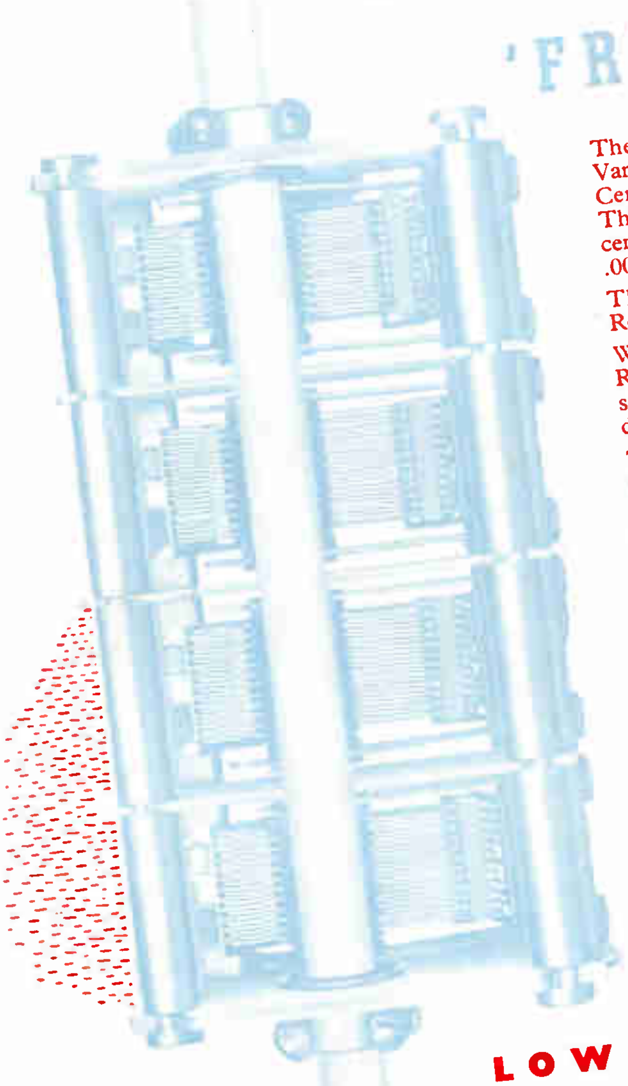
WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

MAY 1952

VOL. 29 No. 344 THREE SHILLINGS AND SIXPENCE



FOR HIGH-FREQUENCY INSULATION—specify

'FREQUELEX'

The illustration shows a Four Gang Radio Variable Condenser using our "**FREQUELEX**" Ceramic Rod for the Centre Rotating Spindle. This Rod is 7½″ long × .437″ diameter, centreless ground to within plus or minus .0005″. Maximum camber allowance of .002″.

This is only one of many applications where Rods made to close limits are required.

We specialise in the manufacture of Ceramic Rods and Tubes of various sections in several classes of materials over wide dimensional ranges.

The Principal Materials Are :—

1. **Porcelain for general insulation.**
2. **Frequelex for High Frequency insulation.**
3. **Permalex and Templex for Capacitors.**

The degree of accuracy depends on the size of the Rod or Tube, but the standard degree of accuracy is outlined in the Inter Service Component Manufacturer's Council—Panel R Specification embodied in our Catalogue of Radio Frequency Ceramics, copy of which will be sent on request.

Large Rods up to 44″ long and 1¼″ square are used as supports for Tuning Coils, etc.

We shall be pleased to have your enquiries for all sizes of Tubes and Rods. Prompt deliveries can be given for most sizes.

Condenser manufactured by Messrs. WINGROVE & ROGERS LTD.

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TRADE MARK

World Radio History

'VARIAC' voltage regulating transformers

Reg'd Trade Mark

With a 'VARIAC' voltages are instantly and minutely adjustable from 0-Line Voltage, or in some cases up to 17% above line voltage. Type 50-B 'VARIAC,' as illustrated left, is often operated in a 3-gang assembly on 3-phase work to control 21Kva.

Type 200 C.U.H. 'VARIAC'

Type 100-R 'VARIAC'

SERIES 50 'VARIAC' TRANSFORMERS.

SPECIFICATIONS

Type	Load Rating	Input Voltage	Current		Output Voltage	No-Load Loss	Net Price £ s. d.*
			Rated	Maximum			
50-A	5 kva	115 v.	40 a	45 a.	0-135 v.	65 watts	44 18 6
50-B	7 kva	230/115 v.	20 a	31 a.	0-270 v.	90 watts	44 18 6

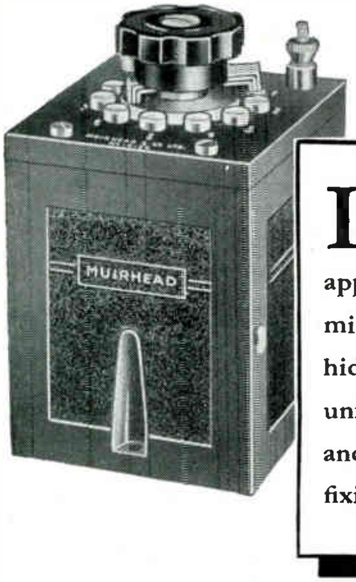
* All 'VARIAC' prices plus 20% as from 23rd Feb. 1952

Write for catalogue V549 which gives full details of 'VARIAC' transformers and suggestions for use.

CLAUDE LYONS LIMITED

ELECTRICAL AND RADIO LABORATORY APPARATUS, Etc.

180 Tottenham Court Road, London, W.1; and 76 Oldhall Street, Liverpool 3, Lancs.



UNIVERSAL UNITS

RESISTANCE · CAPACITANCE · INDUCTANCE

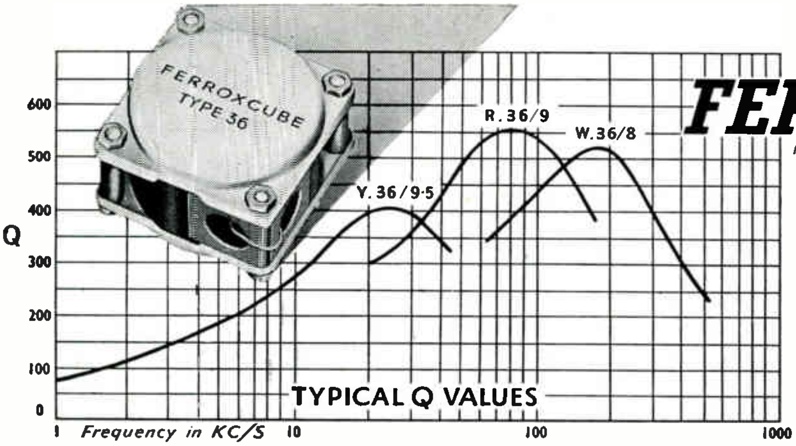
IN education and in industry, these units find a host of applications. There is a physical reality about them which appeals to the elementary student and which is necessarily missing from the more expensive boxes where switches are hidden mysteries and connexions must be taken on trust. This unit form of construction is economical and very convenient, and the moulded containers are sensibly engineered, so that fixing to a panel or to each other is quite simple.

WRITE FOR DESCRIPTIVE LITERATURE

MUIRHEAD & Co., LTD.
PRECISION ELECTRICAL INSTRUMENT MAKERS
BECKENHAM · KENT · ENGLAND
Phone: BECkenham 0041 Telegrams & Cables: MUIRHEADS ELMERS-END

PRECISION
MUIRHEAD
ELECTRICAL INSTRUMENTS

543



FERROXCUBE

FERROMAGNETIC FERRITE

For Line Communications:

IN THE design of Mullard pot core assemblies types 36 and 25 full advantage is taken of the characteristics of Ferroxcube to produce inductances of remarkably high "Q" factors. This, combined with ease of winding, makes these cores very suitable for use in filter networks and wherever high quality inductances are required.

Fine adjustment of inductance is obtained by control of the air gap rather than by variation of the turns.

The good screening properties of the Ferroxcube and the convenient shape of the assemblies, which allows stacking or individual mounting, are other features which distinguish these Mullard cores.

OUTSTANDING FEATURES

- ★ Low hysteresis coefficient
- ★ High values of inductance
- ★ Low self capacitance
- ★ Controllable air gap facilitating inductance adjustment
- ★ Self screening
- ★ Controlled temperature coefficient
- ★ Operation over a wide frequency range
- ★ Ease of winding and tapping
- ★ Easily mounted

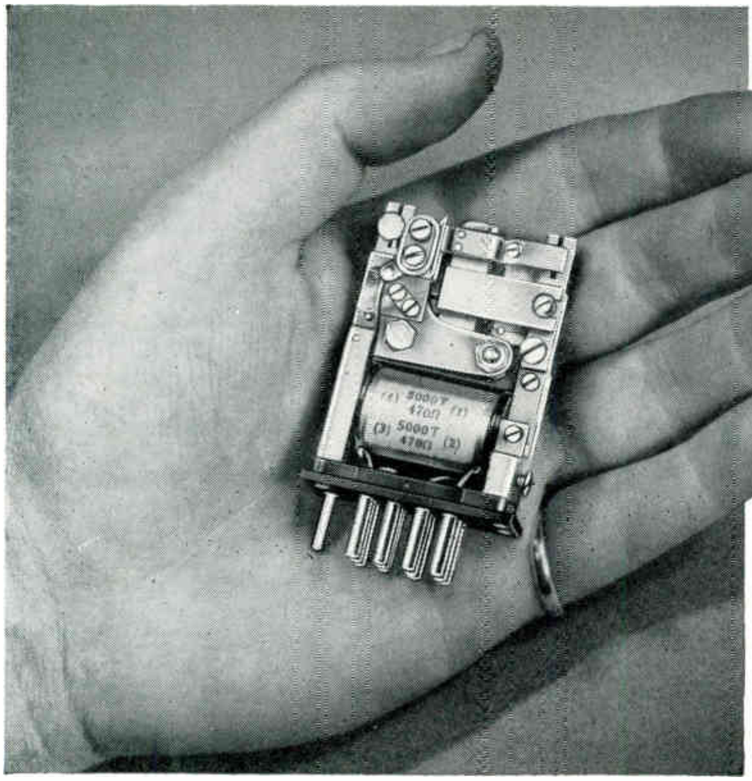
PLEASE WRITE FOR FULL DETAILS

Mullard

Mullard *FERROXCUBE*
FERROMAGNETIC FERRITE

MULLARD LIMITED · CENTURY HOUSE · SHAFTESBURY AVENUE · LONDON · W.C.2

(MF375)



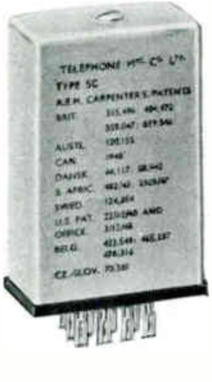
SMALL
BUT
VERY
GOOD!

Considering it is only the size of a matchbox the Type 5 Carpenter Polarized Relay is capable of a surprisingly high performance providing answers to problems in many fields of electrical engineering. Outstanding features of the Type 5 include:

HIGH OPERATIONAL SPEED • FREEDOM FROM CONTACT REBOUND
IMMUNITY FROM POSITIONAL ERROR • GOOD CONTACT PRESSURES
HIGH SENSITIVITY • ACCURACY OF SIGNAL REPETITION
RUGGED DESIGN • EXCEPTIONAL THERMAL STABILITY

Plug or solder tag base optional.

Dimensions — (With cover. Excluding connecting pins.) $2\frac{3}{16}$ *ins. high.* $1\frac{7}{16}$ *ins. wide.* $\frac{3}{4}$ *in. deep. Weight (including socket)* 4.8 *oz.* (137 *gm.*)



Complete specification and further details of the complete range of Carpenter Relays may be had on request.

TMC

CARPENTER
POLARIZED
RELAY TYPE 5

Manufactured by the Sole Licensees:

TELEPHONE MANUFACTURING CO. LTD

Contractors to Governments of the British Commonwealth and other Nations

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Capacitors by Wego

for
CW
VHF
RADAR
X-RAY
SMOOTHING
ENERGY STORAGE
IMPULSE GENERATORS
AND OTHER ELECTRONIC APPLICATIONS

Full information will be supplied on request.

WEGO CONDENSER CO. LTD.

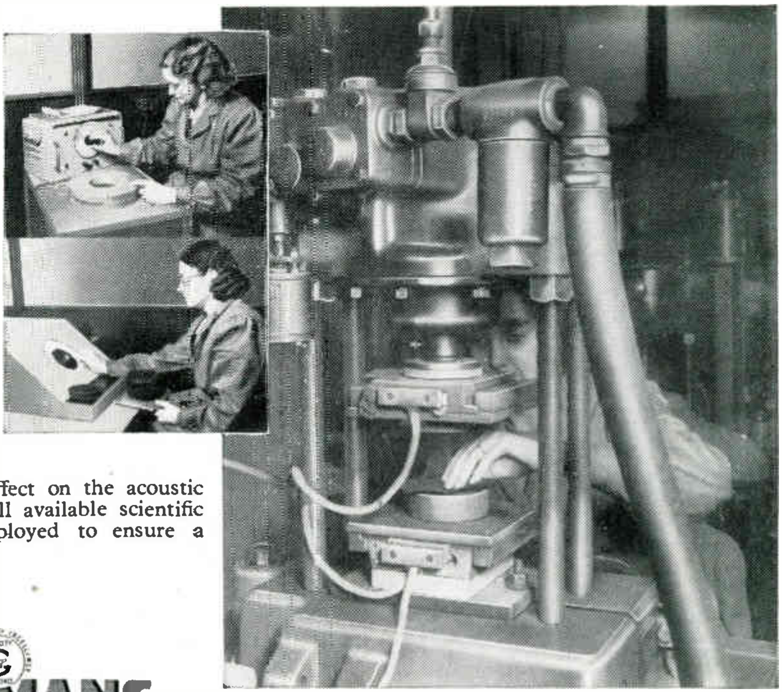
BIDEFORD AVENUE, PERIVALE, GREENFORD, MIDDLESEX. Telephone : Perivale 4277.

An infinite capacity . . .

Third of a series telling the story of Goodmans Loudspeakers.

"An infinite capacity for taking pains" aptly summarises the closely controlled techniques employed in the production of Goodmans speakers. Here, in the cone moulding department, the cones, on which the speaker performance ultimately depends, receive their final precision "moulding" and inspection. Moulding is just one method of treatment employed. The cones are given a special pressure treatment. They may then be resin treated, accurately trimmed to size and inspected.

Each of the processes has a profound effect on the acoustic properties of the finished speaker, and all available scientific resources are employed to ensure a rigorous control.



(*Above*) Operating a moulding press. (*Inset, above*) The fundamental resonance of the cone is determined by clamping the diaphragm at its periphery and driving it by another loudspeaker. This loudspeaker is fed from a variable frequency oscillator and air-coupled to the diaphragm under test. At the fundamental resonance, a noticeable increase in amplitude of the driver diaphragm is observed. (*Inset, below*) A final visual check for consistency.

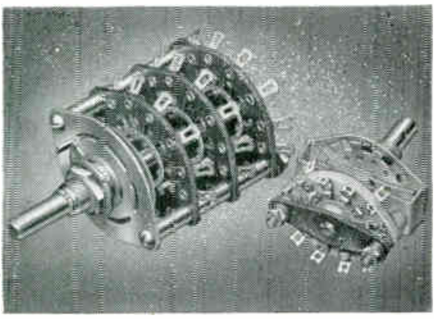
AXIOM 150
Mk II
12-inch
HIGH
FIDELITY
Loudspeaker

This is the latest in the Goodmans High Fidelity range. Bass resonance 35 c.p.s. *Write for details.*

GOODMANS
INDUSTRIES LIMITED
Axiom Works, Wembley, Middx.
Telephone: WEMbley 1200

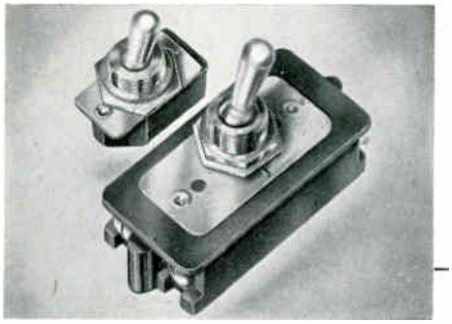
World Radio History

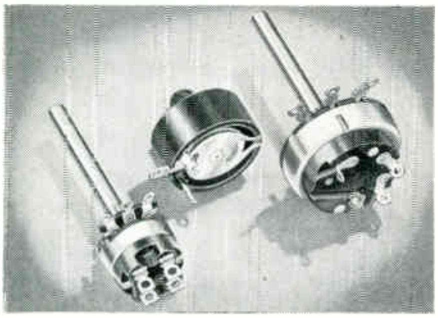
Service to the ELECTRONICS INDUSTRY



OAK SWITCHES are supreme in the radio and electronic fields. OAK—the superior wafer-type switch — incorporates self-cleaning double-contact clips and floating rotors ensuring self-alignment.

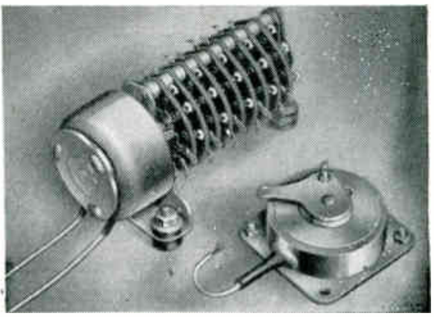
CUTLER-HAMMER SWITCHES are famous in the electronic and electrical industries throughout the world for reliability and efficiency. They are available in a wide range of ratings and with several types of operating mechanisms such as lever, slider, trigger, or plunger actions.





POTENTIOMETERS are ruggedly built for long and reliable service under the most exacting conditions. There is a full range of composition types, with or without switches, and wire-wound types for television applications.

ROTARY SOLENOIDS are compact, robust, and efficient electro-mechanical devices with a powerful snap-action rotary movement. As circuit selectors—with Oak switch sections — they have numerous applications in the electronic and telecommunication fields.



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AUDIO OSCILLATORS

Laboratory Standard B.F.O. Type L.O. 800 and Portable Model L.O. 50.

B.S.R. Beat Frequency Oscillators have established themselves throughout the world as leaders in their field.

Models are available up to 100 kc at power outputs of up to 5 watts.

These instruments are distinguished for their superb engineering and individual accuracy.

Full technical details and prices gladly sent on request.

BIRMINGHAM SOUND REPRODUCERS LIMITED, OLD HILL, STAFFS.

A.C. MILLIVOLTMETER

Model VM 63S1

This instrument is a probe type valve voltmeter covering a wide frequency band from 30 cycles to 150 megacycles. The 5″ scale indicator carries individual scales for each range. For frequencies up to 50 Mc/s no frequency correction is required. For higher values the variation does not exceed ±1 db. A special feature consists of automatic overload protection on all ranges. The instrument operates off 100/250 volts A.C. mains.

VOLTAGE RANGES: 0-150, 0-500, 0-2,000 mill volts.

ACCURACY: ± 5% of f.s.d.

FREQUENCY RESPONSES: flat from 50 c/s to 50 Mc/s. ±1 db up to 150 Mc/s.

DIMENSIONS: 8″ × 12″ × 8″ (deep).

FINISH: Steel cabinet finished in grey crinkle lacquer.

