 11, No. 6, pp. 452–470.) Results of measurements are discussed qualitatively in relation to the glass structure. No effect of irradiation on the dielectric losses at low temperatures, such as the formation of colour centres in quartz crystals (see 2768 of 1956), is found. Various loss mechanisms are summarized.

621.315.616 **2230**

Variation with Pressure of the Permittivity of Polythene.—A. C. Lynch & P.L. Parsons. (*Nature, Lond.*, 30th March 1957, Vol. 179, No. 4561, p. 686.)

621.318.132 : 621.314.22(43) **2231**

Magnetically Soft Alloys as Material for Use in Instrument Transformers.—O. E. Nölke. (*Arch. tech. Messen*, Nov. 1956, No. 250, pp. 259–262.) Details of German alloys are given. Characteristics and costs are compared in graphical form.

621.318.134 : 538.65 : 534.232 **2232**

Performance of Ceramic Ferrite Resonators as Transducers and Filter Elements.—C. M. van der Burgt. (*J. acoust. Soc. Amer.*, Nov. 1956, Vol. 28, No. 6, pp. 1020–1032.) A detailed review with numerical and graphical data of the properties of modern piezomagnetic materials. 69 references.

621.318.2 (43) **2233**
Commercial Types of Permanent Magnet, particularly for Measuring Instruments.—H. Fahlenbrach. (*Arch. tech. Messen*, Oct. & Nov. 1956, Nos. 249 & 250, pp. 237–240 & 263–264.) Summary of modern manufacturing processes, characteristics and applications of German magnetic materials. 25 references.

539.23 **2234**
Vacuum Deposition of Thin Films. [Book Review]—L. Holland. Publishers: Chapman & Hall, London, 1956, 542 pp., 70s. (*Nature, Lond.*, 9th March 1957, Vol. 179, No. 4558, pp. 501–502.)

MATHEMATICS

51 **2235**
On the Integration of Nonlinear Parabolic Equations by Implicit Difference Methods.—M. E. Rose. (*Quart. appl. Math.*, Oct. 1956, Vol. 14, No. 3, pp. 237–248.)

512.831 **2236**
A Method for Treating the Stability Problem in Matrix Eigenvalue Problems.—H. R. Schwarz. (*Z. angew. Math. Phys.*, 25th Nov. 1956, Vol. 7, No. 6, pp. 473–500.) Given the eigenvalue problem $(A - \lambda E)x = 0$ for real or complex matrices A, the number of eigenvalues λ with positive real parts is determined without evaluating the characteristic polynomial. A procedure is developed for transforming the given matrix into a reduced form by applying a finite series of elementary transformations; the problem can then be solved immediately.

517 **2237**
A Method for the Construction of Green's Functions.—B. A. Boley. (*Quart. appl. Math.*, Oct. 1956, Vol. 14, No. 3, pp. 249–257.) The Green's function associated with any partial differential equation is obtained as the solution of an integral equation, as the limit of an infinite sequence of functions. Convergence of this sequence is proved for the case of Helmholtz's equation.

517 : 535.13 : 538.56 **2238**
On the Solution of Maxwell's Equations in Cylindrical Coordinates by means of Laplace Transforms and Finite Fourier and Hankel Transforms.—H. Delavault. (*C. R. Acad. Sci., Paris*, 25th Feb. 1957, Vol. 244, No. 9. pp. 1146–1149.)

519.2 : 621.39 **2239**
Entropy of Stochastic Processes.—M. Rozenblat-Rot. (*C. R. Acad. Sci. U.R.S.S.*, 1st. Jan. 1957, Vol. 112, No. 1, pp. 16–19. In Russian.)

MEASUREMENTS AND TEST GEAR

53.087/.088 **2240**
Taking Account of Systematic Errors in Measurements.—H. Weyerer. (*Naturwissenschaften*, Nov. 1956, Vol. 43, No. 21, p. 492.) Systematic errors cannot be dealt with by averaging techniques applicable to random errors; a formula is presented which permits the systematic errors to be taken into account.

621.317.335+621.317.41].029.64 **2241**
: 621.318.134
Measurement of Dielectric and Magnetic Properties of Ferromagnetic Materials at Microwave Frequencies.—W. von Aulock & J. H. Rowen. (*Bell Syst. tech. J.*, March 1957, Vol. 36, No. 2, pp. 427–448.) Measurements are made by observing the perturbation in a cylindrical cavity, excited at 9·2 kMc/s, due to the insertion of a small ferrite sample. Thin disk samples yield more accurate results below ferromagnetic resonance whereas small spheres are preferable near resonance. Experimental results are given for low-loss BTL ferrite. The loss below resonance is considerably lower for polycrystalline ferrites than that predicted by Polder's theory for single-crystal ferrites.

621.317.335.2 **2242**
A Simple Apparatus for Measuring Circuit Capacitances.—J. C. S. Richards. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 118–120.) An instrument is described for measuring capacitance to earth in the range 0–300 pF with accuracy within ± 2%.

621.317.444 **2243**
Continuously Indicating Precision Magnetometer.—G. W. Green, R. C. Hanna & S. Waring. (*Rev. sci. Instrum.*, Jan. 1957, Vol. 28, No. 1, pp. 4–8.) A magnetic field can be measured by finding the resonance frequency of a coil suspended in it. Simple auxiliary apparatus gives an accuracy within 1% and 0.01% can be achieved.

621.317.7 : 621.316.87 **2244**
: 621.396.822.029.6
A New Standard for Very Low Noise Powers in the Microwave Region.—H. Jung. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 50–52.) The use of heated polar liquids as noise sources is proposed. A tube through which the heated liquid flows is fitted to the waveguide in place of a gas-discharge noise generator. Good broad-band matching and accuracy is obtained; noise temperatures of gas discharges found in this way agree fairly well with available data.

621.317.7 : 621.396.324 **2245**
Laboratory Test Equipment for Synchronous Regenerative Radiotelegraph Systems.—Hilton, Law, Lee & Levett. (See 2288.)

621.317.7 : 621.397.6 **2246**
Electronic Video-Pattern Generator with Continuously Variable Patterns.—W. Dillenburger & J. Wolf. (*Elektronische Rundschau*, Nov. 1956, Vol. 10, No. 11, pp. 293–296.) The application and the basic circuits of such an instrument are described.

621.317.7.087.6 **2247**
Servo-Operated Recording Instruments.—R. L. Gordon: A. J. Maddock. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, p. 187.) Comment on 3830 of 1956 and author's reply.

621.317.742.029.64 **2248**
A Coaxial Standing-Wave Detector for the S-Band.—L. W. Shawe & G. W. Fynn. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 188–190.)

621.317.75 : 537.226/.227 **2249**
Bridge for Accurate Measurement of Ferroelectric Hysteresis.—H. Diamant, K. Drenck & R. Pepinsky. (*Rev. sci. Instrum.*, Jan. 1957, Vol. 28, No. 1, pp. 30–33.) This instrument gives an undistorted display of hysteresis loops even with samples of relatively high conductivity. The bridge measurements are independent of the frequency and waveform of the applied voltage.