SENSITIVE PANEL MOUNTING METERS

SIZE	2½″	3½″	5″
RANGE	25μA to 50A	10μA to 50A	10μA to 50A

Prices on application

Available for immediate delivery from our Stockists, M.R. Supplies, Ltd., 68, New Oxford Street, W.C.1, or write to:

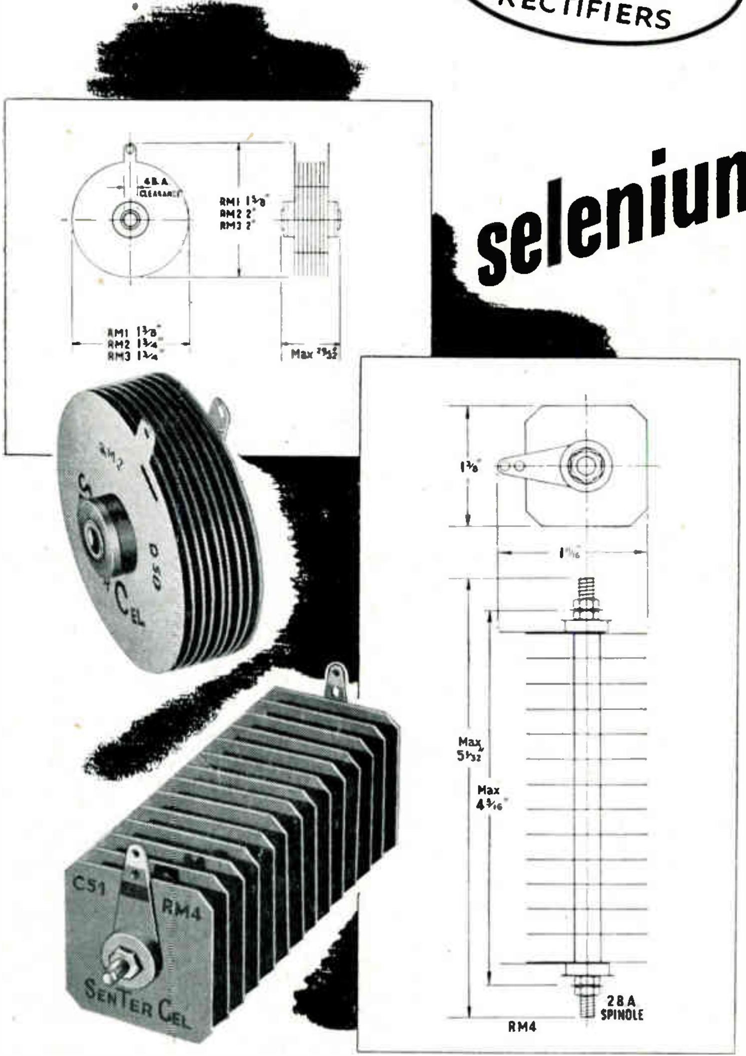
BRITISH PHYSICAL LABORATORIES

HOUSEBOAT WORKS · RADLETT · HERTS · Telephone: RADlett 5674-5-6

World Radio History

10 advantages of SELENIUM SenTerCel RECTIFIERS miniature selenium rectifiers

REGISTERED TRADE MARK



Compare these outstanding features with those of the rectifiers which at present you are using :—

- **Less wiring**
- **Unlimited instantaneous overload such as the charging current of de-formed electrolytic capacitors, or even a short circuit.**
- **Far lower heat dissipation.**
- **No "warming-up" period.**
- **No valve-holder.**
- **Practically indestructible in normal service.**
- **No limit to size of electrolytic capacitor.**
- **Saves weight.**
- **Saves space.**
- **Low in cost.**

Study these **RATINGS**

TYPE	RM1		RM2		RM3		RM4		
Maximum ambient temperature	35°C	55°C	35°C	55°C	35°C	55°C	35°C	40°C	55 C
Maximum output current (mean)	60mA	30mA	100mA	60mA	120mA	90mA	275mA	250mA	125mA
Maximum input voltage (r.m.s.)	125V		125V		125V		250V		
Maximum peak inverse voltage	350V		350V		350V		700V		
Max. instantaneous peak current	Unlimited		Unlimited		Unlimited		Unlimited		
Weight	1 oz.		1.4 oz.		2 oz.		4.5 oz.		

REGISTERED TRADE MARK
SELENIUM
SenTerCel
RECTIFIERS

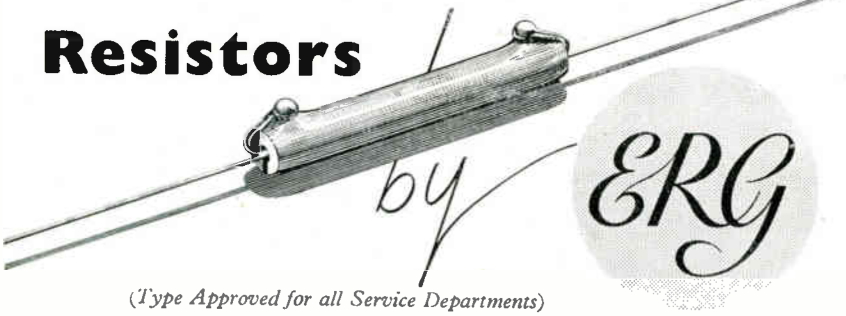
Standard Telephones and Cables Limited

(Registered Office : Connaught House, Aldwych, W.C.2)
RECTIFIER DIVISION: Warwick Road, Boreham Wood, Hertfordshire.
Telephone : Elstree 2401 Telegrams: Sentercel, Borehamwood

CONTROL

The manufacture of resistors is *not* like "shelling peas". The reverse is true. Specialists alone fully appreciate the diverse problems. A standard Service-type vitreous-enamelled resistor, for example, is completed after twenty separate operations, each of which calls for close control to ensure maximum reliability and stability in the field. The microscope (x 100) is constantly used to examine the standard of these individual operations and is evidence of our insistence that 100% efficiency is maintained throughout production.

Resistors



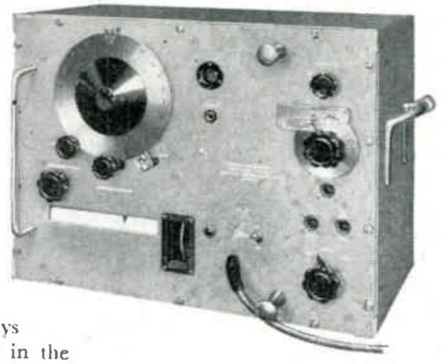
(Type Approved for all Service Departments)

Depending upon the duty of a resistor, special protective coatings are available:

VITREOUS · CEMENT
SILICONE · LACQUER

Full information on the application of ERG Wire Wound Resistors is to be obtained from our London Sales Office: 10 Portman Square, London, W.1. (Welbeck 8114).

ERG INDUSTRIAL CORPORATION LTD · MATTHEW STREET · DUNSTABLE · BEDS.



Closing a Frequency Gap

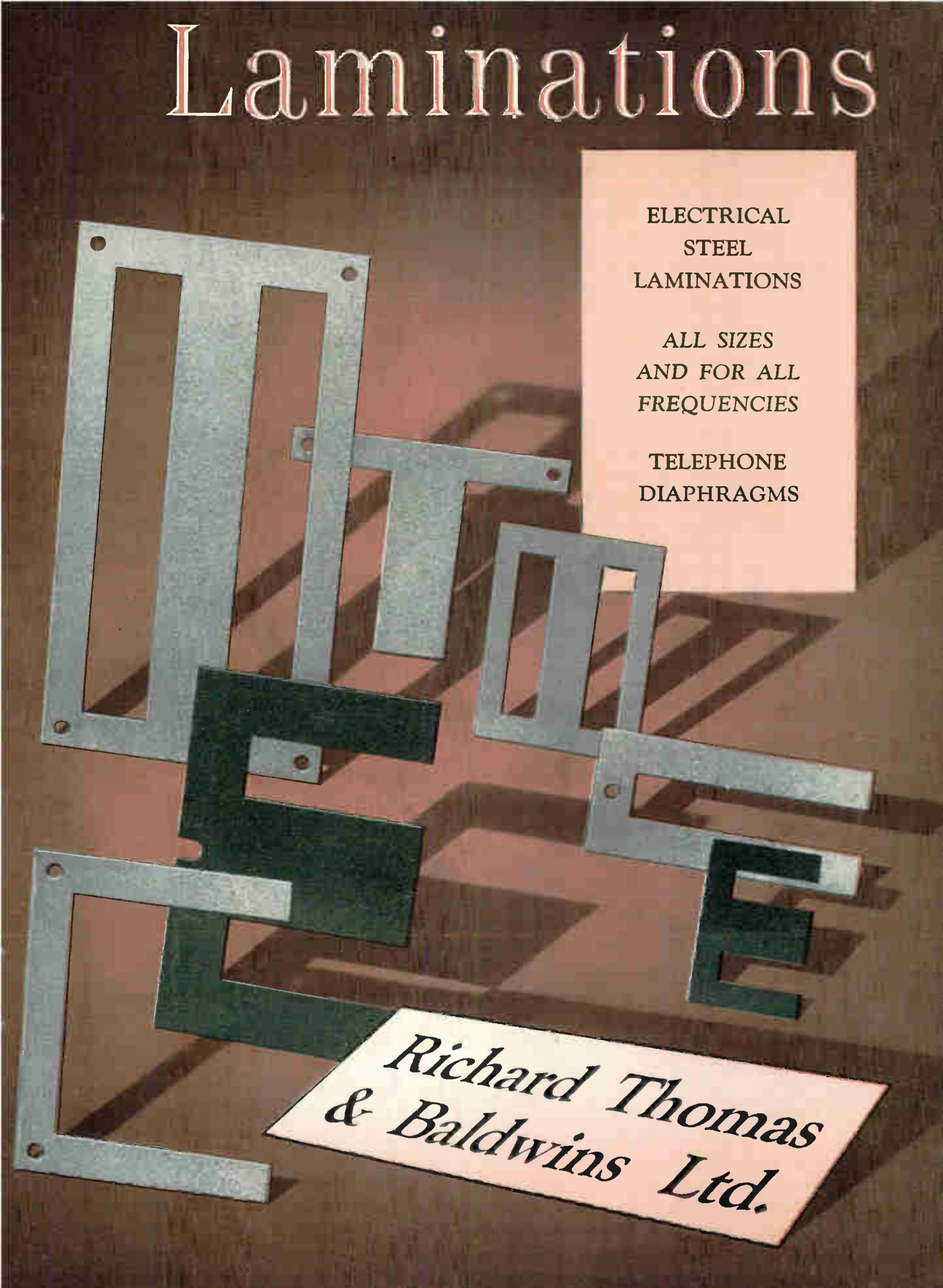
360-3000 Mc/s

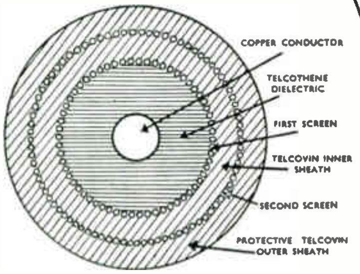
Frequency allocations in the decimetre region — communication, industrial, medical and television relay — have created a demand for test equipment which is not always easily met; there is here something of a gap in the frequency spectrum. Crystal Calibrator TF723A steps ideally into the breach, covering frequency determinations from 360 to 3,000 Mc/s on unknown sources with extensions where the order of frequency is known. This wide-range crystal-standardised instrument, with its broad/narrow band detector and precision interpolating device, is also invaluable as a calibrator of simple S-band oscillators for harmonic use in the X-band.

MARCONI instruments

Signal Generators · Bridges · Valve Voltmeters · Output Meters · Wave Meters · Wave Analysers · Beat Frequency Oscillators

MARCONI INSTRUMENTS LTD · ST. ALBANS · HERTS · PHONE: ST. ALBANS 6161/7
Northern Office: 30 Albion Street, Hull. **Midland Office:** 19 The Parade, Leamington Spa.
Export Office: Marconi House, Strand, London, W.C.2





double screened

COAXIAL CABLES

★Wire braid screens, as commonly used on flexible R.F. cables, fail to exhibit an increasing measure of shielding with rise of frequency, the proportion of leakage tending to increase at frequencies higher than, say 1.0 Mc/s. In certain circumstances the effectiveness of a single braid as a screen has been found inadequate, and for such cases a range of double screened cables is offered.

Two types are available, the first having the two screens continuously in contact and the second having the screens separated by a Telcovin insulating layer: in general both types have similar performance as regards screening.

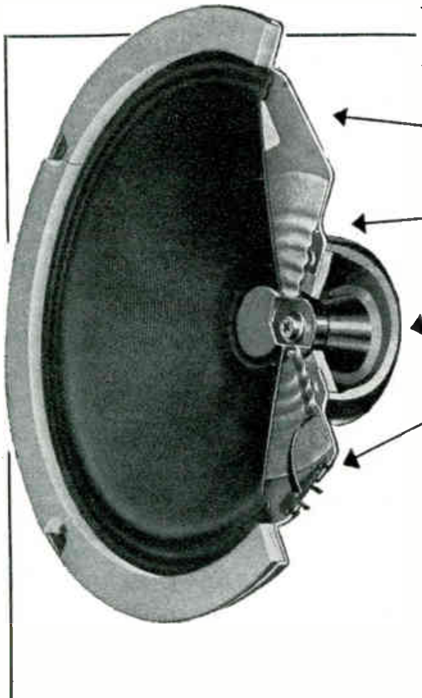
The addition of the second braid may be expected to improve the screening of a cable by a factor which varies from about 6 db at low frequencies to some 30 db at very high frequencies. In all other electrical properties these cables are identical with their normal counterparts.

Available in the following types: (a) with Screens in contact—K.16.YM, PT.1.YM, PT.11.YM. (b) with Screens separated — K.16.MYM, PT.1.MYM, PT.11.MYM. *Further particulars on application.*

TELCON RF cables

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD
Head Office: 22 Old Broad Street, E.C.2. *Telephone:* LONdon Wall 7104
Enquiries to: Telcon Works, Greenwich, S.E.10. *Telephone:* GREenwich 3291

External Field



ZERO

Any loud-speaker with a ring magnet has a strong external field. This is unimportant in a radio set, but it matters a great deal in television, particularly in compact designs.

With centre-pole construction, as designed by R. & A., and total enclosure of the magnet system, much of the flux leakage is confined within the pot-shell itself. Using aluminium instead of mild steel for the chassis also helps, though at the expense of strength and rigidity.

But these are only palliatives, so we developed (and patented) a simple and effective method whereby, after assembly and magnetising, all external flux is eliminated without reducing the flux in the gap.

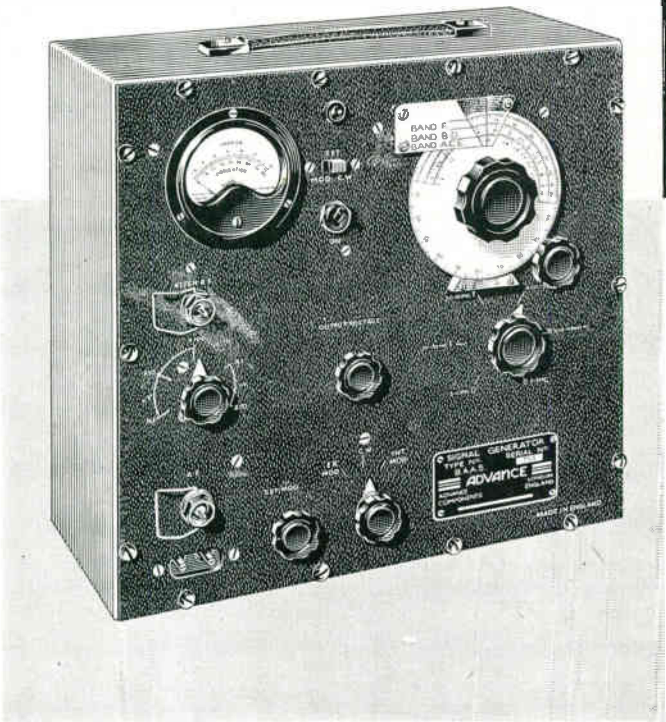
This method enables us to make—and support—our claim of 'Zero External Field', and accounts in part for the growing popularity of R. & A. Reproducers among leading television manufacturers.

REPRODUCERS AND AMPLIFIERS LIMITED
WOLVERHAMPTON · ENGLAND
Telephone: *Wolverhampton* 22241 (5 lines) *Telegrams:* *Audio, Wolverhampton*

R&A

World Radio History

ADVANCE COMPONENTS LTD., BACK ROAD, SHERNHALL STREET, LONDON, E.17 *Telephone : LARkswood 4366/7/8*



MODEL A 100 kc/s—80 Mc/s in six bands

MODEL B 30 kc/s—30 Mc/s in six bands

Calibration accuracy of both models is ± 1%

ADVANCE TYPE B4

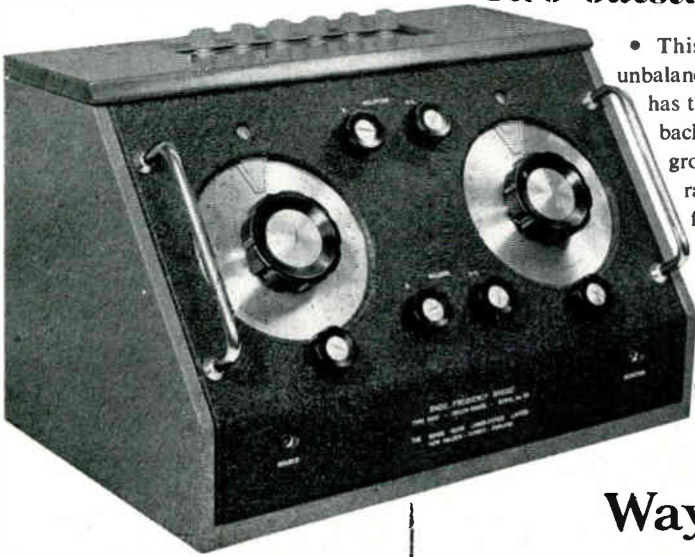
The Advance type B4 is a tried and proven generator which is essentially simple to use. One special feature is the accuracy of the R.F. output over the entire frequency range, achieved by the use of a crystal voltmeter and the subsequent elimination of all circuits having poor frequency characteristics.

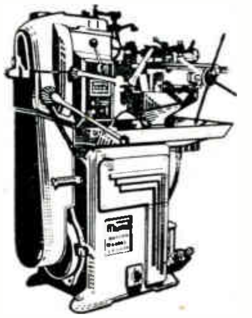
Full Technical Details
available in Folder S/11/V.

Advance

signal generator

ADVANCE COMPONENTS LTD., BACK ROAD, SHERNHALL STREET, LONDON, E.17 *Telephone : LARkswood 4366/7/8*






BROOKES
CRYSTALS
6851 KC/S

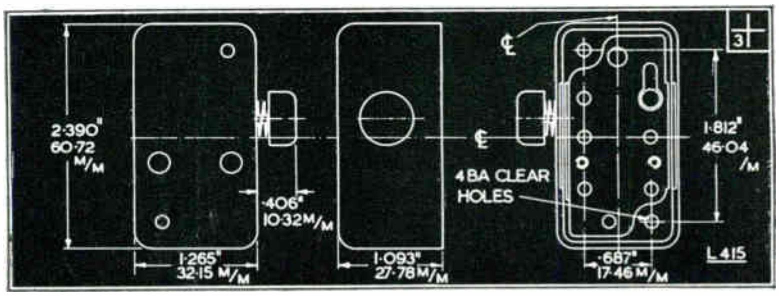
Two Marconi RB.109 Automatic Marine Beacons are being erected in South Georgia, primarily for the use of Antarctic whaling fleets. The stations are designed to operate without attention for three months at temperatures down to 12°F and wind velocities up to 120 m.p.h.

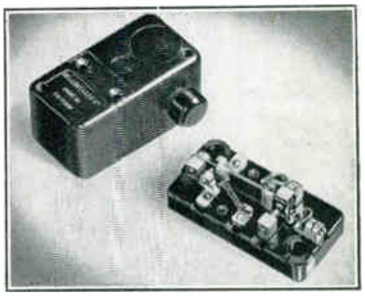
Fully duplicated beacons, Type WB.8, are being installed on Troughton Island, off Western Australia, to aid shipping in the vicinity of the dangerous Penguin shoals. The station will provide high power MF beacon transmission by automatic time control and on "request".