621.317.755 : 621.385.83 **2250**
Blue-Trace Oscillograph, a New Instrument for recording Nonperiodic Phenomena.—W. Dietrich. (*Nachrichtentech. Z.*, Nov. 1956, Vol. 9, No. 11, pp. 504–507.) The equipment described uses a skiatron-type tube. The dark trace produced persists for several days, under appropriate conditions, or it can be erased in a few seconds by means of a built-in heater. Frequency components up to 15 kc/s can be recorded at writing speeds not exceeding 400 m/s.

621.317.763 **2251**
Resistive Fins Improve Wavemeter Tuning.—K. Ishii. (*Electronic Ind. Tele-Tech.*, Nov. 1956, Vol. 15, No. 11, pp. 59 . . 128.) To increase the absorption of electric field energy in cylindrical cavity wavemeters a conventional flat power absorber was fitted with radial fins projecting into the cavity. The improvement is evident from a comparison of the tuning characteristics before and after modification.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

539.16.08 : 621.385.15 **2252**
Electron Multipliers for the Registration of Corpuscular and Hard Electromagnetic Radiations.—T. M. Lifshits. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1272–1283.) The 13-stage electron multiplier, which is similar to that described by Allen (1106 of 1948),

uses an activated Cu-Al-Mg alloy cathode and secondary-electron emitters; the amplification factor lies between 10^9 and 10^{11} at a voltage of 300 V per stage. Mg or Ta photocathodes are used in the ultraviolet counter, and a cathode comprising 20 layers of Pt foil in the X- and γ-ray counters.

551.508.1 : 621.398 2253

The Scatter Error of the 'Modell Lang' Radiosonde.—W. Klinkow & R. Weide. (*Z. Met.*, Oct. 1956, Vol. 10, No. 10, pp. 308–313.) A report is presented of tests on this radiosonde, which is the type used in the East German meteorological service. Masking by fortuitous errors made it impossible to determine the scatter between readings given by different specimens of the same model.

616-7 : 621.374.3 : 621.314.7 2254

A Transistor Cardiotachometer.—L. Molyneux. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 125–127.) A small, portable, battery-operated instrument designed for use in the operating suite of a hospital.

621.317.39 : 531.71 : 621.319.43 2255

Design of Capacitance Displacement Transducers.—R. K. Vinycomb & F. E. Martyr. (*Instrum. Practice*, Nov. 1956, Vol. 10, No. 11, pp. 985–987.) Practical details, including a nomogram, are given for simple piston-type coaxial-cylinder capacitors for measuring mechanical displacements over a wide range.

621.373.52 : 621.43.04 2256

A New Electronic Ignition System for Motor Cars.—M. J. Guiot. (*Électronique, Paris*, Nov. 1956, No. 120, pp. 51–52.) The equipment described, which is now produced commercially, uses an 80-kc/s transistor oscillator and step-up transformer producing 12 to 20 kV. High efficiency and output independent of motor speed are its chief advantages.

621.383.2 : 621.385.832 : 778.5 2257

The Myriatron.—G. H. Lunn & R. A. Chippendale. (*Electronic Radio Engr*, May 1957, Vol. 34, No. 5, pp. 156–160.) The principles of operation of an image dissector for high-speed cinematography are described.

621.384.6 2258

Electrostatic Lens.—N. P. Carleton. (*Rev. sci. Instrum.*, Jan. 1957, Vol. 28, No. 1, pp. 9–10.) A lens having the potential function $V(r,z) = \alpha(2z^2 - r^2)$ in cylindrical coordinates was found to focus a highly divergent ion beam more effectively than conventional lenses.

621.384.6 2259

Variable-Energy Particle Accelerators.—J. W. Gallop. (*Nature, Lond.*, 2nd March 1957, Vol. 179, No. 4557, p. 492.) Comment on recent developments in design of proton accelerators.

621.384.612 2260

Method of Investigating Radial-Phase Oscillations of Electrons in a Synchrotron.—Yu. M. Ado. (*Zh. eksp. teor. Fiz.*, Sept. 1956, Vol. 31, No. 3(9), pp. 533–534.) The principles of a method based on the observation of light radiated by the electrons are described.

621.384.613 2261

Approximations for Linear Betatron Oscillations.—F. T. Adler & D. Baroncini. (*Nuovo Cim.*, 1st Nov. 1956, Vol. 4, No. 5, pp. 959–974. In English.) "Approximation methods for calculating the characteristic exponent of extended Hill equations are derived and applied to the computation of linear betatron oscillations."

621.385.833 2262

Aperture Aberration of Strong-Focusing [electron] **Lenses.**—M. Y. Bernard & J. Hue. (*C. R. Acad. Sci., Paris*, 4th Feb. 1957, Vol. 244, No. 6, pp. 732–735.) Continuation of analysis (1559 of May) with a note on the size and shape of the focal distortion caused.

621.385.833 2263

The Theory of the Reflection Electron Microscope.—D. Wiskott. (*Optik, Stuttgart*, Oct. & Nov. 1956, Vol. 13, Nos. 10 & 11, pp. 463–478 & 481–493.) The theory of an electron microscope for viewing the object by reflected electrons is developed on the basis of geometrical optics and wave mechanics; the approximate solutions derived agree with experimental results. In practice the resolution obtainable should reach 120–150 Å for a field strength of 100 kV/cm.

621.385.833 2264

The Resolving Power of an Emission-Type Electron Microscope in the Presence of a Diaphragm, and the Velocity Spectrum of Transmitted Electrons.—C. Fert & R. Simon. (*C. R. Acad. Sci., Paris*, 25th Feb. 1957, Vol. 244, No. 9, pp. 1177–1179.) The analysis of the microscope described earlier (904 of March) shows that the resolution is independent of the spread of the velocities of the electrons emitted by the cathode.

PROPAGATION OF WAVES

621.396.11 2265

Radio Wave Propagation.—(*Nature, Lond.*, 16th Feb. 1957, Vol. 179, No. 4555, pp. 354–356.) Report on a colloquium held in Paris, September 1956, covering tropospheric and ionospheric propagation and general theoretical problems. Papers are to be published in *Onde élect.*

621.396.11 2266

On the Multiple Diffraction of Electromagnetic Waves by Spherical Mountains.—K. Furutsu. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 331–390.) The treatment discussed in 3186 of 1956 is extended to the problem of multiple diffraction. The formulae obtained cover a wide range of angles and are applicable to diffraction by the earth's surface.

621.396.11 2267

The Calculation of Field Strength over Mixed Paths on a Spherical Earth.—K. Furutsu & S. Koimai. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 391–407.) Graphs and tables of factors required in field strength calculations based on the formula derived in 2191 of 1956 (Furutsu) are given.

621.396.11 : 511.510.535 2268

D-E Layer Electron Model Revised from Considerations of the Diurnal Variation of Experimental Results.—T. Kobayashi. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 279–305.) The electron model (2194 of 1956) is modified on the basis of an analysis of experimental results obtained by various authors and a revision of Chapman's theory. Absorption charts are compared and the use of transmission curves in calculations is illustrated.

621.396.11 : 551.510.535 : 523.75 2269

Some Effects of Intense Solar Activity on Radio Propagation.—Houston, Ross & Schmerling. (See 2128.)

621.396.11 : 551.510.535 : 621.317.75 2270

Measurement of Ionospheric Path-Phase for Oblique Incidence.—R. Price & P. E. Green, Jr. (*Nature Lond.*, 16th Feb. 1957, Vol. 179, No. 4555, pp. 372–373.) Three techniques for direct measurement of path/phase variations at oblique incidence are outlined. They are based on heterodyning the received wave train with an i.f. that is an integral multiple of the pulse repetition rate. Sample records are shown. Experiments to be made using Cs frequency standards include the examination of multipath transmissions associated with forward scatter.

621.396.11.029.45 : 551.594.6 2271

Lightning and the Propagation of Audio-Frequency Electromagnetic Waves.—Ya. L. Al'pert. (*Uspekhi fiz. Nauk*, Nov. 1956, Vol. 60, No. 3, pp. 369–389.) See 919 and 920 of March (Al'pert & Borodina).

621.396.11.029.45 : 621.396.933.2 2272
: 551.594.6

Very-Low-Frequency Propagation and Direction-Finding.—F. Horner. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 73–80.) Direction-finding observations on a c.w. transmitter at 16 kc/s have established the magnitude of polarization errors with crossed-loop aerials. Errors on atmospherics are similar but may have less practical importance depending on how the results are used. The reflecting properties of the ionosphere at 16 kc/s were found to depend on the azimuthal direction of propagation.

621.396.11.029.55 : 551.510.535 2273

Propagation on 27 Mc/s via E_s-Layer Reflections.—Y. Uesugi, I. Kasuya & J. Orimo. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 265–278.) Report on propagation tests carried out over 540–1 470-km paths to investigate the validity of an empirical formula relating

fE_s to field strength, derived by Kono et al. (1770 of 1955). Disagreement at higher field strengths could be explained by assuming partial reflections.

621.396.81.029.55 **2274**

Index of Short-Radio-Wave Intensity.—Y. Hakura & M. Miyamoto. (*J. Radio Res. Labs, Japan*, Oct. 1956, Vol. 3, No. 14, pp. 307–329.) The field strength of the 10- and 15-Mc/s WWV transmissions received at Hiraiso (Japan) was analysed by the statistical method outlined. The daily indices from 1950 to 1955 are tabulated.

621.396.812.3.029.64/.65 **2275**

Some Problems Posed by Wave Propagation at 8-mm and 3-cm Wavelength over the Sea and through Rain.—D. G. Kiely. (*Ann. Télécommun.*, Nov. & Dec. 1956, Vol. 11, Nos. 11 & 12, pp. 233–244 & 267–279.) Account of tests carried out in 1951 and 1952 and separately covered by previous reports (see e.g. 1554 and 1774 of 1954).

RECEPTION

621.396.621 : 621.376.33 **2276**

Principles of Design of Battery-Operated Frequency-Modulation Receivers.—R. A. Lampitt & J. P. Hannifan. (*J. Brit. Instn Radio Engrs*, March 1957, Vol. 17, No. 3, pp. 173–185.) A theoretical circuit diagram of a nine-valve transportable receiver is included. The main emphasis of the discussion is on the mixer, i.f. amplifier, and demodulator stages.

621.396.621 : 621.376.33 **2277**

Limiters and Discriminators for F.M. Receivers: Part 3.—G. G. Johnstone. (*Wireless World*, March & May 1957, Vol. 63, Nos. 3 & 5, pp. 124–127 & 235–240.) An analysis and design procedure are detailed for the 'idealized' ratio detector together with a comparison with the Foster-Seeley arrangement. Parts 1 & 2 : 1220 of April.

621.396.621 : 621.396.215 **2278**

Frequency Diversity in the Reception of Selectively Fading Binary Frequency-Modulated Signals.—J. W. Allnatt, E. D. J. Jones & H. B. Law. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 98–110. Discussion, pp. 147–152.) The use of frequency diversity is advocated to obtain all available information from both the marks and spaces in radio-telegraphy. An experimental demodulation unit showed, in laboratory tests and in the field, the advantages of diversity over conventional methods.

621.396.621 : 621.396.215 **2279**

The Signal/Noise Performance Rating of Receivers for Long-Distance Synchronous Radiotelegraph Systems using Frequency Modulation.—H. B. Law. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 124–129. Discussion, pp. 147–152.) Experimental and theoretical results indicate that the steady-signal error-liability of f.m. radio-telegraph receivers of the limiter-discriminator type is characterized by a simple exponential function of the signal/noise ratio. Fading-signal performance with or without diversity is readily derived from the steady-signal performance.

621.396.812 : 621.396.215 **2280**

The Detectability of Fading Radiotelegraph Signals in Noise.—H. B. Law. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 130–140. Discussion, pp. 147–152.) An ideal receiver for binary synchronous telegraphy is defined and the noisy-signal performance of a practical receiver measured in terms of its departure from the ideal. Analysis leads to a mathematical specification for the ideal diversity receiver which provides a basis for the design of practical receivers.

621.396.812.029.64 **2281**

An Experimental Study of some Fading Characteristics of 10-cm Waves in the Scatter Region.—D. G. Kiely, S. J. Robinson & F. C. Chesterman. (*J. Brit. Instn Radio Engrs*, March 1957, Vol. 17, No. 3, pp. 161–171.) Data presented include the short-term fading rate, amplitude, and fading pattern correlation using spaced aerials, for a 100-mile path over the Bristol Channel, and the amplitude of mean-level fades in the North Sea area.

621.396.812.3.001.57 **2282**

An Improved Fading Machine.—H. B. Law, F. J. Lee, R. C. Looser & F. A. W. Levett. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 117–123. Discussion, pp. 147–152.) A fading signal with a Rayleigh amplitude distribution and random phase variations was obtained by mixing six components, with slightly different and suitably varying frequencies.

STATIONS AND COMMUNICATION SYSTEMS

621.376.3 **2283**

An Investigation of the Spectra of Binary Frequency-Modulated Signals with Various Build-Up Waveforms.—J. W. Allnatt & E. D. J. Jones. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 111–116. Discussion, pp. 147–152.) Spectra were determined experimentally. Results suggest that trapezoidal modulation gives the smallest bandwidth for a given total build-up time.

621.376.5 : 621.373.431.1 **2284**

A Method of Time-Pulse Transformation.—I. A. Zakharya & V. N. Mikhailovski. (*Avtomatika i Telemekhanika*, Sept. 1956, Vol. 17, No. 9, pp. 836–846.) The properties are considered of a new system of transforming the voltage amplitude of rectangular pulses into time intervals between the leading edges of pulses of higher frequency. The system includes a cathode-coupled multivibrator circuit. Analysis suggests applications in telemetry systems.

621.39 : 534.78 **2285**

A Development of the Collard Principle of Articulation Calculation.—J. Collard: D. L. Richards & R. B. Archbold. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, p. 196.) Comment on 3873 of 1956 and authors' reply.

621.39.001.11 **2286**

Theory of Transmission of Information through Stochastic Communication Channels.—M. Rozenblat-Rot. (*C. R. Acad. Sci. U.R.S.S.*, 11th Jan. 1957, Vol. 112, No. 2, pp. 202–205. In Russian.) Mathematical paper.

621.39.001.11 **2287**

On the Capacity of a Discrete Channel: Part 2.—S. Muroga. (*J. phys. Soc. Japan*, Oct. 1956, Vol. 11, No. 10, pp. 1109–1120.) Extension of the theoretical treatment of noisy channels outlined in Part 1 (254 of 1954).