MARCONI marine beacons

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · CHELMSFORD · ESSEX

The "Belling-Lee" page for Engineers





THERMAL DELAY SWITCHES

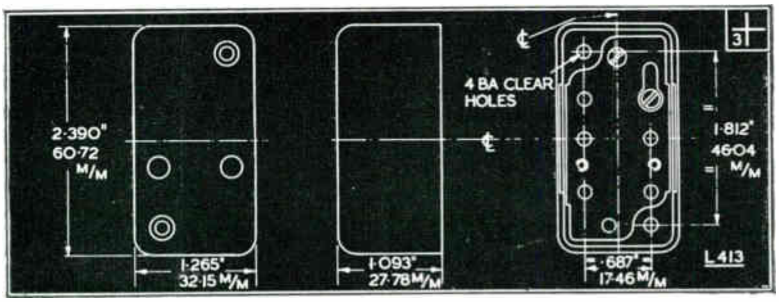
LIST NUMBERS

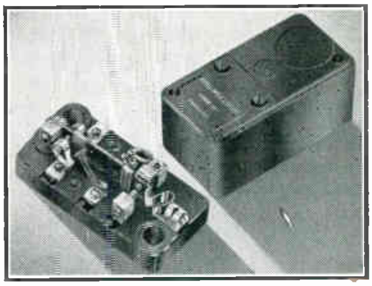
L.413	L.423
L.415	L.424
L.417	L.395

Thermal delay switches for use with motor drives, electrical tools, etc.; also for application to non-critical process timing. The type illustrated above (List Number L.415) shows a manual resetting switch.

Where an automatic self-resetting type is required, these are available under List Number L.413 (illustrated below).

Apart from the resetting mechanisms, the general arrangement and electrical characteristics of the two types are similar. Each is fitted with Standard instrument contacts which will break a maximum current of 4 amps. at 250 volts A.C., or 2 amps. at 50 volts D.C.





They can also be supplied to special orders, to break up to 20 amps. at 250 volts A.C. or 5 amps. at 100 volts D.C.

The maximum continuous rating is 10 amps.; normal heater loading for continuous operation, 3-4 watts at any voltage up to 50 volts A.C. or D.C.

For intermittent operation, a heater loading up to 25 watts is permissible. The heater may be in series with main contacts, or independent, being insulated for 250 volts A.C. working potential to bi-metal.

FURTHER DETAILS ON APPLICATION

BELLING & LEE LTD

CAMBRIDGE ARTERIAL RD., ENFIELD, MIDDX., ENGLAND

Electrical Standards for Research and Industry

Testing and Measuring Apparatus

FOR COMMUNICATION
ENGINEERING

SULLIVAN PORTABLE GALVANOMETERS

EMPLOYING A NEW

SUSPENDED COIL
PORTABLE GALVANOMETER UNIT

which may be supplied alone or boxed complete with scale, illumination (with Mains Transformer) and novel Scale Magnification

These Galvanometers are also available as

DIRECT-READING

MICROAMMETERS

MILLIVOLTMETERS

and OHMMETERS

A compact, sensitive, yet robustly suspended galvanometer has been developed recently in our laboratories and, having undergone extensive trials, has proved to be extremely reliable for all purposes. All galvanometers are fitted with shock-absorbing non-sticking stops, thus overloads of up to 100 times full-scale current may be applied without risk of damage to the movement.

It is available as a compact unit for bench use, mounted in a bakelite case measuring only 12 × 8 × 4 cms. and is eminently suitable for mounting in the client's own equipment—a simple bracket mounting is incorporated to facilitate this.

It is available also in portable form in a polished teak case (complete with scale and illumination) with different internal optical arrangements of some novelty which give, in effect, various scale distances without having to resort to large and awkwardly shaped boxes. In some cases effective scale-reading magnification of approximately 8 to 1 is obtained within a small box measuring only 27 × 16 × 16 cms. They may be used for all "null" balance measurements, such as for Wheatstone and Kelvin bridge work, in which case they are provided with centre zero scales. They may, however, if desired, be fitted with side zero scales for accurate deflection measurements—a high degree of law linearity rendering this possible.

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WIRELESS ENGINEER

The Journal of Radio Research and Progress

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	V_{g2} max	600 V
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WIRELESS ENGINEER

Vol. 29 MAY 1952 No. 344

Effect of Torsion on a Longitudinally-Magnetized Iron Wire

We have received from Mr. W. V. Dromgoole, of Christchurch, New Zealand, a letter dated 19th January, 1952, in which he describes a very interesting application of the effect of torsion on a longitudinally-magnetized iron wire. We agree with him that it may have some practical applications in the field of electrical measurements and we therefore feel justified in discussing it in some detail.

As long ago as 1847 Matteucci examined the change of magnetism of an iron rod when twisted to and fro while a magnetizing current was maintained in a surrounding solenoid. This and many other experiments, especially by Kelvin, are described in Ewing's 'Magnetic induction in iron and other metals.' It is pointed out that when subjected to a torsional strain, each portion of the twisted rod experiences a simple shearing stress, which may be regarded as made up of a tension in a direction at 45° to the direction of the axis, and an equal compression also inclined at 45° and at right angles to the tension. Since tension tends to increase the magnetic susceptibility in the direction of the stress, whereas compression tends to decrease it, the effect of torsion is to give a helical quality to the magnetization, a circular component being superposed on the longitudinal magnetization. Although the applied H is axial, the resulting magnetic flux has the character of a right- or left-handed screw, depending on the direction of the twist.

This phenomenon forms the basis of the experiment described by Mr. Dromgoole and shown in Fig. 1. A solenoid of 200 turns of No. 32 B. and S. wire was wound on a glass tube of $\frac{1}{8}$-in. bore and supplied with current from an audio oscillator, the frequency of which could be varied up to 20 kc/s. A 30-gauge iron wire was passed through the tube and also formed part of an electric circuit, the ends of the iron wire being connected to the input terminals of a 100/1 transformer. The output terminals of the transformer were connected to a Cossor double-beam oscilloscope. With the supply adjusted to 1,000 c/s, the current in the

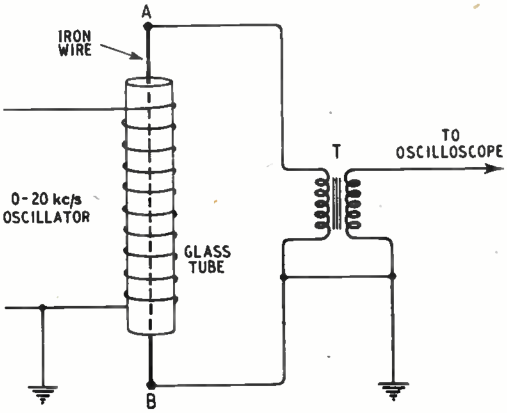


Fig. 1.

solenoid was about 90 mA and the voltage on the oscilloscope about 5 millivolts, *but, on holding the end A of the iron wire and slowly twisting the end B through* 90°, *the voltage on the oscilloscope rose to about* 1,500 *millivolts.* If twisted in the other direction the same voltage was obtained, but of opposite phase. The variation of voltage with the angle of twist is roughly as indicated in Fig. 2, the phase reversing with the direction of twist. The stress produced by a given angle of twist will depend on the length of the iron wire, which was 7½ in.

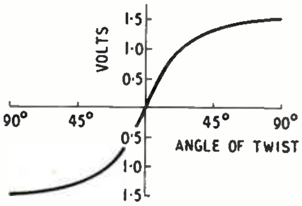


Fig. 2.

From what we said above it is obvious that the cause of the e.m.f. induced in the circuit is the circular component of the alternating magnetic flux in the iron wire, which may be regarded as linking the electric circuit. If one regards the axis of the wire as the electric circuit, then it is linked by all the circular flux; nearer the surface the linkage becomes less and less, and longitudinal eddy currents will be set up in the wire.

It was found that the best results were obtained with annealed soft iron wire. Thick wires or rods produced the same effect. It was also found that the effect was not changed by giving the wire preliminary twists through 360°, and that the effect increased with frequency up to 7–16 kc/s but decreased beyond 20 kc/s. At zero twist, even if the wire is thoroughly annealed, there may be a small e.m.f. induced due to the coupling between the two circuits, but this will be negligibly small compared with the magnetic effect on twisting the wire.

On removing the transformer and connecting the iron wire directly to the oscilloscope, the latter indicated that about 50 millivolts was produced by a twist of 90°, and the waveforms were approximately as shown in Fig. 3. Bringing a horse-shoe magnet near the solenoid, and thus superposing a steady magnetic field on the wire, decreases the effect. Subjecting the wire to tension when twisting it causes a small reduction in the effect.

Mr. Dromgoole suggests several practical applications of the device. It appears to have possibilities as a torque-measuring apparatus (both static and dynamic) and also for the transmission of data involving the conversion of mechanical movements into electrical signals of varying amplitude and phase. A direct-current meter movement can be arranged to twist a fine iron wire and thus transmit alternating signals.

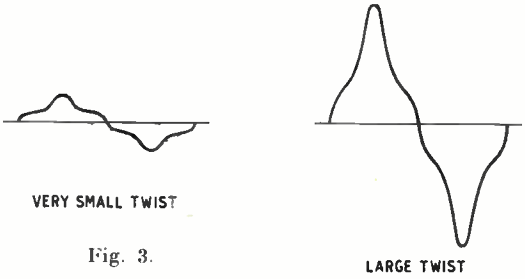


Fig. 3.

This editorial note is only intended to be an introduction to a subject that raises many interesting questions and calls for research into the effects of varying the material employed and the treatment to which it is subjected.

G. W. O. H.

Further Details of the Dromgoole Effect

In a further communication received after the preparation of the Editorial, Mr. Dromgoole refers to further experiments that he has carried out, and gives the following information.

Wires up to ¼-in. diameter were also used and the effect is still the same. It was found that any material having magnetic properties exhibited the effect, and the magnitude of the effect appears to be a function of the permeability of the material used.

Thus:

(*a*) Unannealed iron wire ..	effect large
(*b*) Annealed iron wire	very large
(*c*) Mild steel (normal state) ..	fairly large
(*d*) Mild steel (annealed) ..	large
(*e*) Stainless steel	not large
(*f*) Nickel	small

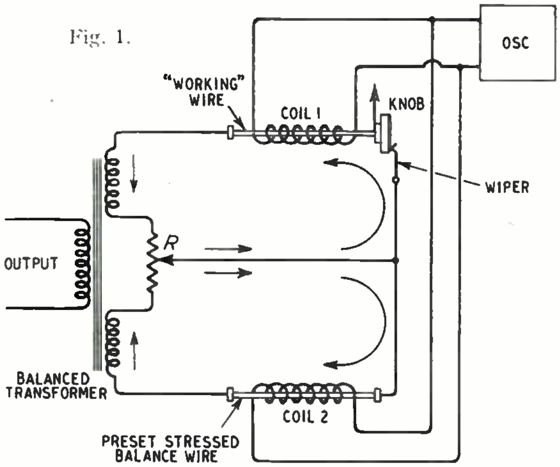
It will be noted that while nickel has marked magnetostrictive properties, it does not exhibit the described effect to any great degree.

It was found that a long single-layer coil is better than a multi-layer one.

An iron wire (28 gauge) was wound around other similar wire so as to produce a helix. The two ends of the helix were then pulled outwards until it became a straight wire. The wire so treated was then placed within the coil as before and the effect was still shown to exist. (A wire so treated must possess immense stresses due to the abnormal distortion placed on it.)

Magnetic materials in the form of wire, rod, or long thin sheet, show a residual signal when *no* torsion is evident, which appears to be a function of the magnetic state of strain in the material (i.e., annealed iron wire shows less residual signal voltage than unannealed, also a piece of mu-metal sheet gave a much smaller residual signal than a piece of ordinary transformer iron).

Fig. 1.

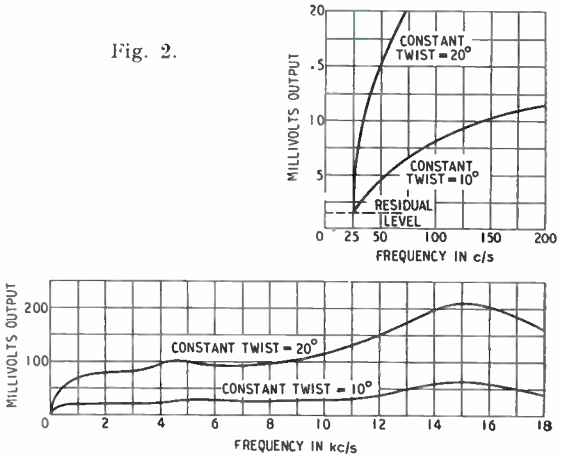


From the above observation it appears that stresses in wire or other conveniently sized material may be located for a specific purpose or during manufacture.

Reduction of Residual Signal

In cases where applications require a sharp null at zero torsion (e.g., for bridge circuits), a similar coil and wire may be set up, and the wire stressed to the degree necessary to balance out the residual produced in the 'working' wire. This is shown in Fig. 1. Final balance is given by potentiometer *R*.

Fig. 2.



Oscillator Frequency

The frequency used was 15 kc/s because the maximum output obtainable on the 5-V range used was a maximum at this frequency. A check over the whole range of the oscillator (0–20 kc/s) showed that the effect falls off sharply below 300 c/s; it is large from 300 c/s to 20 kc/s. A check with an r.f. oscillator of small output showed that the effect was still evident at from 20 to 250 kc/s. Fig. 2 shows the variation of effects with frequency for constant twists of 10° and 20°. The voltage across the coil was maintained constant at 1·5 V.

G. W. O. H.

AMPLIFIER FREQUENCY RESPONSE

Effect of Feedback

By D. A. Bell, M.A., B.Sc., M.I.E.E.

(Department of Electrical Engineering, University of Birmingham)

SO much can be done with negative feedback that one may be tempted to regard it as a panacea and to assume that "all amplifiers are imperfect but all imperfections can be reduced to insignificant proportions by the use of feedback." It is the purpose of this note to recall the fact that there are some imperfections which cannot be reduced by the use of feedback. For example, it is very well known that the reduction of noise and non-linear distortion is proportional to the gain between the input point to which the feedback is returned and the point at which the noise or distortion enters the system.[1]

Another point is that the use of feedback to modify the frequency response of an amplifier cannot change the gain-bandwidth product which is an intrinsic characteristic of the particular device (e.g., type of valve) used to give power gain: circuit and feedback devices can merely redistribute the available gain over different frequencies. The simplest example is the single-stage amplifier having a single time-constant, such as a valve feeding a load circuit consisting of a resistance R shunted by stray capacitance C. If the amplification ratio at zero frequency is A_0R that at any other frequency is

$$A = \frac{A_0R}{1 + j\omega CR} \quad \cdots \quad \cdots \quad \cdots \quad (1)$$

The effect of feedback is given by writing $A_F = A/(1 - A\beta)$ where β is the ratio of feedback amplitude (e.g., voltage) to output amplitude, and for negative feedback the product $A\beta$ must be negative. Applying this to (1) produces

$$A_F = \frac{A_0R}{1 + \beta A_0R + j\omega CR} \quad \cdots \quad \cdots \quad (2)$$

This reduces the dependence on frequency, but also reduces the zero-frequency gain in the ratio $R/(1 + \beta A_0R)$. Suppose now that instead of applying feedback the value of R had been reduced, R in (1) being replaced by $R' = R/(1 + \beta A_0R)$. This would yield

$$A' = \frac{A_0R'}{1 + j\omega CR'} = \frac{A_0R}{1 + \beta A_0R + j\omega CR}$$

so that precisely the same effect in terms of gain-bandwidth can be obtained by reducing the value of load resistance as by applying negative feedback.

MS accepted by the Editor, July 1951

Improvement can, of course, be obtained by using several stages of lower gain to replace the single stage, but it is still a matter of indifference whether the gain per stage is reduced by feedback or by circuit adjustment. It may also be necessary to consider the power-handling capacity of the valve. For example, in a wideband amplifier driving an electrically-deflected cathode-ray tube the first requirement is to develop sufficient output voltage. But this requires a certain current into the stray capacitance, and any system of feedback which maintains the voltage output at the higher frequencies must demand both a higher anode current from the output valve and a larger driving power to its grid.

A slightly more subtle problem is set by the proposal to use differentiated feedback in the positive sense so as to reduce the effect of a time-constant in an amplifier, the idea being that if the gain can be increased by positive feedback during rapid changes of amplitude, the transient or high-frequency response will be improved. Now a differentiating circuit can be described in terms of sinusoidal frequency analysis as one which produces an output in quadrature with the input and of an amplitude increasing linearly with frequency. Hence β in this case may be written as $+ j\omega T$ where T may be called the time-constant of the differentiating network and fixes the magnitude of the feedback at any given frequency. Then, it is suggested, the formula corresponding to (2) will be

$$A_F = \frac{A_0R}{1 - j\omega TA_0R + j\omega CR} \quad \cdots \quad (3)$$

so that if T is adjusted to make $TA_0R = CR$ the resulting amplification ratio with feedback should be simply equal to A_0R; i.e., we have an amplifier with a perfectly flat frequency response. In that case the system would in fact be on the verge of instability, the mechanism of which will appear below; and since it could be made to present an output impedance which was constant and resistive at all frequencies, its total Johnson noise (integrated over all frequencies) would be infinite. But the real difficulty is that the operation suggested in formula (3) could only be performed if we had the free disposition of certain essential circuit constants, yet the proposal arises specifically because there are certain circuit constants which are inherent in the available equipment and cannot be changed. This will be made clearer by a particular example.

Let us try to apply the method of formula (3) to the valve amplifier with resistive load and stray capacitance, using a mutual inductance as shown in Fig. 1 to provide the differentiated feedback. To simplify analysis, assume that the valve drives constant current through the combined load, and that the impedance looking into the secondary of the mutual inductance is negligible compared with the grid-cathode impedance of the valve. Then the grid-cathode voltage is

$$V = V_s + j\omega M i_R \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

where V_s is the input signal voltage and i_R the current in the resistive branch of the anode circuit; and the total anode current is $i_a = gV$ where g is the mutual conductance of the valve. The current i_a divides between the resistance and the capacitance branches, the part flowing through the resistance being

$$i_R = i_a/(1 - \omega^2 LC + j\omega CR) \quad \ldots \quad (5)$$

Substituting in (5) the value $i_a = gV$, where V is given by (4), it is found that the voltage developed across the resistance is

$$V_R = Ri_R = \frac{gV_sR}{1 - \omega^2 LC + j\omega CR - j\omega gM} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

It is now apparent that if the time-constant CR is exactly cancelled by an equal magnitude gM the output tends to infinity at the frequency defined by $\omega^2 LC = 1$, which is the mechanism which justifies saying that the system is on the verge of instability if the time-constant is completely annulled. If the time-constant is only partially annulled, there will still be a peak at this frequency; and it will be accompanied by a phase-shift of 90°, whatever its magnitude.

The new resonant frequency is partly determined by the magnitude of L, which in turn is governed by the condition $L \geqslant M$; but if we are prepared to use amplification in the ratio X:1 in the feedback path, so that M may be made small when ωgM is replaced by ωgMX, the resonant frequency can be pushed up to a point well above the working frequency-band. This, however, could equally be achieved by using a high-frequency boost circuit (or 'phase-advancer') in front of the valve stage under consideration. At the cost of additional amplification (such as is now postulated for the feedback path) an increase of gain at the top of the working band can be obtained with a network which peaks at a much higher frequency and thus gives a performance similar to that of the feedback system described by equation (3).

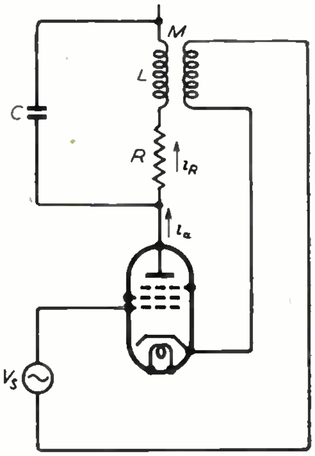


Fig. 1. *Circuit used to demonstrate the characteristics of differentiated feedback.*

The general rule is that anything which could be done by feedback in a stable system could alternatively be done by a suitable equalizer network. The choice between the two is a matter of convenience in size of circuit element, effect of feedback in constancy of amplifier characteristic, etc. Negative feedback usually has advantages in terms of long-term constancy of characteristic and improved linearity, but positive feedback has the opposite effect. A nominally quadrature positive feedback is no exception; for in addition to the specific case analysed above there is a general theorem (demonstrated by Bode) that any negative reactance can be replaced by a combination of a positive reactance and a negative resistance. In most cases, therefore, the use of differentiated positive feedback should be minimized.

REFERENCE

[1] H. W. Bode, "Network Analysis and Feedback Amplifier Design Van Nostrand, New York, 1945, pp. 3–45.

RESONANT CIRCUIT WITH PERIODICALLY-VARYING PARAMETERS

By P. Bura*, M.Sc., A.C.G.I., D.I.C., and D. M. Tombs†, M.Sc., A.C.G.I., D.I.C., A.M.I.E.E.

(* *Edison Swan Electrical Co.* † *Electrical Department of Imperial College, London.*)

(*Concluded from p. 100, April issue*)

Part 2—Excitation of Oscillations by the Periodic Variation of Resistance

SYMBOLS

ω = angular frequency of the resistance variation; i.e., of voltage applied to the grid of the dynatron.

$\delta_n = \dfrac{R_n}{\omega L}$

$z = \omega t/2$.

q = charge on the capacitor.

$u = qe^{(\chi t)} = e^{\mu z}\phi(z, \sigma)$ = solution of Hill's equation

$$\ddot{u} + [\theta_o + 2\sum_{n=1}^{\infty}(\theta_{nc}\cos 2nz + \theta_{ns}\sin 2nz)]u = 0$$

μ = parametric exponent, determining the initial rate of build up of V_c.

$\theta(z,\sigma)$ = periodic function of z; i.e., of time t; period $\dfrac{2\pi}{\omega}$.

σ = auxiliary parameter, used in the solution of Hill's equation.

$$\theta_o = \frac{4}{\omega^2 LC} - \sum_{n=1}^{\infty}\delta_n{}^2$$

θ_{nc}, θ_{ns} = coefficients of the periodic terms in Hill's equation obtained from values of δ_u (p. 16).

$$\left.\begin{array}{l}\alpha(\sigma),\ \beta(\sigma) = \text{functions of } \sigma\\ p(\sigma),\ q(\sigma) = \text{functions of } \sigma\\ A(z, \sigma),\ B(z, \sigma) = \text{functions of } z \text{ and } \sigma\end{array}\right\}\ \text{Used in solving Hill's equation.}$$

C_o = resonant capacitance.

f_o = resonant frequency.

$$\left.\begin{array}{l}\Delta c = c - c_o,\ \Delta' c = c_2 - c_1\\ \Delta f = f - 2f_o,\ \Delta' f = f_2 - f_1\end{array}\right\}\ \text{bands within which parametric oscillations can be excited with a given grid drive } V.$$

$\chi = c_o/c$ = fractional capacitance detuning.

$y = 2f_o/f$ = fractional frequency detuning.

V = voltage applied to the grid.

$a, b, c\ldots$ = constants determining the empirical relation between V and R_n.

$\delta_o = \dfrac{R_c}{\omega L}$, $\mu' = (\mu - \delta_o)\chi$ or $(\mu - \delta_o)y$.

Remaining symbols the same as those in Part 1.

8. Introduction

Oscillations excited by the periodic variation of a circuit parameter were first discovered in a field remote from electrical oscillations.

In 1859 F. Melde carried out an experiment in which one end of a horizontal thread was fixed, the other being attached to the prong of a massive low-frequency fork, mounted vertically and moving in the direction of the string. When the fork was set in motion and the tension of the thread was suitably adjusted, the thread vibrated at right angles to its length at a frequency one-half that of the fork. This was the case of periodically varying tension of the string.

In 1887 Lord Rayleigh solved the problem theoretically and suggested the possibility of a similar type of electrical oscillations.

However, it was not until 1931 that electrical oscillations were excited by similar means. Winther-Günther achieved this by varying periodically the inductance of an oscillatory circuit. To obtain a sufficient variation of the inductance, he connected in series two phase windings of the stator and two phase windings of the rotor of a 3-phase machine, and drove the rotor at the required speed.

Capacitively-excited oscillations were obtained in 1933 by Mandelstam and Papalexi. They have since developed parametric alternators for which they claim efficiencies comparable with those of ordinary types of machines.

The physical basis of excitation of oscillations of this type is straightforward. Let us take as an example the inductive case. Imagine that, due to some disturbance, transient oscillations are excited in the oscillatory circuit, the inductance of which can be altered, by doing mechanical work on the coils or their magnetic field, at any point of the oscillatory cycle.

If, at the point when current in the circuit is at its maximum, we decrease the inductance of the circuit by pulling two coils apart, or withdrawing a magnetic core against the force of the field, we shall inject into the circuit an amount of energy equal to the work done. When the current has dropped to zero, a quarter of a cycle later, let us bring the inductance back to its original value. No energy is subtracted from the circuit, since current and magnetic field are zero at this moment. We repeat this again in the following half-cycle, injecting energy into the circuit at twice the frequency of its oscillations. If the amount of energy injected is greater than the resistive loss, the oscillations will increase in amplitude until a breakdown occurs or non-linearity brings the rise to an end.

Similar reasoning can be applied to the capacitive case. If, by using valve circuits, the resistance of the circuit can be made negative during a part of the oscillatory cycle, periodically-varying resistance can be made to excite oscillations.

9. Theoretical Solution

Starting with equation (3) with the right-hand side equal to zero, we have:

$$\frac{d^2u}{dt^2} + \left[\frac{1}{LC} - \frac{R^2(t)}{4L^2} - \frac{1}{2L}\frac{dR(t)}{dt}\right] u = 0 \qquad (3)$$

If the effective resistance in the circuit be represented by a power series of V_g — grid voltage $R(t) = a + bV_g + cV_g^2 + \ldots \quad .. \quad (23a)$

then for $V_g = V \sin \omega t$ we get

$$R(t) = R_o + R_1 \sin \omega t + R_2 \cos 2\omega t$$
$$+ R_3 \sin 3\omega t + \ldots \quad .. \quad .. \qquad (23)$$

where $R_o = a + \frac{1}{2}cV^2 + \frac{3}{8}eV^4 \ldots,$

$R_1 = V\,(b + \frac{3}{4}dV^2 + \frac{5}{8}fV^4 + \ldots)$ etc.

Substituting for $R(t)$ in (3) and putting $z = \frac{\omega t}{2}$, $\delta_n = \frac{R_n}{\omega L}$ we have

$$\frac{d^2u}{dz^2} + \left[\left(\frac{2\omega_o}{\omega}\right)^2 - \frac{1}{2}\sum_n \delta_n^2\right.$$
$$\left. + 2\sum_n (\theta_{ns} \sin 2nz + \theta_{nc} \cos 2nz)\right] u = 0$$

or
$$\frac{d^2u}{dz^2} + \left[\theta_0 + 2\sum_n (\theta_{ns} \sin 2nz\right.$$
$$\left. + \theta_{nc} \cos 2nz)\right] u = 0 \quad .. \quad .. \qquad (24)$$

where :

$$\theta_{1s} = \tfrac{1}{2}(\delta_1\delta_2 + \delta_3\delta_4 - 2\,\delta_0\delta_1 - \delta_2\delta_3 - \delta_4\delta_5 + \ldots)$$
$$\theta_{1c} = -\delta_1, \quad \theta_{2s} = -2\delta_2, \text{ etc.}$$

Equation (24) represents an extended form of Hill's equation $\frac{d^2u}{dt^2} + (\theta_o + 2\sum \theta_{nc} \cos 2nz)u = 0.$

It is solved by a method similar to that used by E. L. Ince in solving Hill's equation.

Assume a solution

$$u = e^{\mu z}\phi(z,\sigma) \quad .. \quad .. \quad .. \qquad (25)$$

where

$$\mu = p_1{}^c(\sigma)\,\theta_{1c} + \ldots p_n{}^c(\sigma)\,\theta_{nc} + \ldots + q_1{}^c(\sigma)\,\theta_{1c}{}^2$$
$$+ \ldots + q^c{}_n\,\theta^2{}_{nc} \ldots + q^c{}_{nm}\,\theta_{nc}\,\theta_{mc} + \ldots$$
$$+ p_1{}^s(\sigma)\,\theta_{1s} + \ldots p_n{}^s(\sigma)\,\theta_{ns} + \ldots + q_1{}^s(\sigma)\,\theta_{1s}{}^2$$
$$+ \ldots + q_n{}^s(\sigma)\,\theta_{ns}{}^2 + \ldots + q_{nm}{}^s(\sigma)\,\theta_{ns}\,\theta_{ms}$$
$$+ \ldots + q_{12}(\sigma)\,\theta_{1c}\,\theta_{2s} + q_{21}(\sigma)\,\theta_{2c}\,\theta_{1s} + \ldots$$
$$+ q_{nm}(\sigma)\,\theta_{nc}\,\theta_{ms} + \ldots \quad .. \quad .. \qquad (25a)$$

$$\phi = \sin(z - \sigma) + A^c{}_1(z,\sigma)\,\theta_{1c} + \ldots A_n{}^c(2,\sigma)\,\theta_{nc}$$
$$+ \ldots B_n{}^c(z,\sigma)\,\theta^2{}_{nc} + \ldots + B^c{}_{nm}\,\theta_{nc}\,\theta_{mc}$$
$$+ \ldots + A_1{}^s(z,\sigma)\,\theta_{1s} + \ldots A_n{}^s(z,\sigma)\,\theta_{ns}$$
$$+ \ldots + B_n{}^s(z,\sigma)\,\theta^2{}_{ns} + \ldots$$
$$+ B^s{}_{nm}(z,\sigma)\,\theta_{ns}\,\theta_{ms} + \ldots + B_{11}(z,\sigma)\,\theta_{1c}\,\theta_{1s}$$
$$+ B_{12}(z,\sigma)\,\theta_{1c}\,\theta_{2s} + B_{21}(z,\sigma)\,\theta_{2c}\,\theta_{1s} + \ldots$$
$$+ B_{nm}(z,\sigma)\,\theta_{nc}\,\theta_{ms} + \ldots \quad .. \quad .. \qquad (25b)$$

where $p, q \ldots$ are unknown functions of σ only.
$A, B \ldots$ are unknown functions of σ and z.
σ is an auxiliary parameter determined from the relation.

$$\theta_0 = 1 + \alpha^c{}_1(\sigma)\,\theta_{1c} + \ldots + \alpha^c{}_n(\sigma)\,\theta_{nc} + \ldots$$
$$+ \beta^c{}_n(\sigma)\,\theta^2{}_{nc} + \ldots + \beta^c{}_{nm}\,\theta_{nc}\,\theta_{mc} + \alpha^s{}_1(\sigma)\,\theta_{1s}$$
$$+ \ldots \alpha^s{}_n(\sigma)\,\theta_{ns} + \ldots + \beta^s{}_n(\sigma)\,\theta_n{}^2{}_s$$
$$+ \ldots \beta^s{}_{nm}(\sigma)\,\theta_{ns}\,\theta_{ms} + \ldots + \beta_{11}(\sigma)\,\theta_{1c}\,\theta_{1s}$$
$$+ \beta_{12}(\sigma)\,\theta_{1c}\,\theta_{2s} + \beta_{21}\,\theta_{2c}\,\theta_{1s} + \ldots$$
$$+ \beta_{nm}(\sigma)\,\theta_{nc}\,\theta_{ms} + \ldots \quad .. \quad .. \quad .. \qquad (25c)$$

where $\alpha, \beta \ldots$ are functions of σ only.

Substituting from (25) for u in (24) we have:

$$\mu^2\phi(z,\sigma) + 2\mu\frac{d\phi(z,\sigma)}{dz} + \frac{d^2\phi(z,\sigma)}{dz^2}$$
$$+ \left[\theta_o + 2\sum_n (\theta_{nc} \cos 2\,nz + \theta_{ns} \sin 2\,nz)\right]$$
$$\phi(z,\sigma) = 0, \text{ or } \frac{d^2\phi}{dz^2} + 2\mu\frac{d\phi}{dz} + \left[\theta_0 + \mu^2\right.$$
$$\left. + 2\sum_n (\theta_{nc} \cos 2_{nz} + \theta_{ns} \sin 2\,nz)\right]\phi = 0 \quad (26)$$

Substituting for $\phi(z,\sigma)$, $\mu(\sigma)$ and $\theta_0(\sigma)$ from (25a, b, c), and equating to zero terms with θ_{1c}, $\theta_{1s} \ldots$ as coefficients, $p(\sigma) \ldots \alpha(\sigma) \ldots A(z,\sigma)$ are found step by step.

Thus, taking first the terms with θ_{1c} as a coefficient we get

$$\frac{d^2A^c{}_1}{dz^2} + A_1{}^c + 2p^c{}_1 \cos(z - \sigma) + \alpha^c{}_1 \sin(z - \sigma)$$
$$+ 2 \cos 2z \sin(z - \sigma) = 0,$$

or
$$\frac{d^2A^c{}_1}{dz^2} + A^c{}_1 + 2p^c{}_1 \cos(z - \sigma) + \alpha^c{}_1 \sin(z - \sigma)$$
$$+ \sin 3(z - \sigma) - \cos 2\sigma \sin(z - \sigma) - \sin 2\sigma \cos (z - \sigma) = 0.$$

We now impose the condition contained in (25b) that $\phi(z,\sigma)$ is to contain no terms in $\cos(z - \sigma)$, while the coefficient of $\sin(z - \sigma)$ is to be unity. This means that $A^c{}_1(z,\sigma) \ldots A^c{}_n(z,\sigma) \ldots \beta^c{}_n(z,\sigma)$ etc., and $A^s{}_1(z,\sigma) \ldots A^s{}_n(z,\sigma) \ldots$ etc., must not contain any terms involving $\cos(z - \sigma)$ or $\sin(z - \sigma)$.

These conditions are necessary to ensure that solution of equation (26) [viz., $\phi(z,\sigma)$], is periodic in z.

It can be shown from the general theory of the linear differential equations with periodic coefficients that $\phi\,(z, \sigma)$ is periodic and, therefore, the above condition must hold.

We can, therefore, equate the terms containing $\sin\,(z - \sigma)$ and $\cos\,(z - \sigma)$ to zero.

Thus

$$2\,p^{c}_{1} \cos\,(z - \sigma) - \sin 2\sigma \cos\,(z - \sigma) = 0$$

or $p^{c}_{1} = \frac{1}{2} \sin 2\sigma$

and $\alpha^{c}_{1} \sin\,(z - \sigma) - \cos 2\sigma \sin\,(z - \sigma) = 0$

or $\alpha^{c}_{1} = \cos 2\sigma$

$\therefore \quad \dfrac{d^2 A_1{}^c}{dz^2} + A_1{}^c + \sin\,(3z - \sigma) = 0$, the particular integral solution of this is $A^{c}_{1} = \frac{1}{8} \sin\,(3\,z - \sigma)$.

In a similar way remaining $A(z, \sigma) \ldots B\,(z, \sigma)$, $p\,(\sigma) \ldots q\,(\sigma) \ldots$, and $\alpha\,(\sigma) \ldots, \beta\,(\sigma) \ldots$ can be found.

The full details of the solution are too lengthy to be included.

In practice sufficient accuracy is obtained by considering terms of the first and second order only; i.e., $A\,(z, \sigma) \ldots B\,(z, \sigma) \ldots; p\,(\sigma) \ldots, q(\sigma) \ldots$ $\alpha\,(\sigma) \ldots,\ \beta\,(\sigma) \ldots$—the terms that have as coefficients the products of not more than two θ, (since $\theta < 1$).

The solution is

$$\begin{aligned}\theta_0 = 1 &- \sum_{n=2}^{\infty} \frac{1}{2\,(n^2 - 1)} \left(\theta_{nc}{}^2 + \theta_{ns}{}^2\right) \\ &+ \left[\sum_{n=1}^{\infty} \frac{1}{2_n\,(n+1)} \left(\theta_{nc}\,\theta_{n+1,c}\right) + \theta_{ns}\,\theta_{n+1,s}\right) \\ &+ \theta_{1c}\Bigg] \cos 2\sigma + \left[\sum_{n=1}^{\infty} \frac{1}{2_n\,(n + 1)} (\theta_{nc}\theta_{n+1,s} \right. \\ &\left. - \theta_{ns}\theta_{n+1,c}) + \theta_{1s}\right] \sin 2\sigma + \tfrac{1}{8}(\theta_{1c}{}^2 \\ &- \theta_{1s}{}^2)\cos 4\sigma + \tfrac{1}{4}\,\theta_{1c}\theta_{1s} \sin 4\sigma + \ldots \qquad \ldots \quad \ldots \quad \ldots \quad (27)\end{aligned}$$

or $\theta_o = T_o + T_{c2} \cos 2\sigma + T_{s2} \sin 2\sigma + T_{c4} \cos 4\sigma + T_{s4} \sin 4\sigma$ .. .. (27a)

where T_{c2}= terms with $\cos 2\sigma$ as coeff., T_{s2}= terms with $\sin 2\sigma$ as coeff., etc., and

$$\begin{aligned}\mu = \tfrac{1}{2}&\left[\theta_{1c} + \sum_{n=1}^{\infty} \frac{1}{2\,n\,(n + 1)} (\theta_{nc}\,\theta_{n+1,c} \right. \\ &\left. + \theta_{ns}\,\theta_{n+1,s})\right] \sin 2\sigma - \\ - \tfrac{1}{2}&\left[\theta_{1s} + \sum_{n=1}^{\infty} \frac{1}{2n\,(n + 1)} (\theta_{nc}\,\theta_{n+1,s} \right. \\ &\left. - \theta_{n+1,c}\,\theta_{ns})\right] \cos 2\sigma \qquad \ldots \quad \ldots \quad (28)\end{aligned}$$

or $\mu = \frac{1}{2}\,(T_{c_2} \sin 2\sigma - T_{s_2} \cos 2\sigma)$ .. (28a)

(27a) can be written as

$$\begin{aligned}\theta_o - T_o - T_{c_4} \cos 4\sigma - T_{s_4} \sin 4\sigma \\ = \sqrt{T_{c_2}{}^2 + T_{s_1}{}^2} \cos\,(2\sigma - \alpha)\end{aligned}$$

where $\alpha = \tan^{-1} \dfrac{T_{s2}}{T_{c2}}$

and similarly

$$\mu = \tfrac{1}{2} \sqrt{T_{c_2}{}^2 + T_{s_2}{}^2} \sin\,(2\sigma - \alpha)$$

$$\begin{aligned}\therefore 4\mu^2 = T_{c_2}{}^2 + T_{s_2}{}^2 - [\,\theta_o - T_o \\ - T_{c_4} \cos 4\sigma - T_{s_4} \sin 4\sigma]^2 \qquad \ldots \quad (29)\end{aligned}$$

An approximate expression for μ can be easily derived from (29), viz.

$$T_{c_2} \approx \theta_{1c},\ T_{s2} \approx \theta_{1s} + \tfrac{1}{4}\,\theta_{1c}\,\theta_{2s},\ T_{c4} = T_{s4} \approx 0,$$

$$T_o = 1 \qquad \theta_o = \frac{4}{\omega^2 LC} - \sum_{n=1}^{\infty} \delta^2{}_n$$

For constant $f = 2f_o$ and detuning the capacitance $x = \dfrac{C_o}{C}$, $\theta_o = x - \displaystyle\sum_{n=1}^{\infty} \delta^2{}_n$

For constant $C = C_o$ and frequency detuning

$$\nu = \frac{2\,f_o}{f},\ \theta_o = \nu^2 - \sum_{n=1}^{\infty} \delta^2{}_n$$

Neglecting $\displaystyle\sum_{n=1}^{\infty} \delta^2{}_n$, $\theta_o = T_o = x - 1$ for const. $f = 2f_o$
$= \nu^2 - 1$ for const. $C = C_o$

With the above approximations (29) can be written as

$$4\mu^2 = \theta_{1c}{}^2 + (\,\theta_{1s} + \tfrac{1}{4}\,\theta_{1c}\,\theta_{2s})^2 - (x - 1)^2$$

or

$$4\mu^2 = \theta_{1c}{}^2 + (\,\theta_{1s} + \tfrac{1}{4}\,\theta_{1c}\,\theta_{2s})^2 - (\nu^2 - 1)^2 \qquad \ldots \quad \ldots \quad \ldots \quad (30)$$

The θ-terms are only constant for a given frequency f and capacitance C. If we want to be able to calculate the behaviour of the circuit when it is detuned from $f_o = \frac{1}{2}f$, $C_i = C_o$ we have to take into account variation of θ-terms with f and C.