621.396.324 : 621.317.7 **2288**

Laboratory Test Equipment for Synchronous Regenerative Radiotelegraph Systems.—C. G. Hilton, H. B. Law, F. J. Lee & F. A. W. Levett. (*Proc. Instn elect. Engrs*, Part B, March 1957, Vol. 104, No. 14, pp. 141–147. Discussion, pp. 147–152.) Element error rate is measured directly.

621.396.41 **2289**

Double-Sideband vs Single-Sideband Systems.—J. P. Costas. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 534–537.) The utility of s.s.b. as opposed to d.s.b. transmissions is questioned on particular aspects such as spectrum conservation, power gain, waveform preservation, propagation and expense.

621.396.41 **2290**

Synchronous Communications.—R. R. McPherson. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 537–538.) Comment on 936 of March (Costas).

621.396.41 **2291**

Single-Sideband Technique.—(*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 538 . . 540.) Comments on two of the papers noted in 937 of March and authors' replies.

621.396.41 **2292**

S.S.B. Performance as a Function of Carrier Strength.—N. H. Shepherd: W. L. Firestone. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 541–543.) Comment on 938 of March and author's reply.

621.396.41 : 621.396.11 **2293**

Single-Sideband Techniques in U.H.F. Long-Range Communications.—J. E. Bartow: W. E. Morrow, Jr, C. L. Mack, Jr, B. E. Nichols & J. Leonhard. (*Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, p. 539.) Note of correction to 939 of March.

621.396.5 : 621.396.65 **2294**

The Application of Rural Radio to Telephone Networks.—C. B. Wooster.

(*A.T.E. J.*, Oct. 1956, Vol. 12, No. 4, pp. 300–312.) A description of commercially available v.h.f. f.m. equipment for both subscriber and junction working. Signal/noise ratios >51 dB are attainable. See also 3040 of 1954 (Felix & Wooster).

621.396.65.029.6 **2295**

Propagation Test on Microwave Communications Systems.—H. R. Mathwich, E. D. Nuttall, J. E. Pitman & A. M. Randolph. (*Elect. Engng, N.Y.*, Nov. 1956, Vol. 75, No. 11, pp. 1020–1025; *Commun. & Electronics*, Jan. 1957, No. 28, pp. 685–691.) Report of tests at 955·5, 1 965 and 6 730 Mc/s over a land path 20 miles long carried out over a period of 16 months.

SUBSIDIARY APPARATUS

621.311.6 : 541.133 **2296**

A Constant-Current Device for Use in the Measurement of Transference Numbers by the Moving-Boundary Method.—D. T. Hopkins & A. K. Covington. (*J. sci. Instrum.*, Jan. 1957, Vol. 34, No. 1, pp. 20–21.) "A circuit is described which will supply a current of between 0·5 and 2·5 mA, constant to 0·1%, with a ten-fold load impedance change, in the range 5–500 kΩ."

621.316.722.078.3 **2297**

A Low-Voltage D.C. Stabilizer using a Saturated-Diode Controller.—F. A. Benson & M. S. Seaman. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 121–125.) Supplies current up to 30 A.

TELEVISION AND PHOTOTELEGRAPHY

621.397.2 **2298**

Increasing the Efficiency of the Transmission of Television Signals.—D. A. Novik. (*Radiotekhnika i Elektronika*, Sept. 1956, Vol. 1, No. 9, pp. 1230–1239.) The bandwidth-compression system discussed is based on a transformation of the time-scale of the television signal. Block diagrams of the system are given.

621.397.24 : 621.315.212.1 **2299**

The 'G-Line' Community TV System.—R. B. Gary. (*Radio & Telev. News*, Nov. 1956, Vol. 56, No. 5, pp. 40–41.) Description of a 15-mile transmission system using the Goubau line to bring television signals to a U.S. community outside the normal reception area. The channel-13 signals are converted to channel 4 before launching by a 58-in.-diameter, 45°-taper conical horn on to the polyethylene-coated line. The line is suspended from telephone poles. Nine line amplifiers are used along the line.

621.397.5 : 621.396.4 **2300**

Television with Multiple Sound Channels.—A. Dubec. (*Électronique, Paris*, Nov. 1956, No. 120, pp. 31–36.) From a comparison of various methods of combining several different sound transmissions with a single picture signal a carrier-current multiplex system and a p.a.m. system appear the most suitable. Basic characteristics and circuits are discussed with reference to French standards.

621.397.621.2 : 535.623 **2301**

Some Considerations concerning the Gamma of a Tricolour Picture Tube.—W. F. Niklas. (*J. Soc. Mot. Pict. Telev. Engrs*, Oct. 1956, Vol. 65, No. 10, pp. 546–551.) The expression for gamma is derived and its correlations with gun design parameters found. Methods of compensation for different red, blue and green phosphor efficiencies and the influence of manufacturing tolerances on gamma are discussed. Among gun designs which permit the use of equal drives on all three guns the triplet with different spacings in the triode gives the best results if close tolerances can be maintained.

621.397.7 : 621.396.712.3 **2302**

The Du Mont Telecentre.—R. D. Chipp. (*J. Soc. Mot. Pict. Telev. Engrs*, Oct. 1956, Vol. 65, No. 10, pp. 535–542.) Description of architectural features and of some of the equipment installed.

621.397.8 **2303**

The Black-White Step in Vestigial-Sideband Television Transmissions.—D. Bünemann & W. Händler. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 457–466.) Analysis of investigations made to establish tolerances for the various elements of television transmitters in conformity with C.C.I.R. standards. The reproduction of a black-white step as characterized by rise time, overshoot and smearing was examined; some methods of improving picture quality are discussed.

621.397.5 : 535.623 **2304**

Principles of Color Television. [Book Review]—K. McIlwain & C. E. Dean (Eds). Publishers: Wiley & Sons, New York, and Chapman & Hall, London, 1956, 595 pp., 104s. (*Nature, Lond.*, 30th March 1957, Vol. 179, No. 4561, pp. 645–646.) A work by the Hazeltine Laboratories Staff. "This book should be of great value to professional television engineers engaged in research and development, in equipment design or in broadcasting."

TRANSMISSION

621.396.61 : 621.376.3 **2305**

Out-of-Channel Radiation from Mobile F.M. V.H.F. Transmitters.—A. L. Rowles. (*Electronic Engng*, March 1957, Vol. 29, No. 349, pp. 102–107.) A low-pass filter following the clipper-type limiter reduces the power radiated in unwanted sidebands produced by harmonic distortion in the limiter.

VALVES AND THERMIONICS

621.314.7 : 621.318.57 **2306**

The Symmetrical Transistor as a Bilateral Switching Element.—Trousdale. (See 2043.)

621.314.7 : 621.375.4 **2307**

Transistor Bias Stabilization.—J. S. Murray. (*Electronic Radio Engr*, May 1957, Vol. 34, No. 5, pp. 161–165.) "A method of using two transistors in cascade is described which enables the operating conditions of the first to be stabilized to a high degree. As a result, it becomes practicable to operate with a very low collector-base voltage and so to minimize semiconductor noise."

621.314.7 : 681.142 **2308**

The Junction Transistor as a Computing Element.—Wolfendale, Morgan & Stephenson. (See 2036.)