Representing the dynatron as a varying resistance in parallel with the resonant circuit it can easily be shown that $R_n \propto \dfrac{1}{C}$,

$$\therefore\ \delta_n = \frac{R_n}{\omega L} \propto \frac{1}{Cf}$$

or $\delta_n = xy\,\delta_{no}$, where δ_{no} is value of δ_n at $f = 2f_o$ and $C = C_o$; $x = \dfrac{C_o}{C}$, $\nu = \dfrac{2f_o}{f}$.

Substituting the new value of δ_n in the expressions for θ_s [Equation (24)] we have to replace θ_{1c} by $xy\theta_{1c}$, θ_{2c} by $x^2y^2\theta_{2c}$, θ_{1s} by $x^2y^2\theta_{1s}$, θ_{2s} by $xy\ \theta_{2s}$, etc.

Thus (30) becomes

$$4\mu^2 = \theta_{1c}x^2 + x^4(\theta_{1s} + \tfrac{1}{4}\theta_{1c}\theta_{2s})^2 - (x-1)^2$$

and

$$4\mu^2 = \theta^2{}_{1c}y^2 + y^4(\theta_{1s} + \tfrac{1}{4}\theta_{1c}\theta_{2s})^2 - (y^2-1)^2 \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

Equations (31) can be still further simplified by neglecting $\theta_{1s} + \frac{1}{4}\theta_{1c}\theta_{2s}$, which is small compared with θ_{1c}.

Thus a good indication of the value of μ is obtained from a simple expression

$$4\mu^2 \approx \theta_{1c}{}^2x^2 - (x-1)^2 \text{ and } 4\mu^2 \approx \theta_{1c}y^2 - (y^2-1)^2 \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

where $\theta_{1c} = -\delta_1 = -\dfrac{R_1}{2\omega_oL}$, $x = \dfrac{2f_o}{f}$, $y = \dfrac{C_o}{C}$

and $R_1 = V(b + \frac{3}{4}dV^2 + \frac{5}{8}fV^4)$

If the operating point is chosen on the straight portion of the $i_a - V_g$ characteristic of the dynatron, constants d and f will be small and can be neglected.

Thus

$$R_1 \approx bV, \therefore \theta_{1c} = -\frac{b}{2\omega_oL}V$$

$$\text{and} \quad 4\mu^2 = \frac{b^2}{4\omega_o{}^2L^2}V^2x^2 - (x-1)^2 \quad \ldots \quad (32a)$$

for $x = 1$ (i.e., $f = 2f_o$) and $y = 1$ (i.e., $C = C_o$)

$$4\mu^2 = \frac{b^2}{4\omega_o{}^2L^2}V^2 \text{ and } \mu = \frac{1}{2}\frac{b}{\omega_oL}V \quad (32b)$$

We can, therefore, expect an approximately linear relation between μ and the grid drive voltage V; i.e., the initial rate of build up of the oscillations is proportional to V.

To find the region within which oscillations can be excited, we have to find values of x or y for which the decrement of the circuit $\delta_o = \dfrac{R_o}{2\omega_oL}$ is equal to μ.

We have, therefore, to solve the following equation

$$4\delta_o{}^2x^2 = \theta_{1c}{}^2x^2 + (\theta_{1s} + \tfrac{1}{4}\theta_{1c}\theta_{2s})^2x^4 - (x-1)^2$$

$$\text{or } 4\delta_o{}^2 = \theta_{1c}{}^2 + (\theta_{1s} + \tfrac{1}{4}\theta_{1c}\theta_{2s})^2x^2 - \left(1 - \frac{1}{x}\right)^2$$

and

$$4\delta_o{}^2y^2 = \theta_{1c}{}^2y^2 + (\theta_{1s} + \tfrac{1}{4}\theta_{1c}\theta_{2s})^2y^4 - (y^2-1)^2 \quad \ldots \quad \ldots \quad \ldots \quad (33)$$

These are best solved by Horner's method, but a fairly accurate result is obtained if $\theta_{1s} + \frac{1}{4}\theta_{1c}\theta_{2s}$ is neglected; viz.,

$$4\delta_o{}^2 = \theta_{1c}{}^2 - \left(1 - \frac{1}{x}\right)^2,$$

$$1 - \frac{1}{x} = \pm\sqrt{\theta_{1c}{}^2 - 4\delta_o{}^2}$$

$$\text{or } \frac{C}{C_o} = 1 \mp \sqrt{\theta_{1c}{}^2 - 4\delta_o{}^2}$$

$$\text{i.e. } C_1 = C_o - C_o\sqrt{\theta_{1c}{}^2 - 4\delta_o{}^2}$$

$$\text{and } C_2 = C_o + C_o\sqrt{\theta_{1c}{}^2 - 4\delta_o{}^2} \quad \ldots \quad (34)$$

$$\text{and } \frac{\Delta' C}{C_o} = 2\sqrt{\theta_{1c}{}^2 - 4\delta_o{}^2} = \frac{1}{\omega_oL}\sqrt{R_1{}^2 - 4R_o{}^2}$$

$$\approx \frac{1}{\omega_oL}\sqrt{b^2V^2 - 4R_o{}^2} \quad \ldots \quad \ldots \quad (34a)$$

Thus oscillations are excited between C_1 and C_2; ΔC being a function of the grid drive V, for a given circuit.

Similarly for the frequency region

$$\Delta' f = 2f_o\sqrt{\delta_{1c}{}^2 - 4\delta_o{}^2} = \frac{1}{2\pi L}\sqrt{R_1{}^2 - 4R_o{}^2}$$

$$= \frac{1}{2\pi L}\sqrt{b^2V^2 - 4R_o{}^2} \quad \ldots \quad \ldots \quad (34b)$$

$$\Delta' f = f_2 - f_1$$

The frequency region $\Delta' f$ within which oscillations can be excited refers to the driving frequency f. The frequency band within which the circuit oscillates is exactly one-half of the driving frequency band; i.e., $\frac{1}{2}\Delta' f$.

From equations (34a) and (34b) the lowest grid-drive voltage V, which can excite the oscillations corresponds to $\Delta' f = \Delta' C = 0$, or

$$\delta_{1c}{}^2 = 4\delta_o{}^2; \text{ i.e., } R_1 = 2R_o \text{ and } V = \frac{2R_o}{b} \quad \ldots (35)$$

Thus, to excite the oscillations the amplitude of the resistance variation must be at least twice the constant resistance of the circuit.

The full solution is given by $u = e^{\mu z}\phi(z, \sigma)$

$\phi(z, \sigma)$ consists of the fundamental and all the odd harmonics, of which only the third is of any importance; viz.,

$$\phi(z, \sigma) = \sin(z - \sigma) + \tfrac{1}{8}\theta_{1c}\sin(3z - \sigma) + \ldots \quad \ldots \quad \ldots \quad \ldots \quad (36)$$

$\theta_{1c} = \dfrac{R_1}{\omega L} \approx 0{\cdot}04$, therefore the third-harmonic content would be approximately $0{\cdot}5\%$.

Changing from z to ωt and from n to V_c we have

$$V_c = \frac{1}{C}e^{\frac{1}{2}\mu\omega t - \chi(t)}\phi\left(\frac{\omega}{2}t, \sigma\right)$$

$$\text{where } \chi(t) = \frac{1}{2L}\int^{t} R(\tau)\alpha\tau$$

$$R(t) = R_o + R_1\sin\omega t + R_2\cos 2\omega t + \ldots$$

$$\therefore \quad \chi(t) = \frac{R_o}{2L}t - \frac{R_1}{2\omega L}\cos\omega t + \frac{R_2}{4\omega L}\sin 2\omega t + \ldots$$

$$= \chi_o t - \delta_1\cos\omega t + \tfrac{1}{2}\delta_2\sin 2\omega t + \ldots$$

$$e^{-\chi(t)} = e^{-\chi_o t}.\ exp(-\delta_1\cos\omega t + \tfrac{1}{2}\delta_2\sin 2\omega t + \ldots)$$

But $e^{-\delta_1 \cos \omega t} = J_o(i\delta_1) + 2\sum_{n=1}^{\infty} i^n J_n(i\delta_1) \cos n\omega t$

$$e^{\frac{1}{2}\delta_2 \sin 2\omega t} = J_o\left(i\frac{\delta_2}{2}\right) - 2iJ_1\left(i\frac{\delta_2}{2}\right)\sin 2\omega t$$

$$+ 2J_2\left(i\frac{\delta_2}{2}\right)\cos 4\omega t - 2iJ_3\left(i\frac{\delta_2}{2}\right)\sin 6\omega t + \ldots$$

$$\therefore V_c = \frac{1}{C} e^{(\frac{1}{2}\omega\mu - \chi_o)t}\left[J_o(i\delta_1) + 2\sum_{n=1}^{\infty} i^n J_n(i\delta_1)\cos n\omega t + \ldots\right]$$

$$\left[J_o\left(i\frac{\delta_2}{2}\right) - 2iJ_1\left(i\frac{\delta_2}{2}\right)\sin 2\omega t + \ldots\right]$$

$$\times\left[\sin\left(\tfrac{1}{2}\omega t - \sigma\right) + \tfrac{1}{8}\theta_{1c}\sin\left(\tfrac{3}{2}\omega t - \sigma\right) + \ldots\right] \quad \ldots \quad \ldots \quad \ldots \quad (37)$$

(37) can be represented as an infinite sum of harmonic terms. Harmonics introduced by $e^{-x(t)}$ combine with those of $\phi(\frac{1}{2}\omega t, \sigma)$.

Only odd half-harmonics of ωt are produced, since $\phi(\frac{1}{2}\omega t, \sigma)$ does not contain any even harmonics of ω. Thus we are left with the fundamental of frequency $\frac{1}{2}f$ and odd harmonics $3/2f$, $5/2f$, etc.

In practice there always will be some second harmonic as a direct result of having voltage of frequency f applied to the grid.

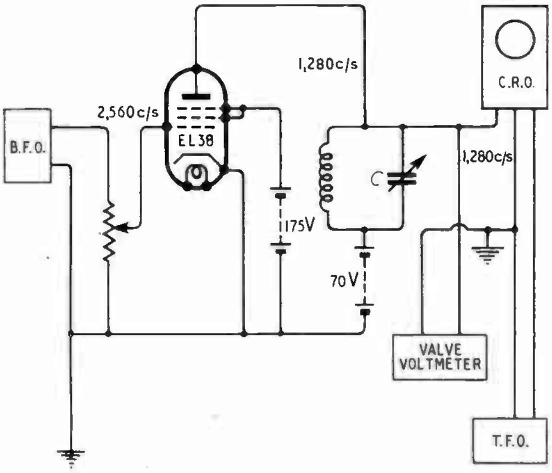


Fig. 5. *Circuit for the excitation of parametric oscillations.*

Expression (37) represents the state at the beginning of the inception of oscillations. As soon as V_c begins to rise (i.e., provided $\frac{1}{2}\omega\mu > \chi_o$ non-linearity of the $i_a - v_a$ characteristic of the dynatron will increase the mean resistance of the circuit; i.e., χ_o.

The increase of χ_o will at first be gradual, but as soon as V_c becomes large enough to reach the 'knee' of the negative slope of the i_a-v_a characteristic, further increase is rapidly brought to a stop. When V_c reaches its maximum value, $\frac{1}{2}\omega\mu = \chi_o$. Thus, knowing μ and the characteristics of the valve, Vc can be found.

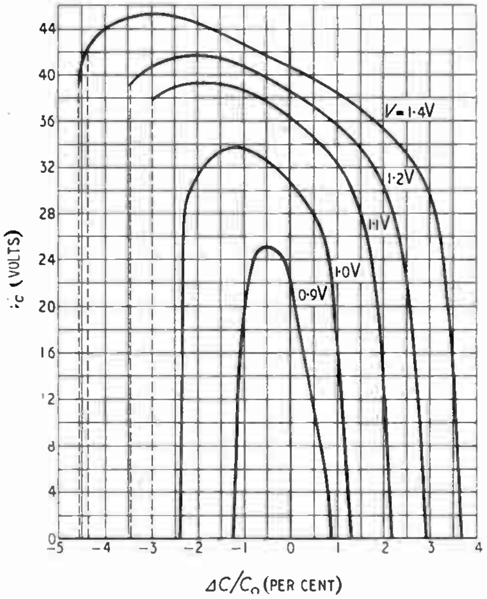


Fig. 6. *Parametric response. Shows the tuning range over which oscillations were observed at given amplitudes of grid-voltage variation. The frequency in all cases was exactly one-half the frequency of the grid voltage (resistance variation).*

10. Experimental Results

Measurements were made on the circuit shown in Fig. 5. 2560-c/s voltage was applied to the grid of the valve and when the resonant circuit was tuned to 1280-c/s oscillations were built up.

V_c was measured by means of a valve voltmeter as C was detuned from its resonance value C_o, while keeping the driving frequency constant at $f = 2f_o$.

Similarly V_c was measured for constant $C = C_o$ while altering the driving frequency from $f = 2f_o$.

These measurements were repeated for different values of the grid-drive voltage V.

The smallest value V for excitation of oscillations was $V = 0{\cdot}84$ V r.m.s. The theoretical value was $0{\cdot}88$ V.

Fig. 6 shows V_c plotted to the base of capacitance detuning. The curves show a very sharp rise and cut-off and a fairly flat response over the oscillatory region.

The curves are asymmetrical about C_o. The larger portion lies in the $C < C_o$ region.

Fig. 7 shows theoretical curves of μ' as a function of detuning $\Delta C/C_o$. These show the same asymmetry as the experimental curves.

Fig. 8 shows V_c as a function of frequency detuning $\Delta f/2f_0$. This curve is very much the same as those for capacitance detuning, except that the region of oscillations in this case expressed as percentage of 2560 c/s was 3·9% as compared with 7·2% of C_0 in the capacitance detuning.

Fig. 9 shows the variation of the capacitance detuning $\Delta C/C_0$ within which oscillations can be excited [Equation (34a)] as a function of the grid-drive voltage V.

The theoretical curve is also shown. There is a good agreement between two curves.

Thus, for $V = 1{\cdot}4$ V experimental $\Delta' C =$ 1246 pF, and theoretical $\Delta' C = 1223$ pF, a difference of 1·8%. Similarly for the frequency band for $V_g = 1{\cdot}4$ V $\Delta' f = 100$ c/s as measured by a beat-frequency oscillator and $\Delta' f = 104{\cdot}8$ c/s—theoretical value.

Fig. 10 shows V_c as a function of V for constant C and f.

As V is increased from its critical value of 0·84 V, V_c increases rapidly, but for $V > 1{\cdot}2$ volts μ is large enough to overcome the small non-linearity of the negative slope of the i_a–v_a characteristic and brings V_c to the knee of the characteristic.

The non-linearity due to the knee is much

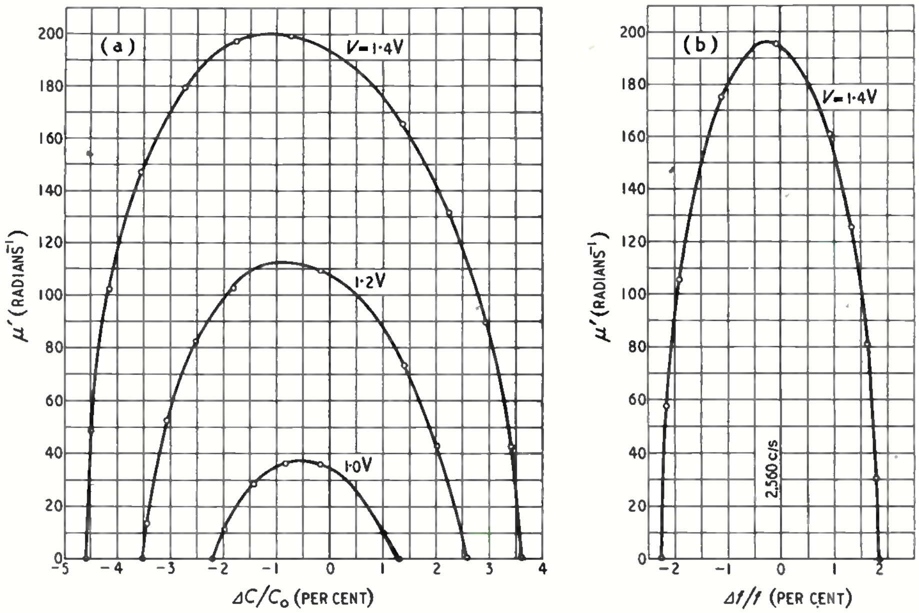


Fig. 7. (above) *Expected oscillation range on theoretical grounds,* (a) *plotted to a base of capacitance de-tuning;* (b) *plotted to a base of frequency detuning.*

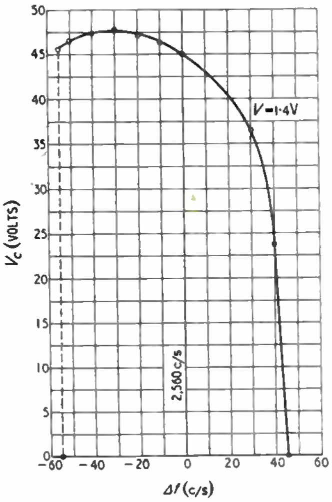
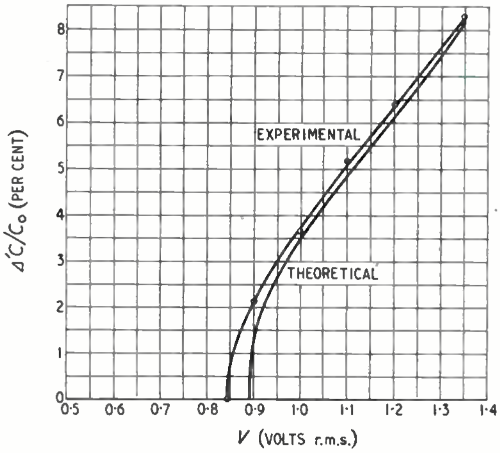


Fig. 8. (left) *Parametric response. Voltage across the capacitor* V_c *for varying frequency of resistance variation.*

Fig. 9. (right) $\Delta' C/C_0 = f(V_g)$ *curves. The oscillation range for differing amplitudes of resistance variation.*



greater than that of the negative slope and V_c can increase only slightly with V.