621.383.27 : 621.373.43 : 535.376 **2309**

An Electron Multiplier as a Pulsed Light Source.—R. Gerharz. (*Z. angew. Math. Phys.*, 25th Nov. 1956, Vol. 7, No. 6, pp. 529–536.) Experiments on multistage photomultipliers with grid control and high overall conductance are discussed. For operation as a pulse generator the tube has a coaxial-line feedback from either the collector or the last dynode to the control grid. The pulse amplitude was about 7 V; the duration was about 8×10^{-9} s, or 3×10^{-9} s when coaxial-line stubs were used. Pulse frequency was about 10 Mc/s with a feedback line of length 25 m. Bluish luminescence was observed particularly at the dynodes carrying the higher currents; the total light energy is estimated at about 0·2 W and the luminescence pulses are coincident with the electrical ones; an electroluminescence process in the MgO secondary-emission layers is believed to be responsible.

621.385.83 : 621.317.755 **2310**

Blue-Trace Oscillograph, a New Instrument for recording Nonperiodic Phenomena.—Dietrich. (See 2250.)

MISCELLANEOUS

621.3-71 **2311**

Heat Control in Electronic Equipment.—E. N. Shaw. (*Electronic Engng*, Jan.–March 1957, Vol. 29, Nos. 347–349, pp. 12–23, 65–70 & 115–118.) An experimental study of natural methods of cooling compact equipment by determining the mechanism of heat loss from basic units of simple design. An appreciation is obtained of the effectiveness of loss by conduction, convection and radiation and the optimum use of each in the construction of single instruments and rack-mounted units is illustrated.

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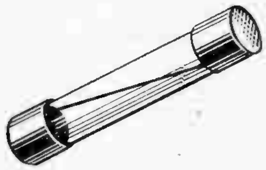

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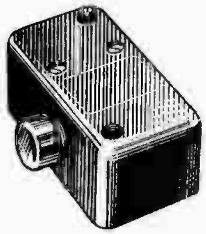

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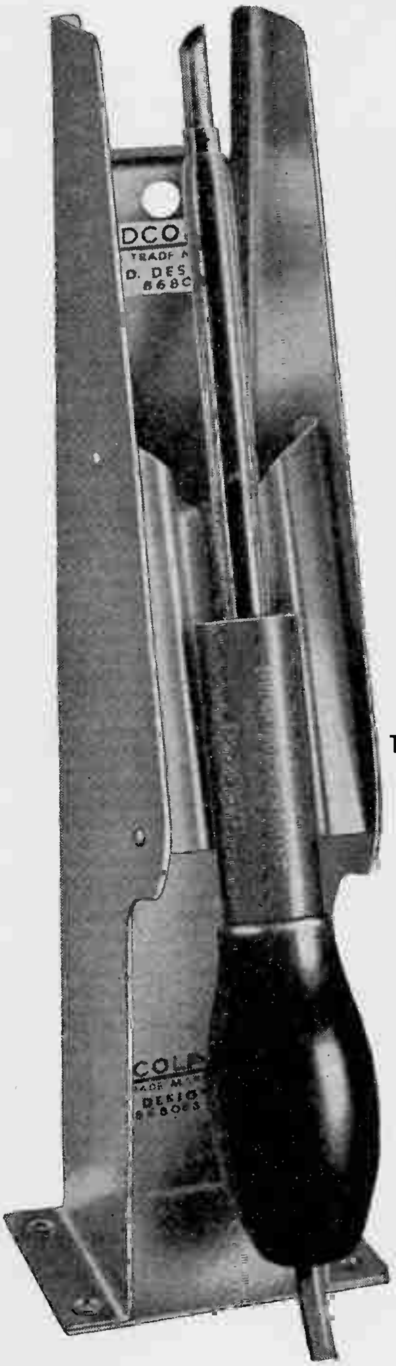

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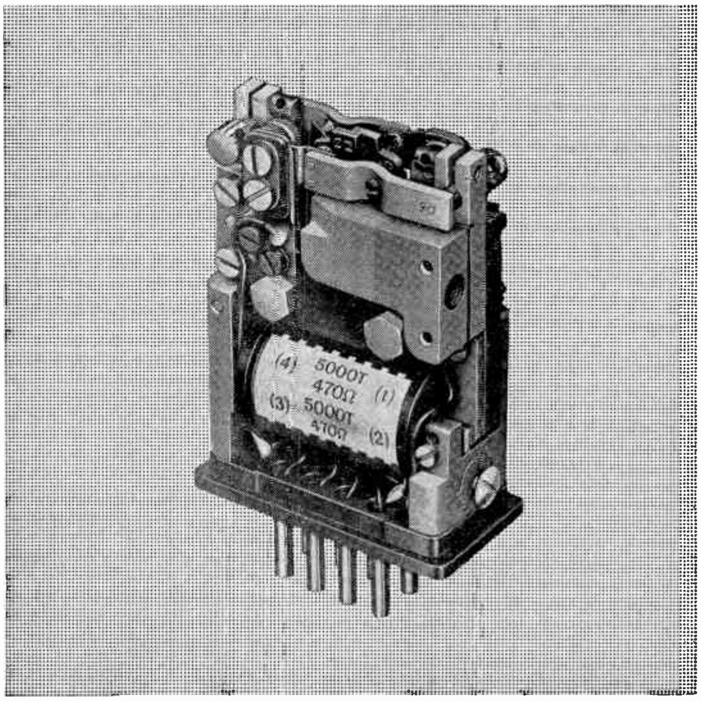

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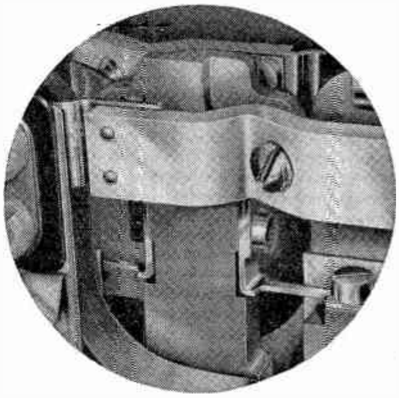

Close-up of armature suspension —magnet removed

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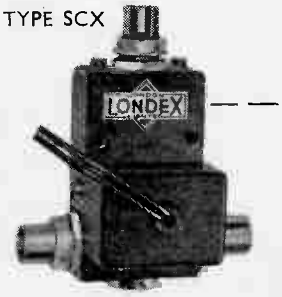