The linear relation between V and μ [Equ. (32b)] results in a linear increase of V_c with V for $V > 1{\cdot}5$.

The harmonic content of the waveform was not examined, but no visible trace of harmonics could be seen in the waveform as viewed on a c.r. oscilloscope.

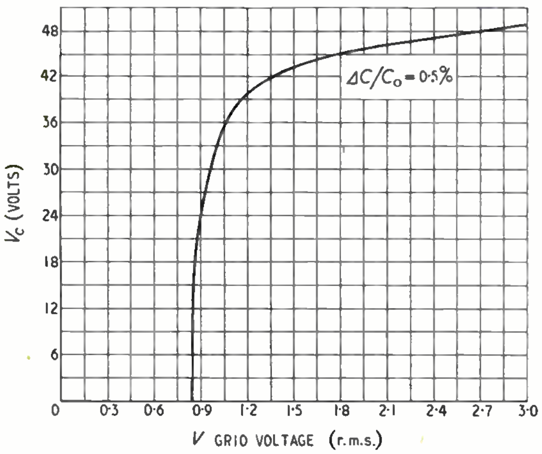


Fig. 10. *Voltage V_c across the capacitor in terms of the resistance swing, which is a function of V. For amplitudes greater than the starting value ($V = 0{\cdot}84$ V), the tendency is for V_c to remain constant.*

The shape of the response curves (e.g., $V_c - \Delta f$) suggests an application of the circuit as a possible filter device. It would have very sharp cut-offs with fairly flat response over the pass-band. The width of the pass-band and the mid-band frequency would be easily adjustable by varying the signal applied to the grid and the tuning of the circuit, respectively. The voltage across the resonant circuit would, however, be exactly one-half the frequency of the applied signal and would stay locked in the 2 to 1 ratio to the frequency of the signal.

The circuit is also suited for rejection of interference, since short-duration atmospherics, etc., will not affect the anode circuit.

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The author is a professor at l'École Supérieure in Paris, and this volume on electrostatics is the first of a work which will comprise several volumes. The object of the series is to give a profound and rigorous development of electromagnetic theory, taking into account any new developments during the last 50 years. The first four volumes of the series will deal with the macroscopic aspect of the subject; subsequent volumes will then deal with the microscopic aspect, which has undergone much greater modifications in recent years.

Of the six chapters, the first deals with the electrostatic field, its general properties and equations, and the second with conductors in the field, the distribution of their charges, and their capacitance. Chapter 3 is devoted to dielectrics, and Chapter 4 to non-homogeneous conductors, Voltaic and Seebeck effects. Chapter 5 deals with the energy of the field; entropy is here introduced, and in the following chapter the mechanical forces are calculated for various bodies including polarized fluids.

Each chapter is divided into two parts; the first part develops the theory and the second part, entitled "compléments et applications," applies it to a number of special cases. It is claimed that the mathematical treatment is graduated, becoming progressively more difficult. Thus, in the first three chapters the theory developed in the first part is applied in the second part to more difficult cases, such as ellipsoids of revolution. The author states in the preface that deductive reasoning is largely employed, compelling one to adopt such rigorous treatment that the form is as near as possible that of a mathematical science. This gives one a good idea of the method of approach and of the standard of the book. We note already on p. 14 references not only to the laws and equations of Coulomb, Gauss, Stokes, Poisson and Laplace, but also to the theorems of Astrogradsky and Noaillon. The first four chapters are more or less on standard lines but done with unusual thoroughness.

Chapter 5, entitled "Internal Energy, Internal Potential and Electrostatic Energy," gives a very thorough investigation of the properties of dielectrics, taking into account things that are usually entirely neglected, especially electrothermal phenomena. One expects some heat to be produced when the dielectric is subjected to an alternating field, but it will come as a great surprise to most people to learn that when carbon bisulphide at 27°C is gradually charged at a constant temperature, less than three-quarters of the energy supplied is stored as electrical energy, the remainder passing to the surroundings in the form of heat. The process is, however, reversible and, on discharging the dielectric, it absorbs heat from the surroundings, so that none of the energy is lost. The process is likened to the isothermal compression and expansion of a perfect gas. A far more striking case is that of the material $2BaTiO_3, 1SrTiO_3$ which at 15°C has a dielectric constant of 6000; whereas in the former case $d\epsilon/dT$ was negative, it is here positive and very large, with the result that the phenomenon is reversed, and on charging, the surroundings supply about 20 times the electrical energy in the form of heat. All these interesting phenomena are discussed in detail.

In the final chapter the same rigorous detailed investigation is made into the mechanical forces acting on conductors and in dielectrics. According to the author the theories of Maxwell are only applicable to an elastic ether and are therefore only of historic interest. He certainly extends his researches into realms that Maxwell never dreamt of.

In equation (6.218) on p. 351, the author has relaxed from his mathematical rigour; a sign is obviously wrong.

This is undoubtedly a book that can be recommended to anyone who wishes to make a thorough study of electrostatics from the mathematical point of view.

G. W. O. H.

Mathematical Engineering Analysis

By Rufus Oldenburger, Ph.D. Pp. 426 + xiv with 220 figs. Macmillan Co., St. Martin's St., London, W.C.2. Price 45s.

This is an unusual type of book. The author, who is with a manufacturing concern in Illinois, says that one of the most difficult tasks in industrial research is that of expressing physical situations in the form of equivalent mathematical relations, and the object of the book is to make transition from physical engineering situations to the corresponding mathematics easier for the reader. Then, with the mathematics as guide, he can better interpret experimental results and plan future physical studies. The book is an outgrowth of a course of lectures given at the Illinois Institute of Technology and is intended to serve as a text in courses on engineering analysis and industrial physics and as a reference work for research directors in industry, for engineering analysts, for development engineers, and for applied scientists in various fields of learning. The book assumes a knowledge of advanced calculus, especially those aspects concerned with line, surface, and volume integrals.

Of the 14 chapters only three deal with electrical matters; the others deal with mechanics of solids, heat, elasticity, fluid mechanics and aerodynamics. Of the 105 electrical pages, 50 are devoted to fundamentals of electricity and magnetism, 30 to various applications, 20 to electromagnetic fields and 5 to problems. As already stated the treatment assumes a knowledge of advanced calculus. We note that the inverse square law is ascribed to Michell and Coulomb, but no clue is given as to the identity of the former.

The author seems to dislike the metric system, for we are told that "H is normally measured in ampere turns per inch" and then "In this figure B is in kilogausses, one gauss being approximately 6·45 lines per square inch. The intensity H is in oersteds; one ampere turn per inch is approximately 0·495 oersted." In the Editorial of June 1948, attention was drawn to the fact that a recent American article had reversed the order of Kirchhoff's first and second laws, an order that had been universally adopted for the last century. Unfortunately the book under review adopts this reversed order without giving any reason.

The various applications in Chapter 4 are a mixed bag, a section on "electric motor raising an elevator car" coming between sections on "electronic amplification stage" and "transmission line." The mathematical equations are developed for the various networks and their mechanical analogies.

The chapter on electromagnetic fields is explained in the opening paragraph, which states that "the material of this chapter is needed for the proof of the Stefan-Boltzmann radiation law of Chapter 8," which deals with heat transfer. The Maxwell equations are developed to give the various properties of radiated waves, leading up to the energy density and the radiation pressure, and proving that in a vacuum for isotropic radiation, the latter is a third of the former.

Of the three chapters on heat, the first deals with the first law of thermodynamics and the second with the second law—fortunately the order of these has not been reversed—and the third chapter with heat transfer.

Of the three chapters on elasticity, the first deals with the fundamental theory, the second with elasticity in one and two dimensions, and the third in three dimensions.

Of the three chapters devoted to fluid mechanics, the first deals with fundamental fluid theory, the second with compressible fluids, including such things as water-hammer phenomena, and the final chapter of 10 pages is devoted to aerodynamics.

With regard to the electrical section, we feel that the author has tried to crowd too much into the available space, with the result that some of the subjects dealt with are necessarily left in an unsatisfactory condition. Such a highly specialized thing as the germanium transistor is a case in point, and might very well have been omitted from a book covering such a wide field.

G. W. O. H.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for March, 1952

Date 1952 March	Frequency deviation from nominal: parts in 10^8		Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
	MSF 60 kc/s 1029-1130 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.	
1**	—	− 3	—
2	0·0	− 2	− 3·0
3	+ 0·2	− 2	− 4·0
4**	—	− 2	—
5*	+ 0·2	− 2	− 4·5
6**	—	− 2	—
7**	—	− 2	—
8	0·0	− 2	− 6·4
9*	+ 0·1	− 2	N.M.
10*	+ 0·1	− 2	− 8·4
11**	—	− 3	—
12*	+ 0·2	− 2	− 9·9
13	+ 0·2	− 2	− 9·4
14	+ 0·2	− 2	− 9·7
15	+ 0·3	− 1	− 10·0
16*	+ 0·4	− 1	N.M.
17	+ 0·4	− 1	N.M.
18	+ 0·5	− 1	− 12·4
19*	+ 0·5	− 2	− 13·0
20	+ 0·5	− 1	− 13·3
21	+ 0·5	− 1	− 13·9
22	+ 0·5	− 1	− 14·3
23	+ 0·5	− 1	− 15·4
24	+ 0·5	− 1	− 15·7
25*	+ 0·5	0	N.M.
26	+ 0·4	− 1	− 16·9
27*	+ 0·5	− 1	− 18·3
28*	+ 0·5	+ 1	− 19·2
29	+ 0·4	+ 2	− 19·2
30	+ 0·4	+ 1	N.M.
31	+ 0·4	+ 2	− 19·8

The transmitter employed for the MSF 60-kc/s signal is sometimes required for another service.

N.M. = Not measured.
* = No MSF transmission at 1029 G.M.T. Results for 1429-1530 G.M.T.
** = No MSF transmission at 1029 G.M.T. or at 1429 G.M.T.

LINEAR RECTIFIERS AND LIMITERS

Effect on Complex Signals and Noise

By D. G. Tucker, D.Sc., Ph.D., A.M.I.E.E.

(Royal Naval Scientific Service)

SUMMARY.—The performance of linear-rectifier and balanced limiter circuits is analysed for an applied signal consisting of a carrier (envelope-modulated or unmodulated) accompanied by other tones or by noise. The method of analysis is simple, avoiding unfamiliar mathematical functions, but assumes that the carrier is the predominant component of the applied voltage. In spite of this assumption, the results obtained hold quite closely even when the signal and noise levels approach equality. For comparison, corresponding results for square-law and cube-law circuits are given.

Among the more interesting results deduced are the following:

(a) the output spectrum of the linear rectifier used as a detector is broader than the original modulation-frequency band (i.e., is broader than half of the applied bandwidth) due to the introduction (mainly) of intermodulation frequencies.

(b) the output spectrum of the limiter used as such is broader than the input for the same reason and, with the same applied signal as the detector, and with good signal/noise ratios the shape of the output spectrum relative to the carrier is identical with that of the detector relative to zero-frequency.

(c) the limiter effects an improvement in signal/noise ratio, amounting to 3 db for good ratios but, of course, largely removes any envelope-modulation from the carrier.

(d) when the linear rectifier (or square-law circuit) is used as a frequency-doubler, and the limiter (or cube-law circuit) is used as a frequency-trebler, then the signal/noise ratio in the harmonic band is at least 4.8 db worse than in the input band.

List of Symbols

r_f = forward resistance of rectifier.

r_b = backward resistance of rectifier.

$\phi(t)$ = switching function of rectifier.
= variation with time of circuit transfer voltage ratio (i.e., output/input).

h_0 = average value of $\phi(t)$.

h_1 = coefficient of fundamental-frequency component of $\phi(t)$.

E_1 = peak amplitude of applied carrier (or main tone).

E_0 = peak amplitude of output carrier (fundamental).

V_{n1} = input r.m.s. noise voltage.

V_{n0} = output r.m.s. noise voltage.
For second and third harmonic bands, '0' is replaced by '20' and '30' respectively.

x = ratio of amplitude of subsidiary tone to main tone.

p = angular frequency of carrier or main tone (rads/sec).

q = difference-frequency (rads/sec).

q_m = modulation-frequency (rads/sec).

k = depth of modulation.

R_1 = input signal/noise ratio.

R_0 = output signal/noise ratio.

E = voltage to which limiter limits.

$J_r(z)$ = Bessel function of first kind, order r, and argument z.

n = any integer.

1. Introduction

THE theoretical analysis of the linear-rectifier and limiter circuits is usually very complicated when the applied signal is more complex than a single tone or envelope-modulated carrier; published treatments have usually involved mathematical functions (e.g., hypergeometric functions) with which engineers are not generally familiar and which therefore obscure the physical significance of the analysis. There is evidently a need for a simpler method of analysis, and this paper presents a quite comprehensive treatment of the properties of these common types of non-linear circuit using only simple and familiar mathematical processes. Unfortunately the method is applicable only when one signal predominates, and thus cannot cope with the application of noise alone to the circuits; but it does cover practically all other likely conditions.

The circuits are assumed non-reactive; this assumption is nearly always necessary to make analysis practicable, and is made in probably all existing published treatments. Moreover, when the linear rectifier is used as a detector it is of the 'average' type and not of the 'envelope-following' type. It is clear, however, that the proportions of the modulation-frequency output components are the same in both types, so this feature is of no practical disadvantage, and, in fact, it permits the extension of the analysis to the application of the circuits as frequency-multipliers.

2. Basic Principle of the Analysis

2.1. *Switching Function of the Linear Rectifier*

A linear rectifier (the term is a paradox and not very satisfactory, but is conventional and well-understood) is one which has a low constant resistance for all positive voltages of applied signal, and a high constant resistance for all negative voltages. Real rectifiers usually approximate closely to this condition over a range of suitably large applied voltage. Let the forward resistance be r_f and the backward resistance be r_b.

When a sinusoidal signal is applied to such a

MS accepted by the Editor, June 1951.

rectifier, it switches from one resistance value to the other as the applied signal passes through zero, and we can plot a graph of its resistance as a time-function as shown in Fig. 1(a), where p is the angular frequency* of the applied signal. This variation in resistance causes a variation in the circuit loss, and the transfer voltage ratio (i.e., volts out/volts in) forms a square-wave time-function as shown in Fig. 1(b). This can be regarded as a modulating (or switching) function, designated as $\phi(t)$, where

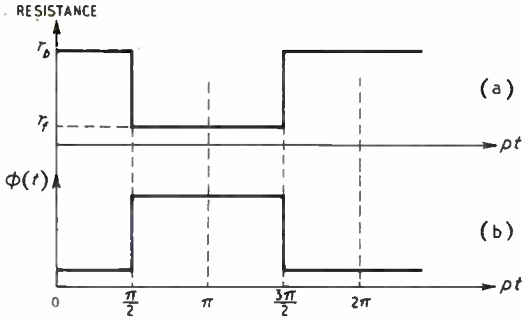

Fig. 1. *Switching of rectifier by single tone.*

$$\phi(t) = h_0 + h_1 [\cos pt - \tfrac{1}{3} \cos 3pt + \tfrac{1}{5} \cos 5pt \ldots]$$

$$= h_0 + h_1 \sum_{n=1}^{\infty} (-1)^{n-1} \frac{1}{(2n-1)} \cdot \cos (2n-1)pt \quad \ldots \quad (1)$$

where h_0 and h_1 are both functions of the circuit resistances and of r_b and r_f. The detector is thus a modulator where the applied signal generates its own modulating function.

If the input signal is $E_1 \cos pt$, the output is

$$E_1 \cos pt . \phi(t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

$$= \tfrac{1}{2}E_1h_1 + E_1h_0 \cos pt + \tfrac{1}{3}E_1h_1 \cos 2pt + \ldots (3)$$

corresponding to the well-known Fourier series for half-wave rectification of a sine-wave.

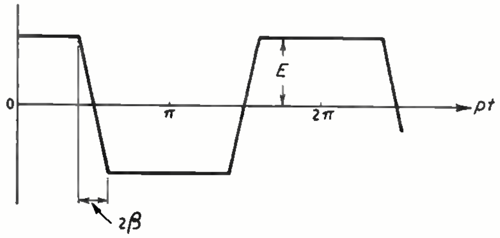

Fig. 2. *Limited cosine wave.*

2.2. *Output Waveform of Balanced Limiter*

A balanced limiter is one which chops the applied signal on both polarities to a voltage dependent on the bias. When a single sinusoidal signal, $E_1 \cos pt$, is applied, the output closely approximates to a trapezoidal wave as shown in Fig. 2, provided that the bias voltage E is very much less than E_1. The interval, β radians, during which the output rises from zero to E is dependent on the ratio of E to E_1. The Fourier series for this waveform[1] is

$$\frac{4E}{\pi} \sum_{n=1}^{\infty} (-1)^{n-1} \frac{1}{(2n-1)} \frac{\sin (2n-1)\beta}{(2n-1)\beta} \cdot \cos (2n-1)pt \quad \ldots \quad (4)$$

When β is so small (i.e., limiting is so heavy) that $\sin (2n-1)\beta \approx (2n-1)\beta$ over a reasonable range of n, then this expression is indistinguishable from a square-wave, and can be written exactly as (1) where $h_0 = 0$ and $h_1 = 4E/\pi$. Thus we shall proceed with the analysis on the basis that the output voltage waveform of the limiter is the same time-function as the switching function of the linear rectifier. Small modifications are easily made in the work which follows if β is not quite so small as to justify this.

2.3. *Phase Modulation due to One Side-Frequency*

Let the applied signal now consist of two sine-waves:

$$E_1[\cos pt + x \cos (p-q)t] \quad \ldots \quad \ldots \quad (5)$$

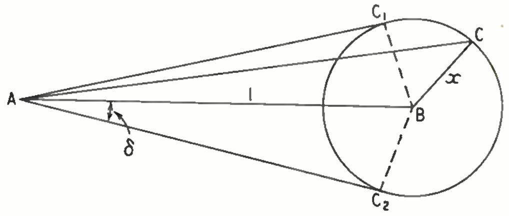

Fig. 3. *Mechanism of phase modulation.*

The function $\phi(t)$ is generated by the zero-crossings of this complex wave, and they are no longer at uniform time-intervals. Consider the vector relationships shown in Fig. 3. The vector AB represents the carrier, and BC the side-frequency at one particular instant. These are generating vectors, and AB is rotating with angular velocity p, and BC with angular velocity $p - q$. Thus BC is rotating with angular velocity q relative to AB, and has a locus (relative to AB) shown by the circle CC_1C_2; so the resultant AC varies in amplitude and phase with a period $2\pi/q$. Thus the signal applied to the circuit is equivalent to a carrier which is both amplitude- and phase-modulated.

The zero-crossings are controlled by the phase-modulation effect, and $\phi(t)$ becomes as shown in Fig. 4. Now if $x \ll 1$, the phase-modulation of the carrier is

$$-x \sin qt \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

so that if we insert this in (1) we obtain

---

* Note that, henceforth, when we refer to a 'frequency' we shall mean 'angular frequency' unless specified otherwise.

$$\phi(t) = h_0 + h_1 \sum_{n=1}^{\infty} (-1)^{n-1} . \frac{1}{(2n-1)} . \cos(2n-1)(pt - x \sin qt) \quad .. \quad (7)$$

This step† appears perhaps more plausible than rigorous, but seems to be quite justifiable[2] and has been checked experimentally by the author in connection with a rather similar modulator problem.[3]

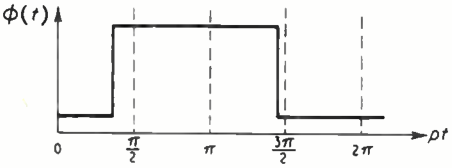

Fig. 4. *Switching function due to two-tone signal.*

By a well-known expansion[4] in terms of Bessel functions, (7) becomes:—

$$\phi(t) = h_0 + h_1 \sum_{n=1}^{\infty} (-1)^{n-1} . \frac{1}{(2n-1)} \Big[J_0\{(2n-1)x\} \cos(2n-1)pt + 2J_1\{(2n-1)x\} \sin(2n-1)pt . \sin qt + 2J_2\{(2n-1)x\} \cos(2n-1)pt . \cos 2qt + \text{etc.} \Big] \quad .. \quad .. \quad .. \quad (8)$$

This represents, provided $x \ll 1$,
(a) the switching function of the linear rectifier, the total output of which is therefore

$$E_1[\cos pt + x \cos(p - q)t] . \phi(t) \quad .. \quad (9)$$

or (b) the total output from the balanced limiter with $h_0 = 0$ and $h_1 = 4E/\pi$.

2.4. *Phase Modulation due to Multiple Side-Frequencies*

We can extend the analysis of the previous section to include two side-frequencies, and then we can infer the results for a large number of side-frequencies.

If the input signal is

$$E_1[\cos pt + x_1 \cos(p - q_1)t + x_2 \cos(p - q_2)t] \quad .. \quad .. \quad (10)$$

then the switching function becomes, still assuming $x_1 \ll 1$ and $x_2 \ll 1$,

$$\phi(t) = h_0 + h_1 \sum_{n=1}^{\infty} (-1)^{n-1} . \frac{1}{(2n-1)} . \cos(2n-1)(pt - x_1 \sin q_1 t - x_2 \sin q_2 t) \quad (11)$$

This can be expanded in terms of Bessel functions, as before, and gives the expression for the switching function of the rectifier or the output of the limiter. Owing to the complexity of the expression when expanded, it is best to go no further in general form, but merely to extract from it the terms appropriate to any particular practical case, as will be done in subsequent sections.

If we attempted to extend the analysis to more than two side-frequencies, the algebra would become far too laborious and bulky. However, a process which works satisfactorily is to write down the output of the circuit (or usually that part of the output lying in the frequency-band of special interest) when there are two side-frequencies, and extend it by inference to include the terms of the same order arising from say n side-frequencies. This is done in the sections which follow. The analysis can then be further extended to include the effect of noise by considering the noise to be made up of an infinite number of side-frequencies of infinitesimal amplitude. If all side-frequencies are considered to be of the same amplitude very simple formulae are obtained.

3. Output of Linear Rectifier as a Detector

When the rectifier is used as a detector, the output components of interest are those which lie in the modulation-frequency band; i.e., those consisting of the q-frequencies and their harmonics. This band is quite distinct from all others if we assume $q \ll p$.

The output of the circuit is the input signal multiplied by $\phi(t)$. It is clear that, as far as the q-band is concerned, only those terms in the expansion of $\phi(t)$ derived from $n = 1$ need be considered.

3.1. *Single Side-Frequency.*

It is easily seen from (8) and (9) that the q-band output is

$$\tfrac{1}{2}E_1 h_1 [x\{J_0(x) + J_2(x)\} \cos qt + \{-xJ_1(x) + 2J_2(x) + xJ_3(x)\} \cos 2qt + x\{J_2(x) + J_4(x)\} \cos 3qt + \text{etc.}] \quad .. \quad .. \quad .. \quad .. \quad (12)$$

Since we have already assumed $x \ll 1$, we can write the output as very nearly

$$\tfrac{1}{2}E_1 h_1 (x \cos qt - \tfrac{1}{4}x^2 \cos 2qt + \tfrac{1}{8}x^3 \cos 3qt + ..) \quad .. \quad .. \quad .. \quad (13)$$

This is actually a very good approximation, as we shall see later.

We see that a detector of so-called 'linear' type gives what is usually regarded as non-linear distortion when used with a single-sideband signal.

Any other terms of interest can be extracted from (9). For example, the d.c. output is

$$\tfrac{1}{2}E_1 h_1 [J_0(x) + xJ_1(x)] \quad .. \quad .. \quad .. \quad (14)$$

$$\approx \tfrac{1}{2}E_1 h_1 (1 + x^2/4) \quad .. \quad .. \quad .. \quad (15)$$

---

† The author was first introduced to this device many years ago by his former Post Office colleague, Mr. W. H. B. Cooper.

3.2. *Modulated Side-Frequency*

First of all consider a single envelope-modulated signal, $E_1(1 + k \cos q_m t) \cos pt$, applied to the circuit. The output is evidently

$$E_1(1 + k \cos q_m t) \cos pt . \phi(t) \quad .. \quad .. \quad (16)$$

where $\phi(t)$ is given by (1). The component at the modulation-frequency is

$$\tfrac{1}{2}E_1 h_1 k \cos q_m t \quad .. \quad .. \quad .. \quad .. \quad (17)$$

and there are no harmonics produced.

Now consider, instead, that the side-frequency of (5) is envelope-modulated. The modulation-frequency output from this is contained in the fluctuations which are now imposed on what was, in the previous section, the d.c. output. Thus, in (15), we replace x by $x(1 + k \cos q_m t)$ and obtain

$$\tfrac{1}{2}E_1 h_1 \left[1 + \frac{x^2}{4}\left(1 + k^2 \cos^2 q_m t + 2k \cos q_m t \right) \right] \quad .. \quad .. \quad .. \quad (18)$$

so that the component at frequency q_m is

$$\frac{x^2}{4} E_1 h_1 k \cos q_m t \quad .. \quad .. \quad .. \quad .. \quad (19)$$

If the stronger signal were not present, this component would have been given by x times (17). Thus the reduction in modulation-frequency output of the weaker signal caused by the presence of the stronger signal is

$$\frac{x}{2} \quad .. \quad .. \quad .. \quad .. \quad (20)$$

This effect is called 'detector discrimination', and attracted a great deal of attention around 1930 and subsequently.[5,6] It is accompanied by harmonic distortion of the modulation-frequency output from the weaker signal.

3.3. *Multiple Side-Frequencies*

First of all consider two side-frequencies. The input signal is given by (10), and $\phi(t)$ by (11). On multiplying this out and making approximations for the Bessel functions on the basis of $x \ll 1$, it is easily found that the q-band output is

$$\begin{aligned} \tfrac{1}{2}E_1 h_1 [& x_1 \cos q_1 t + x_2 \cos q_2 t \\ & - \tfrac{1}{4}x_1^2 \cos 2q_1 t - \tfrac{1}{4}x_2^2 \cos 2q_2 t \\ & + \tfrac{1}{2}x_1 x_2 \cos (q_1 - q_2)t - \tfrac{1}{2}x_1 x_2 \cos (q_1 + q_2)t \\ & + \text{etc.}] \quad .. \quad .. \quad .. \quad .. \quad .. \quad (21) \end{aligned}$$

To a closer approximation, the amplitude of the q_1 and q_2 terms is

$$\tfrac{1}{2}E_1 h_1 \left(1 - \frac{x_1^2}{4}\right)\left(1 - \frac{x_2^2}{4}\right)\left[x_1 \cos q_1 t + x_2 \cos q_2 t \right] \quad (22)$$

If now we consider n side-frequencies, the input signal is

$$\begin{aligned} E_1[& \cos pt + x_1 \cos (p - q_1)t + \dots\dots \\ & + x_n \cos (p - q_n)t] \quad .. \quad .. \quad (23) \end{aligned}$$

and we can infer, without the labour of full analysis, that by comparison with (21) the output of terms in the first and second orders of q must be

$$\begin{aligned} \tfrac{1}{2}E_1 h_1 \Big[& x_1 \cos q_1 t + x_2 \cos q_2 t + \dots + x_n \cos q_n t \\ & - \tfrac{1}{4}x_1^2 \cos 2q_1 t - \tfrac{1}{4}x_2^2 \cos 2q_2 t \dots \tfrac{1}{4}x_n^2 \cos 2q_n t \\ & + \tfrac{1}{2}x_1 x_2 \cos (q_1 - q_2)t + \tfrac{1}{2}x_1 x_3 \cos (q_1 - q_3)t + \dots \\ & + \tfrac{1}{2}x_2 x_3 \cos (q_2 - q_3)t + \tfrac{1}{2} x_2 x_4 \cos (q_2 - q_4)t + \dots \\ & + \dots \\ & \vdots \\ & + \tfrac{1}{2}x_{n-1} x_n \cos (q_{n-1} - q_n)t \\ & - \tfrac{1}{2}x_1 x_2 \cos (q_1 + q_2)t \dots\dots \\ & \vdots \\ & - \tfrac{1}{2}x_{n-1} x_n \cos (q_{n-1} - q_n)t \Big] \quad .. \quad .. \quad (24) \end{aligned}$$

To a closer approximation, the amplitude of the q terms is

$$\tfrac{1}{2}E_1 h_1 \left(1 - \frac{x_1^2}{4}\right)\left(1 - \frac{x_2^2}{4}\right) \dots \left(1 - \frac{x_n^2}{4}\right) \left[x_1 \cos q_1 t + \dots + x_n \cos q_n t \right] \quad (25)$$

The d.c. output is very approximately $\tfrac{1}{2}E_1 h_1$ and more accurately it is

$$\begin{aligned} \tfrac{1}{2}E_1 h_1 \Bigg[& \left(1 - \frac{x_1^2}{4}\right)\left(1 - \frac{x_2^2}{4}\right) .. \left(1 - \frac{x_n^2}{4}\right) \\ & + \frac{x_1^2}{2}\left(1 - \frac{x_2^2}{4}\right)\left(1 - \frac{x_3^2}{4}\right) .. \left(1 - \frac{x_n^2}{4}\right) \\ & + \frac{x_2^2}{2}\left(1 - \frac{x_1^2}{4}\right)\left(1 - \frac{x_3^2}{4}\right) .. \left(1 - \frac{x_n^2}{4}\right) \\ & + \text{etc.} \Bigg] \quad .. \quad .. \quad .. \quad .. \quad (26) \end{aligned}$$

Note that whereas with one side-frequency we assumed $x \ll 1$, we now have to assume that $\sum x \ll 1$.

3.4. *Discussion of Accuracy*

Comparing the results of Section 3.1 with previously-published results for the two-frequency wave,[7,8,9,10] we find that in spite of the very much simpler analysis our results agree remarkably well. Previous results have assumed rectifiers with zero forward and infinite backward resistance and have given current components in an external circuit of zero impedance. Thus, to compare results, we must put our $h_1 = 2/\pi$. We then obtain the comparison shown in Table 1, which is based on the simplified equation (13).

The discrepancies are thus negligible at $x = 0{\cdot}5$, and amount to no more than 1·5 db on the fundamental difference-frequency even at $x = 1$.

The results of Section 3.3, for the case of more than two tones, cannot be checked as there appears to have been no previous publication of this case.

The results of Section 3.2 agree with the earlier publications quoted there.

It is worth noting that the accuracy of the results of Section 3.1 can be improved, if desired, by using the tabulated values of the Bessel functions in (12). For the fundamental when $x = 1$, this gives 0·28 instead of 0·32 in Table 1, an error of only about $\frac{1}{3}$ db relative to the previously-published results.

Now when nx is very small indeed, the only significant components of the output spectrum are the q terms in (24). Thus if our input noise spectrum extends over a band of frequency of width q_0 each side of the carrier, the output spectrum is uniform over a band 0 to q_0 (but excluding d.c.) as shown in Fig. 5(a).

As nx increases, the plus and minus terms in (24) become noticeable. They have a triangular power spectrum, as shown in Fig. 5(b). Thus when the noise and carrier levels are comparable, the output noise spectrum appears as shown in Fig. 5(c).

TABLE 1

Harmonic of difference frequency	$x = 0{\cdot}5$		$x = 1$	
	Previous	Equation (13)	Previous	Equation (13)
Fundamental	0·156	0·159	0·27	0·32
2nd.	0·0186	0·0199	0·053	0·08

3.5. *Noise Interference*

As stated in Section 2.4, the technique for calculating the effect of noise interference in the detection of a carrier is to consider the noise as n infinitesimal side-frequencies, with $n \rightarrow \infty$. If all x terms are made equal, this can be made to correspond to any desired power spectrum of noise over a given band of frequency by suitable arrangement of the frequency-intervals. In this way we can avoid considering noise on a statistical basis.

3.5.1. *Output Noise Spectrum*

Considering n equal tones of amplitude x relative to the carrier, the noise output is given by (24) and (25). The total r.m.s. noise voltage in the output is then approximately

$$V_{n0} = \frac{E_1 h_1}{2\sqrt{2}}\left[\left(1 - \frac{nx^2}{2}\right)nx^2 + \frac{nx^4}{16} + \frac{n(n-1)}{4}x^4\right]^{\frac{1}{2}} \quad .. \quad (27)$$

As $n \rightarrow \infty$, this becomes

$$V_{n0} = \frac{E_1 h_1}{2\sqrt{2}}\sqrt{n}.x\sqrt{1 - \frac{nx^2}{4}}$$

$$\approx \frac{E_1 h_1}{2\sqrt{2}}\sqrt{n}.x\left(1 - \frac{nx^2}{8}\right) \quad .. \quad .. \quad (28)$$

if $\frac{nx^2}{4} \ll 1$

or $V_{n0} = \frac{1}{2}h_1 V_{n1}\left(1 - \frac{1}{4}\frac{V_{n1}^2}{E_1^2}\right) \quad .. \quad .. \quad (29)$

where V_{n1} = input noise voltage (r.m.s.)

When the signal/noise ratio becomes very small, so that the carrier can be neglected, the q terms obviously become negligible and the output

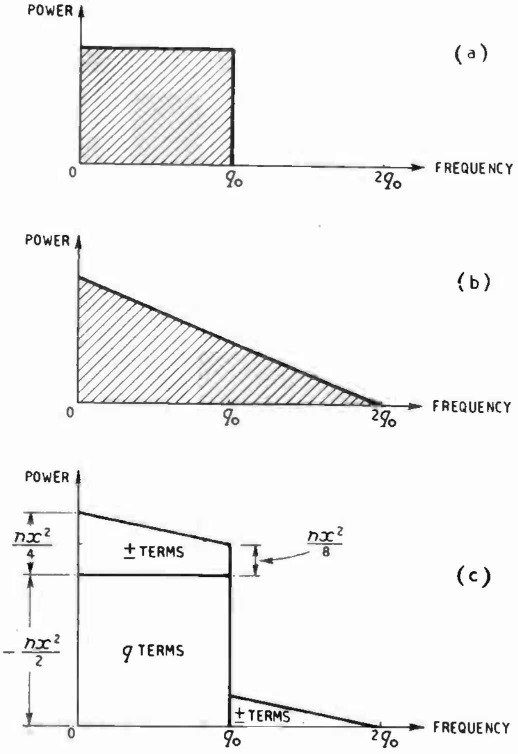

Fig. 5. *Output noise spectra from detector: (a) spectrum of q terms = output when nx* $\ll 1$*; (b) spectrum of ± terms = output when carrier absent; (c) spectrum of output when noise and carrier levels are comparable.*

spectrum comprises only the ± terms, so that the output spectrum is as shown in Fig. 5(b).

Unfortunately there seems at present no simple way of analysing the detector output when the carrier is reduced below a value say two or three times the noise level. We shall thus have to base the remainder of this paragraph on results obtained from rather difficult treatments[11, 14] or from experimental measurements.[12, 13] From these we find that when the carrier and noise levels are equal, the output voltage of noise is about 85% of its value when the carrier is very large, and when the carrier is removed altogether, the noise is reduced to 63%. It is interesting that, in spite of the assumptions made in deriving (29) it is quite accurate up to $nx^2 = 1$ (i.e., signal and noise equal), giving 87·5% instead of the 85% quoted above.

3.5.2. *D.C. Output*

We shall now examine the effect of input noise on the d.c. component of the rectified signal.

On the same basis as before, we take n equal tones of amplitude xE_1 and using (26) we obtain as the d.c. output

$$\tfrac{1}{2}E_1h_1\left[\left(1-\frac{x^2}{4}\right)^n+\frac{nx^2}{2}\left(1-\frac{x^2}{4}\right)^{n-1}\right] \qquad (30)$$

which as $n \to \infty$

$$\approx \tfrac{1}{2}E_1h_1\left(1+\frac{nx^2}{4}\right) \quad \ldots \quad \ldots \quad \ldots \quad (31)$$

$$= \tfrac{1}{2}E_1h_1\left(1+\tfrac{1}{2}\frac{V_{n1}^2}{E_1^2}\right) \quad \ldots \quad \ldots \quad \ldots \quad (32)$$

This shows that the d.c. output is increased by the presence of noise. The results above agree exactly with formulae obtained by Bennett[11] [see his Equ. (12)] for large signal/noise ratio, and in fact hold quite accurately even for noise somewhat greater than the signal.

When the noise is very much greater than the signal, Bennett[11] shows that the d.c. output is approximately [see his formula (11)]:—

$$\tfrac{1}{2}E_1h_1\sqrt{n}.x\frac{\sqrt{\pi}}{2}\left(1+\tfrac{1}{2}\cdot\frac{1}{nx^2}\right) \quad \ldots \quad \ldots \quad (33)$$

$$= \tfrac{1}{2}V_{n1}h_1\sqrt{\frac{\pi}{2}}\left(1+\tfrac{1}{4}\frac{E_1^2}{V_{n1}^2}\right) \quad \ldots \quad \ldots \quad (34)$$

so that when the carrier is absent, the d.c. output

$$= \tfrac{1}{2}V_{n1}h_1\sqrt{\frac{\pi}{2}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (35)$$

3.5.3. *Output due to Envelope-Modulated Signal*

The effect of noise on the output of modulation-frequency, q_m, derived from the detection of an envelope-modulated signal is easily determined from the work of Section 3.3. The simplest process is to consider the sidebands due to q_m as two side-frequencies in the same way as the noise components except that, due to their symmetrical disposition, they cause no phase-modulation of the switching function. We then obtain the result that the output of q_m is

$$\tfrac{1}{2}E_1h_1\left(1-\frac{nx^2}{4}\right)k\cos q_mt \quad \ldots \quad \ldots \quad (36)$$

$$= \tfrac{1}{2}E_1h_1k\left(1-\tfrac{1}{2}\frac{V_{n1}^2}{E_1^2}\right)\cos q_mt \quad \ldots \quad (37)$$

Thus the noise reduces the output of modulation signal.

The modulation has only a small influence on the noise output. We use (29) and allow for the modulation of the carrier by replacing x by $x(1+k\cos q_mt)^{-1}$ which is approximately $x(1-k\cos q_mt)$ if $k \ll 1$. After manipulation, (29) becomes

$$V_{n0} = \tfrac{1}{2}h_1V_{n1}\left[1-\tfrac{1}{2}\frac{V_{n1}^2}{E_1^2}\left(1+\frac{k^2}{2}\right)\right]^{\frac{1}{2}} \quad \ldots \quad (38)$$

These results, which are for noise < signal, do not agree with those given by Ragazzini[15] or Burgess,[16] but these two authors disagree with one another! They, together with Middleton,[17] also discuss the case of noise > signal, but we shall not deal with it here, except to say that the performance is then analagous to the effect of 'detector discrimination' described in Section 3.2; i.e., the strong noise voltage has a marked suppressing effect on the modulation of the weaker signal.

4. Output of Balanced Limiter with Noise Interference

The performance of the limiter is analysed along the same lines as that of the rectifier in Section 3; consequently it is necessary now to give only the main steps in the calculation.