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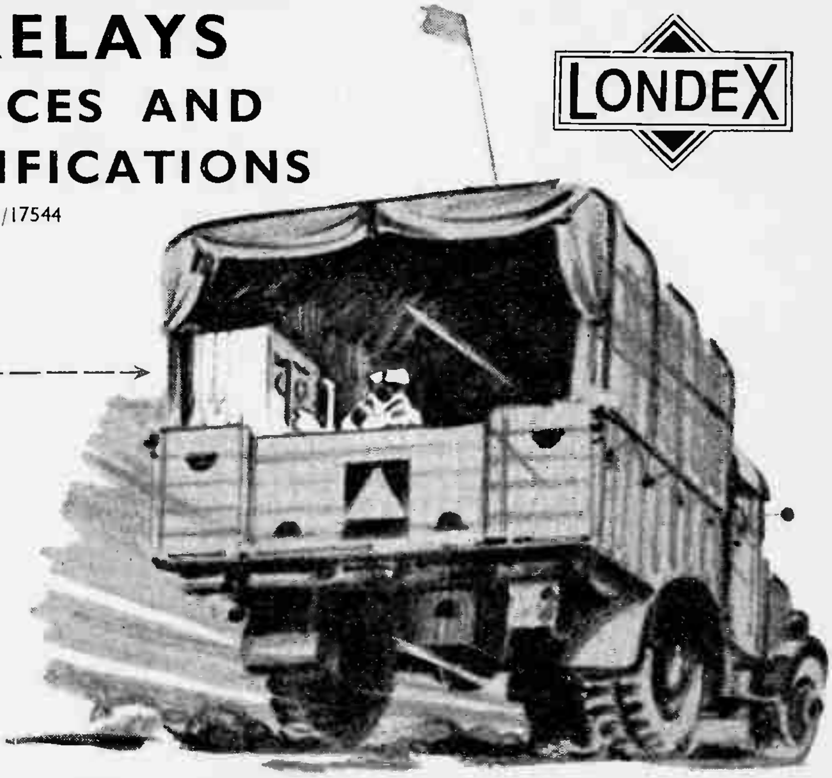

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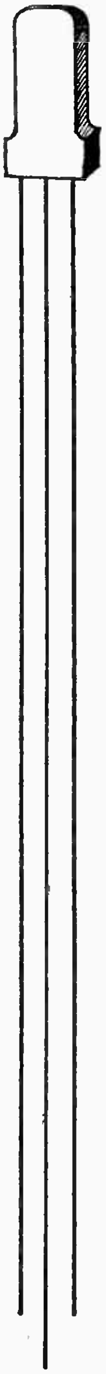

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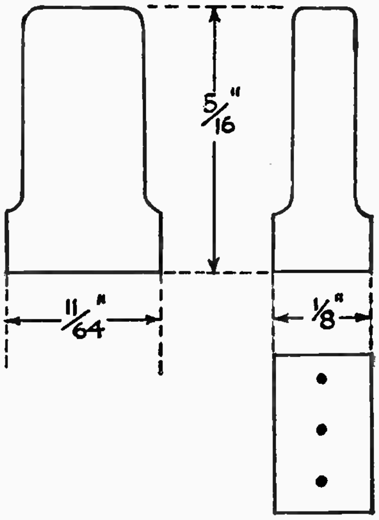

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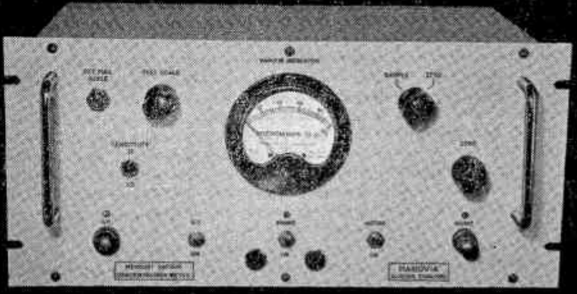

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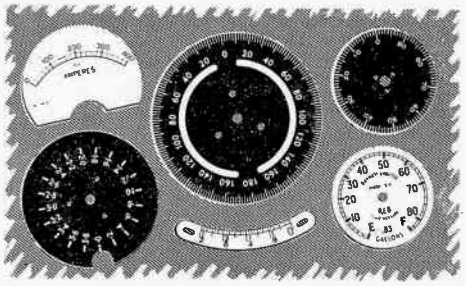

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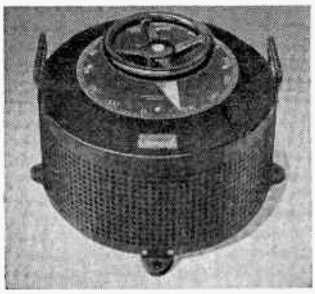

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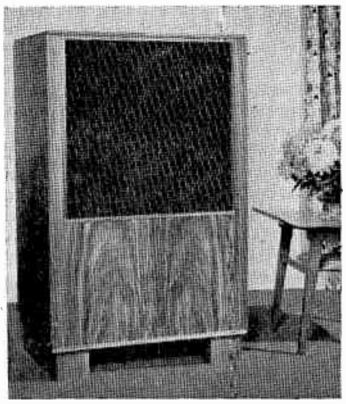

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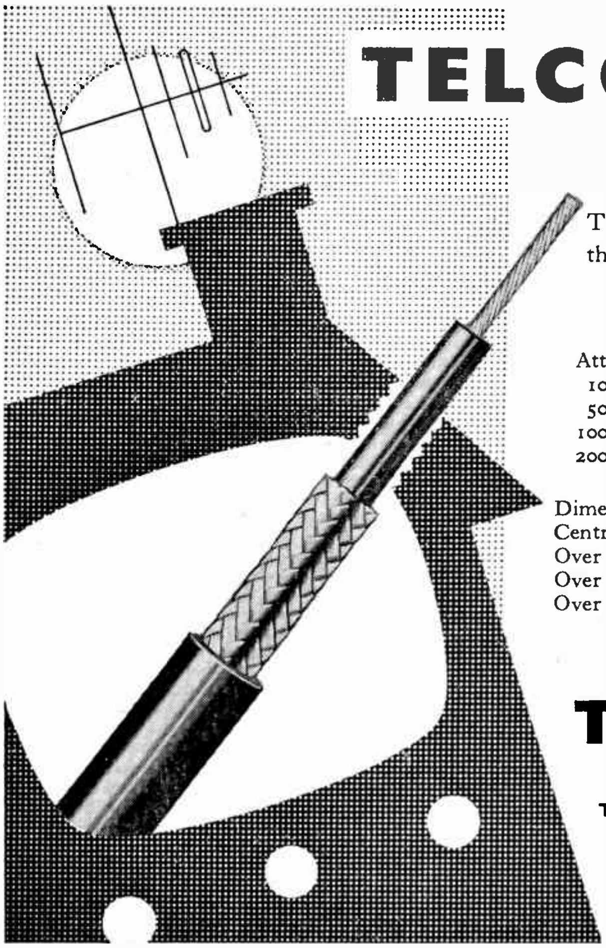

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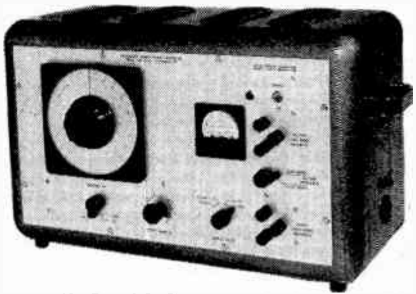

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FREQUENCY 10 c.p.s. to 110 Kc/s
OUTPUT 20 volts into 6 000 ohms
DISTORTION less than 1% over 30 c.p.s.
ACCURACY ± 1½% or 0·5 cycle whichever the greater
OUTPUT LEVEL within ·5dB over 50 c.p.s.

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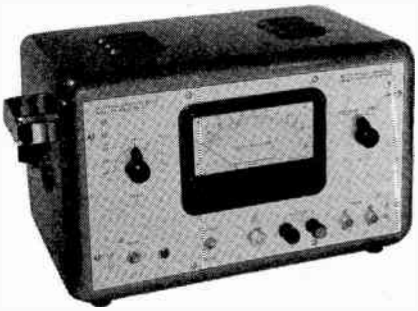

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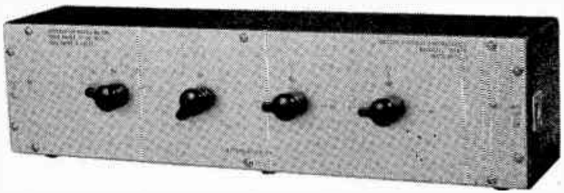
RANGE 0 to 100 Kc/s
ACCURACY ± 1%
INPUT VOLTAGE Min. 75 mV
Max. 15 volts
Provision for external recorder.

ATTENUATOR



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± 5% to 250 Mc/s
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CONNECTIONS 75-ohm co-axial sockets

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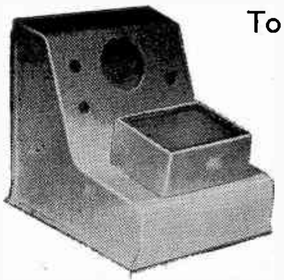

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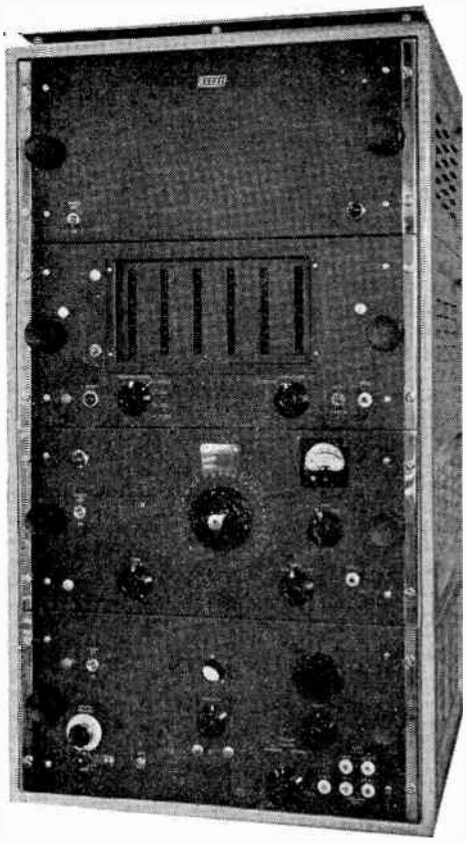

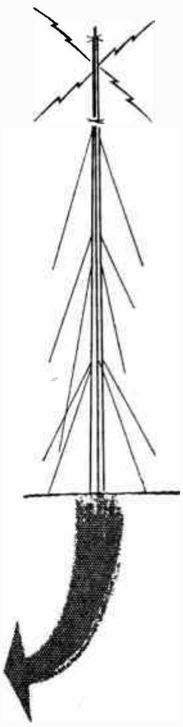

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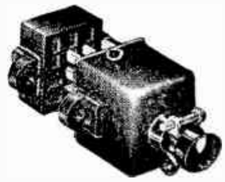

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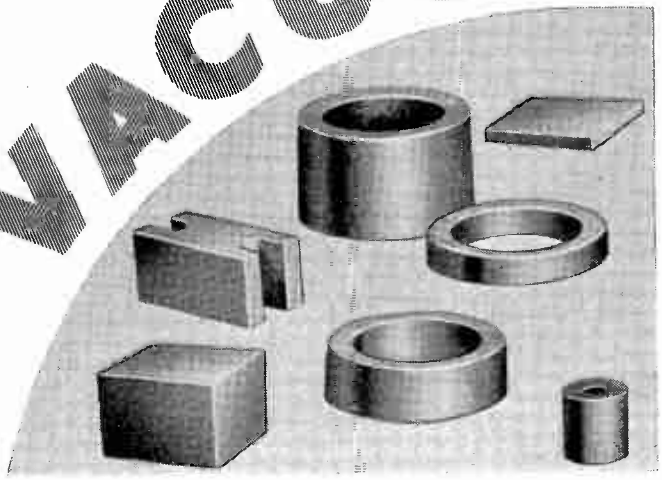

ELECTRONIC & RADIO ENGINEER

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CANDIDATES must be A.M.I.E.E., under 45 and have had considerable experience in installation and running of diesel-operated generating stations, construction and maintenance of both overhead and underground H.V. and L.V. lines, the installation and maintenance of distribution transformers, the testing and maintenance of consumers' meters, the installation and maintenance of C.B. and magneto telephone exchanges including subscribers' P.B.X's, the construction and maintenance of overhead and underground telephone lines, the installation and maintenance of subscribers' services, etc. Knowledge of refrigerating plants desirable.

WRITE Director of Recruitment, Colonial Office, London, S.W.1, giving age, qualifications and experience, quoting BCD 145/34/01. [1089

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DUTIES include staff management and responsibility for maintenance, installation and operation of telecommunications equipment, including exchanges, carrier equipment, telegraph and railway signalling equipment and minor radio stations.

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CANDIDATES under 40 years of age must be Corporate or Graduate Members of the I.E.E. or hold a degree or diploma acceptable by the Institution for Corporate Membership. Two years' experience in practical telecommunications work is necessary.

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PARTICULARS and form of application from the Clerk to the Governors. [1083

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APPLICATION forms, returnable by 19th July 1957, from Establishment Officer, 247/157, Prison Commission, Dean Ryle Street, London, S.W.1. [1081

TRANSFORMERS—small manufacturer, Oxford, seeks young man with good theoretical knowledge as Design Engineer for coupling transformers. Salaried superannuated appointment with good prospects. Box No. 0128. [1087

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APPLICATIONS are invited from suitably qualified engineers to take up a senior appointment in the Network Development Section of a Company which specialises in the design and manufacture of multi-channel line transmission systems. The applicant should preferably have had a wide experience in the design of networks and their application to modern transmission systems. Write giving details of experience to Personnel Manager, Telephone Manufacturing Co., Ltd., Sevenoaks Way, St. Mary Cray, Kent. [1088

RADIO Engineer required by Trinidad Government Wireless Branch, Works and Hydraulics Department for one tour of two years in first instance. Salary scale (including present temporary allowance of £30) equivalent to £780 rising to £1,250 a year. Commencing salary according to qualifications and experience up to maximum of scale. Gratuity at rate equivalent £100–£150 a year. Outfit allowance £60. Free passages. Liberal leave on full salary. Candidates should be A.M.(Brit.)I.R.E. by examination or possess C. & G. Full Technological Cert. in Telecomms, Engineering. They should have had experience in wireless station management and maintenance and in the organisation and operation of communication services. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41953/WJ. [1091

SIGNAL Technician required by Kenya Government Police Force on probation for pensionable employment. Salary scale (including inducement addition) £813 rising to £1,341 a year. Commencing salary according to age and experience. Outfit allowance £40. Free passages for officer and wife and assistance towards cost of children's passages. Liberal leave on full salary. Candidates, preferably not over 40 years of age, must have a wide knowledge of the installation, running and maintenance of H.F. communications equipment, fixed and mobile V.H.F. equipment and installation and maintenance of ancillary equipment. Experience with V.H.F. multi-channel equipment, teleprinters facsimile equipment would be an advantage. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/42335/WJ. [1092

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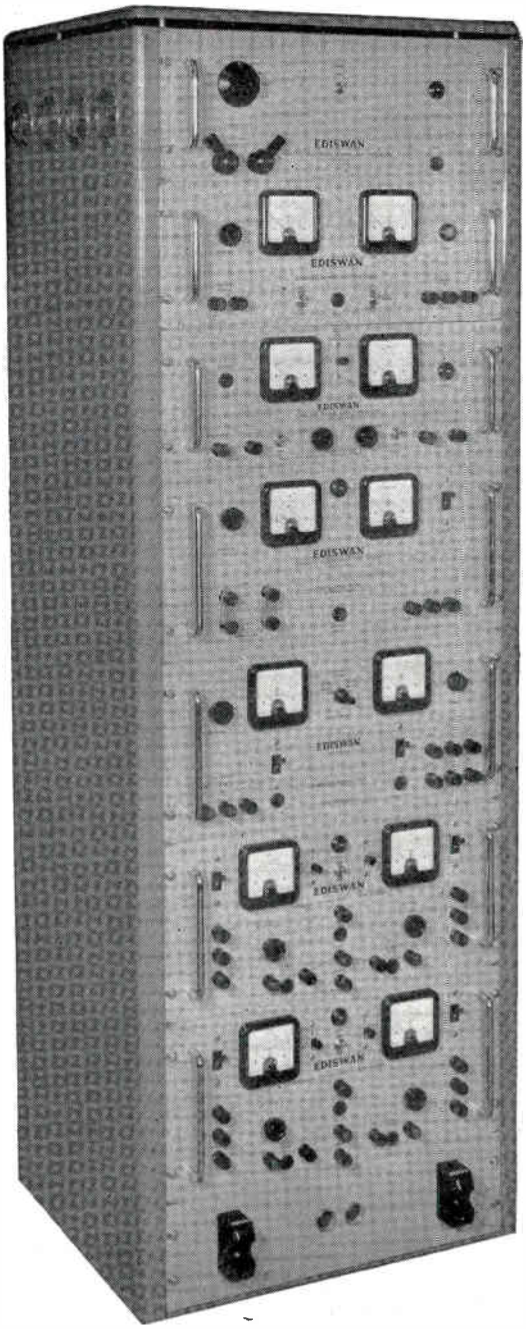

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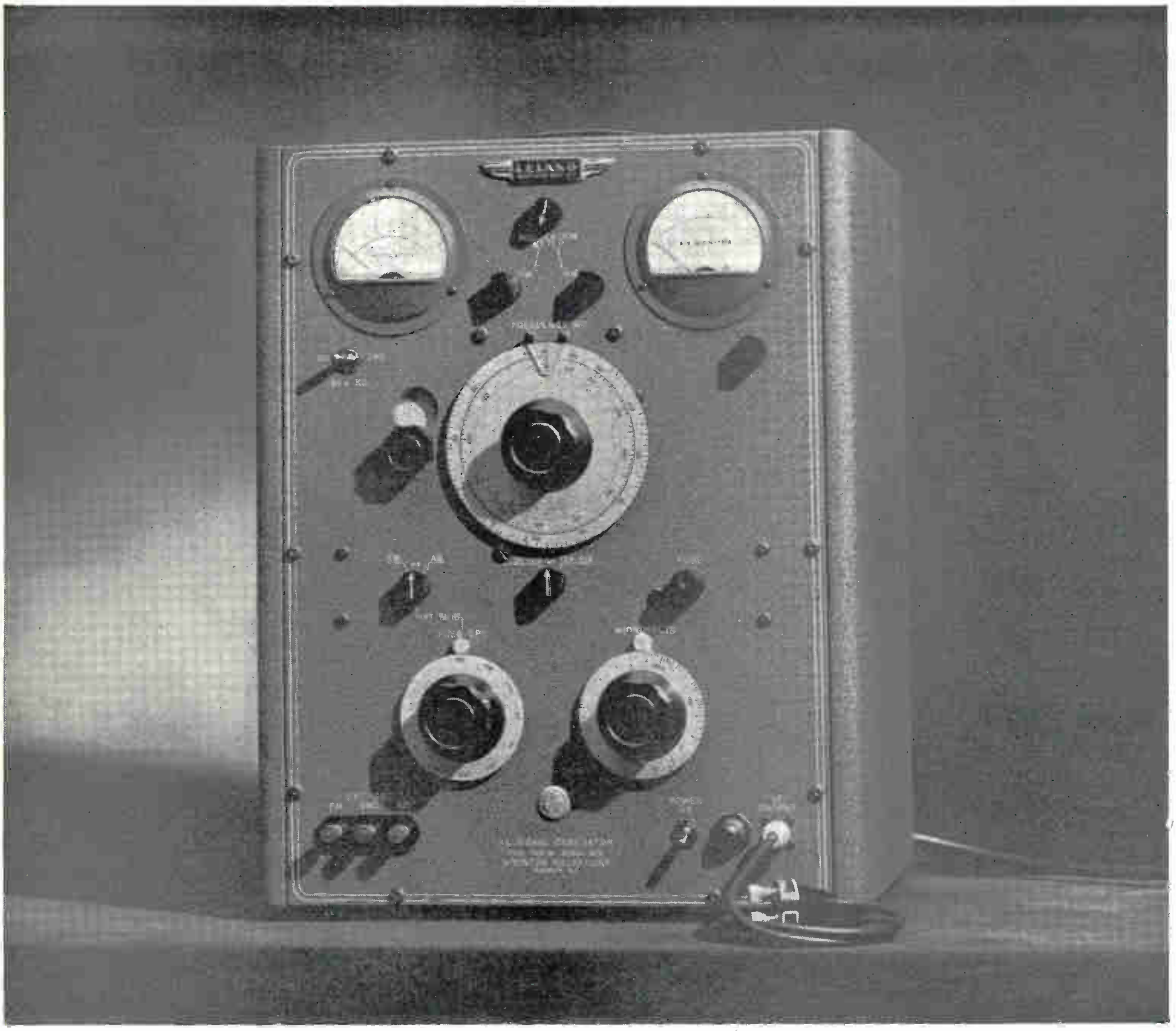

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- ★ **AMPLITUDE MODULATION.** Internal AM available from 0-50% with meter calibrations at 30% and 50% points. External modulation may be used over the range from 0-50%. A front panel jack connects to the screen of the final stage for pulse and square wave modulation.
- ★ **SPECIAL FEATURES.** Incremental frequency range: The Δ F switch permits tuning in increments of ±5, ±10, ±15, ±20, ±25, ±30, ±50, ±60 KC. in the 108 to 216 MC range—half these values in the 54 to 108 MC range. A fine tuning control permits continuous tuning over a range of approximately ±20 KC. in the 108 to 216 MC range, and ±10 KC. in the 54 to 108 MC. range.
- ★ **YOU ARE INVITED** to write for the data sheet on Model 202-E which gives the instrument's full specification, and also for technical information on other instruments in the ranges of **BOONTON, BALLANTINE, DUMONT, FERRIS, BAIRD** and **MEASUREMENTS.**

Boonton instruments are available subject to import licence, from the SOLE CONCESSIONAIRES for the United Kingdom—

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