When a carrier and one side-frequency are applied to the limiter, the output is given by (8). As a rule we are concerned mainly with the frequency components around p (i.e., with the through-transmission) and it is convenient to assume a fairly narrow input frequency-band so that the output bands centred around the odd harmonics of p do not overlap. This gives the same condition as for the linear rectifier, namely $q \ll p$. The p-band output is, therefore,

$$\frac{4E}{\pi}\Big[J_0(x)\cos pt + J_1(x)\{\cos(p-q)t-\cos(p+q)t\} + J_2(x)\{\cos(p-2q)t+\cos(p+2q)t\} + \text{etc.}\Big] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (39)$$

To a good approximation this can be written

$$\frac{4E}{\pi}\cdot\Big[\Big(1-\frac{x^2}{4}\Big)\cos pt+\frac{x}{2}\cos(p-q)t-\frac{x}{2}\cos(p+q)t$$
$$+\frac{x^2}{8}\cos(p-2q)t+\frac{x^2}{8}\cos(p+2q)t$$
$$+\text{etc.}\Big] \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (40)$$

It will be noticed that the ratio of cos pt to cos $(p-q)t$ is now

$$\frac{1-\dfrac{x^2}{4}}{\dfrac{x}{2}} \approx \frac{2}{x} \text{ when } x \text{ is very small} \quad \ldots \quad (41)$$

i.e., it is double what it was in the input. But to compensate this, new frequencies have been introduced, the most important being the 'image' frequency $(p+q)$ at the same amplitude as the input side-frequency $(p-q)$.

With two side-frequencies, the total output is given by (11), and the p-band is

$$\frac{4E}{\pi}\cdot\Big[\Big(1-\frac{x_1^2}{4}\Big)\Big(1-\frac{x_2^2}{4}\Big)\cos pt$$
$$+\frac{x_1}{2}\Big(1-\frac{x_2^2}{4}\Big)\{\cos(p-q_1)t-\cos(p+q_1)t\}$$
$$+\frac{x_2}{2}\Big(1-\frac{x_1^2}{4}\Big)\{\cos(p-q_2)t-\cos(p+q_2)t\}$$
$$+\frac{x_1^2}{8}\Big(1-\frac{x_2^2}{4}\Big)\{\cos(p-2q_1)t+\cos(p+2q_1)t\}$$
$$+\frac{x_2^2}{8}\Big(1-\frac{x_1^2}{4}\Big)\{\cos(p-2q_2)t+\cos(p+2q_2)t\}$$
$$+\frac{x_1x_2}{4}\{\cos(p+q_1-q_2)t+\cos(p-q_1+q_2)t$$
$$-\cos(p+q_1+q_2)t-\cos(p-q_1-q_2)t\}\Big] \quad (42)$$

taking only the terms up to 2nd order in q.

This can be extended by inference to the case of n side-frequencies as was done with the linear-rectifier in Section 3.3.

Then, if we let $n\rightarrow\infty$ and nx^2 be small but finite (assuming equal x terms), we find that the output of noise in the p-band when the carrier tone is predominant but accompanied by an input noise voltage V_{n_1} is

$$V_{n0}=\frac{4E}{\pi}\cdot\frac{1}{\sqrt{2}}\Big[\Big(1-\frac{x^2}{4}\Big)^{2(n-1)}\Big(\frac{nx^2}{2}+\frac{nx^4}{32}\Big)$$
$$+\frac{n(n-1)x^4}{8}\Big]^{\frac{1}{2}}$$
$$\approx\frac{4E}{\pi}\cdot\frac{\sqrt{n}.x}{2}\Big(1-\frac{nx^2}{8}\Big) \quad \ldots \quad \ldots \quad (43)$$

$$=\frac{4E}{\pi\sqrt{2}}\cdot\frac{V_{n1}}{E_1}\Big(1-\tfrac{1}{4}\frac{V_{n1}^2}{E_1^2}\Big) \quad \ldots \quad (44)$$

The signal (cos pt) has an output r.m.s. voltage

$$\overline{E_0}=\frac{4E}{\pi\sqrt{2}}\Big(1-\tfrac{1}{2}\frac{V_{n1}^2}{E_1^2}\Big) \quad \ldots \quad \ldots \quad (45)$$

Let the input signal/noise ratio be

$$R_1=\frac{E_1}{\sqrt{2}V_{n1}} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (46)$$

Then the output signal/noise ratio is

$$R_0=\frac{1-\dfrac{1}{4R_1^2}}{\dfrac{1}{R_1\sqrt{2}}\Big(1-\dfrac{1}{8R_1^2}\Big)}$$
$$\approx\sqrt{2}R_1-\frac{1}{4\sqrt{2}R_1} \quad \ldots \quad \ldots \quad (47)$$

Thus, for good signal/noise ratios, the limiter causes a 3-db *improvement* in ratio, but this improvement slowly diminishes as the input ratio worsens.

As regards the spectrum of the output noise, it is easy to see that, for good signal/noise ratios, this follows the same pattern as was determined for the q-band of the detector. For a uniform input spectrum over a band of width q_0 on each side of the carrier, the output spectrum is as shown in Fig. 6.

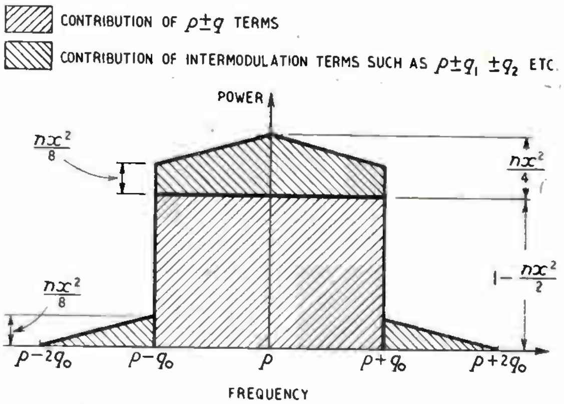

Fig. 6. *Noise spectrum in output of limiter; ordinates marked are approximate relative values.*

5. Output of Linear-Rectifier and Limiter Circuits used as Frequency-Multipliers

Both the circuits which have been considered produce harmonics of the applied signal, and can be used as frequency-multipliers. In these applications it is the multiple of a single tone which is usually required, but often other signals or noise may be present and it is then necessary to know how these affect the signal/background ratio in the harmonic band. The analysis previously used is applied directly, except that now we select those output frequency-components which lie in the desired harmonic band. To ensure that these bands are distinct, we still assume $q \ll p$. For the linear rectifier we shall consider the 2nd harmonic (i.e., $2p$) band, and for the limiter the 3rd harmonic (i.e., $3p$) band. The condition that the carrier signal should be predominant will be retained.

5.1 *Linear Rectifier as Frequency-Doubler*

Starting from (11) we can write down—after rather laborious, but quite simple, expansions—the output in the $2p$-band when the carrier is accompanied by two side frequencies. Replacing the Bessel functions by their approximations for $x \ll 1$ and ignoring terms above the second order in q, we obtain the $2p$-band output:—

$$\begin{aligned}
E_1h_1\Bigg[\bigg\{&\tfrac{1}{2}\left(1-\frac{x_1^2}{4}\right)\left(1-\frac{x_2^2}{4}\right)-\frac{x_1^2}{4}\left(1-\frac{x_2^2}{4}\right)\\
&-\frac{x_2^2}{4}\left(1-\frac{x_1^2}{4}\right)-\frac{1}{6}\left(1-\frac{9x_1^2}{4}\right)\left(1-\frac{9x_2^2}{4}\right)\\
&-\frac{x_1^2}{4}\left(1-\frac{9x_2^2}{4}\right)-\frac{x_2^2}{4}\left(1-\frac{9x_1^2}{4}\right)\bigg\}\cos 2pt\\
&+\frac{x_1}{2}\cos(2p-q_1)t+\frac{x_2}{2}\cos(2p-q_2)t\\
&-\frac{x_1}{6}\cos(2p+q_1)t-\frac{x_2}{6}\cos(2p+q_2)t\\
&+\frac{x_1^2}{8}\Big\{\cos(2p-2q_1)t+\cos(2p+2q_1)t\Big\}\\
&+\frac{x_2^2}{8}\Big\{\cos(2p-2q_2)t+\cos(2p+2q_2)t\Big\}\\
&+\frac{x_1x_2}{4}\Big\{\cos(2p-q_1+q_2)t+\cos(2p+q_1-q_2)t\\
&-\cos(2p+q_1+q_2)t-\cos(2p-q_1-q_2)t\Big\}\Bigg] \quad \ldots \quad \ldots \quad \ldots \quad (48)
\end{aligned}$$

From this we can deduce by inference, as before, the $2p$-band output when there are n side-frequencies.

When the input consists of a signal plus noise, we make $n \to \infty$ and all x terms equal, so that the output of signal in the $2p$-band is

$$\begin{aligned}
&\tfrac{1}{2}E_1h_1\left[\left(1-\frac{nx^2}{4}\right)-\frac{1}{3}\left(1-\frac{9nx^2}{4}\right)\right.\\
&\qquad\left.-\frac{nx^2}{2}\left\{\left(1-\frac{nx^2}{4}\right)+\left(1-\frac{9nx^2}{4}\right)\right\}\right]\cos 2pt\\
&=\tfrac{1}{2}E_1h_1\left[\frac{2}{3}-\frac{nx^2}{2}\left(1-\frac{5}{2}nx^2\right)\right]\cos 2pt \quad \ldots \quad (49)\\
&\approx E_1h_1\left(\frac{1}{3}-\frac{1}{4R_1^2}\right)\cos 2pt \quad \ldots \quad \ldots \quad (50)
\end{aligned}$$

The output of noise is

$$\begin{aligned}
V_{n20}&=\tfrac{1}{2}E_1h_1.\frac{1}{\sqrt{2}}\left(nx^2+\frac{1}{3}nx^2+\frac{nx^4}{2}+\frac{n^2x^4}{2}\right)^{\frac{1}{2}}\\
&=\tfrac{1}{2}E_1h_1\sqrt{\frac{2}{3}}\cdot\frac{1}{R_1}\left(1+\frac{0{\cdot}19}{R_1^2}\right) \quad \ldots \quad (51)
\end{aligned}$$

and the signal/noise ratio in the $2p$-band is

$$\begin{aligned}
R_{20}=\frac{E_{20}}{V_{n20}}&=\frac{\sqrt{2}\left(\dfrac{1}{3}-\dfrac{1}{4R_1^2}\right)}{\sqrt{\dfrac{2}{3}}\cdot\dfrac{1}{R_1}\left(1+\dfrac{0{\cdot}19}{R_1^2}\right)} \quad (52)\\
&\approx R_1.\frac{1}{\sqrt{3}}\left(1-\frac{0{\cdot}94}{R_1^2}\right) \quad \ldots \quad \ldots \quad (53)\\
&\approx \frac{R_1}{1{\cdot}73}\left(1-\frac{1}{R_1^2}\right) \quad \ldots \quad \ldots \quad \ldots \quad (54)
\end{aligned}$$

Thus when R_1 is large, the signal/noise ratio in the $2p$-band is about 4·8 db worse than in the input, and is progressively worsened as R_1 is decreased.

5.2 *Limiter as Frequency-Trebler*

By the same type of process as used above, we can show that the $3p$-band output of the limiter when the predominant carrier is accompanied by two side-frequencies is:—

$$\begin{aligned}
\frac{4E}{3\pi}\Bigg\{&\left(1-\frac{9x_1^2}{4}\right)\left(1-\frac{9x_2^2}{4}\right)\cos 3pt\\
&+\frac{3x_1}{2}\left(1-\frac{9x_2^2}{4}\right)\Big[\cos(3p-q_1)t-\cos(3p+q_1)t\Big]\\
&+\frac{3x_2}{2}\left(1-\frac{9x_1^2}{4}\right)\Big[\cos(3p-q_1)t-\cos(3p+q_2)t\Big]\\
&+\frac{9x_1^2}{8}\left(1-\frac{9x_2^2}{4}\right)\Big[\cos(3p-2q_1)t-\cos(3p+2q_1)t\Big]\\
&+\frac{9x_2^2}{8}\left(1-\frac{9x_1^2}{4}\right)\Big[\cos(3p-2q_2)t-\cos(3p+2q_2)t\Big]\\
&+\frac{9x_1x_2}{4}\Big[\cos(3p+q_1-q_2)t+\cos(3p-q_1+q_2)t\\
&\qquad-\cos(3p+q_1+q_2)t-\cos(3p-q_1-q_2)t\Big]\Bigg\} \quad (55)
\end{aligned}$$

taking only the terms up to second-order in q.

Extending this to the case of n side-frequencies as before, and then regarding the side-frequencies as noise, we find that the signal is

$$\begin{aligned}
&\frac{4E}{3\pi}\left(1-\frac{9nx^2}{4}\right)\cos 3pt \quad \ldots \quad \ldots \quad \ldots \quad (56)\\
&=\frac{4E}{3\pi}\left(1-\frac{9}{4R_1^2}\right)\cos 3pt \quad \ldots \quad \ldots \quad (57)
\end{aligned}$$

and the noise is

$$V_{n30} = \frac{4E}{3\pi} \cdot \frac{1}{\sqrt{2}} \left[\left(1 - \frac{9x^2}{4}\right)^{2n} \cdot \frac{9nx^2}{2} + \frac{81n^2x^4}{8} \right]^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (58)$$

$$= \frac{2E}{R_1}\left(1 - \frac{9}{8R_1^2}\right) \quad .. \quad .. \quad .. \quad (59)$$

So that the signal/noise ratio in the $3p$-band is

$$R_{30} = \frac{1 - \dfrac{9}{4R_1^2}}{\dfrac{3}{\sqrt{2}\,R_1}\left(1 - \dfrac{9}{8R_1^2}\right)} \quad .. \quad .. \quad (60)$$

$$\approx \frac{\sqrt{2}\,R_1}{3}\left(1 - \frac{9}{8R_1^2}\right) \quad .. \quad .. \quad (61)$$

Thus the signal/noise ratio is at least 6½ db worse in the $3p$-band than in the input, and nearly 10 db worse than in the p-band output.

6. Comparison with Results for Square- and Cube-Law Circuits

The performance of square- and cube-law circuits with complex signals and noise is much more easily worked out than that of linear rectifiers and limiters as they have no discontinuity in their response/voltage characteristics. No working will be given here, therefore, but some results will be quoted for comparison with those of the preceding sections.

The square-law circuit is taken to have a relationship between output voltage (v_0) and input voltage (v_1) given by

$$v_0 = a_1 v + a_2 v^2 \quad .. \quad .. \quad .. \quad .. \quad (62)$$

and the cube-law circuit has

$$v_0 = a_1 v + a_2 v^2 + a_3 v^3 \quad .. \quad .. \quad .. \quad (63)$$

With other symbols as used previously, the following are formulae for signal and noise performance worked out on the same basis as in previous sections except that we do not need to assume, in general, that the carrier predominates.

Square-law:—

$$\text{d.c. output} = \tfrac{1}{2}a_2E_1^2\left(1 + \frac{1}{R_1^2}\right) \quad .. \quad (64)$$

$$= a_2V_{n1}^2(1 + R_1^2) \quad .. \quad .. \quad (65)$$

$$p\text{-band output} = a_1 \times \text{input} \quad .. \quad .. \quad (66)$$

q-band noise output, V_{n0}

$$= a_2V_{n1}(E_1^2 + V_{n1}^2)^{\frac{1}{2}} \quad .. \quad .. \quad (67)$$

$$2p\text{-band: signal} = \tfrac{1}{2}a_2E_1^2 \cos 2pt \quad .. \quad (68)$$

$$\text{noise, } V_{n20} = \frac{a_2}{\sqrt{2}}\,\frac{E_1^2}{R_1}\left(1 + \frac{1}{2R_1^2}\right)^{\frac{1}{2}} \quad .. \quad (69)$$

$$\text{S/N ratio, } R_{20} = \frac{R_1}{2}\left(1 + \frac{1}{2R_1^2}\right)^{-\frac{1}{2}} \quad .. \quad (70)$$

$$\approx \frac{R_1}{2}\left(1 - \frac{1}{4R_1^2}\right) \text{if } R_1 \text{ large} \quad .. \quad .. \quad (71)$$

With modulated carrier:

$$\text{d.c. output} = \tfrac{1}{2}a_2E_1^2\left(1 + \frac{k^2}{2} + \frac{1}{R_1^2}\right) \quad .. \quad (72)$$

$$= a_2V_{n1}^2\left[1 + R_1^2\left(1 + \frac{k^2}{2}\right)\right] \quad (73)$$

Modulation-frequency output

$$= ka_2E_1^2 \cos q_mt + \frac{k^2}{4}a_2E_1^2 \cos 2q_mt \quad .. \quad (74)$$

Noise in q-band, V_{n0}

$$= a_2V_{n1}^2\left[1 + 2R_1^2\left(1 + \frac{k^2}{2}\right)\right]^{\frac{1}{2}} \quad .. \quad (75)$$

S/N ratio in q-band (excluding d.c. and harmonics),

$$R_0 = \frac{\sqrt{2}kR_1^2}{\sqrt{\left[1 + 2R_1^2\left(1 + \dfrac{k^2}{2}\right)\right]}} \quad .. \quad (76)$$

Cube-Law:

D.C., q-band and $2p$-band outputs are obviously the same as for the square-law circuit.

$$p\text{-band: signal} = \left[a_1E_1 + a_3E_1^3\left(\frac{3}{4} + \frac{3}{2R_1^2}\right)\right] \cos pi \quad .. \quad .. \quad (77)$$

$$\text{noise} = V_{n1}\left[a_1^2 + 3a_1a_3E_1^2 + \frac{45}{16}a_3^2E_1^4 \left(1 + \frac{1{\cdot}2}{R_1^2}\right)\right]^{\frac{1}{2}} \quad .. \quad (78)$$

The way in which the S/N ratio varies as E_1 is increased from zero is shown in Fig. 7.

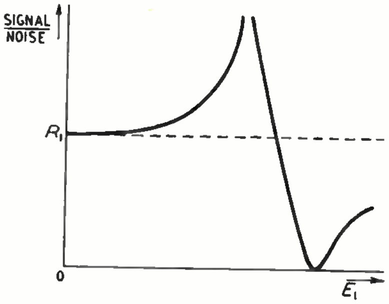

Fig. 7. *Variation of signal/noise ratio in through-transmission band of cube-law circuit (assuming a_3 to be negative, as it usually is).*

$$3p\text{-band: signal} = \tfrac{1}{4}a_3E_1^3 \cos 3pt \quad .. \quad .. \quad (79)$$

$$\text{noise, } V_{n30} = \frac{3}{4\sqrt{2}}a_3E_1^3 \cdot \frac{1}{R_1}\left(1 + \frac{2}{R_1^2} + \frac{1}{3R_1^4}\right)^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (80)$$

$$S/N \text{ ratio}, \ R_{30} \approx \frac{R_1}{3}\left(1 - \frac{1}{{R_1}^2}\right) \text{ if } R_1 \text{ large} \quad (81)$$

7. Acknowledgment

This work was done at H.M. Underwater Detection Establishment, Portland, and is published by permission of the Admiralty.

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PHYSICAL SOCIETY'S EXHIBITION

THE 36th annual exhibition of scientific instruments and apparatus was held by the Physical Society at Imperial College, London, from 3rd to 8th April. The number of exhibits was approximately the same as last year, and although by no means all were new, many that appeared to have been seen before had actually been extensively developed. For some years the boundaries between instruments for the different branches of engineering and pure research have been wearing very thin, and are now practically imperceptible. Not long ago a new type of microscope (other than the electronic variety) would have been considered quite outside the scope of this journal; but one shown this year was in fact made up almost entirely of 405-line television apparatus. The many recording and analysing instruments shown could be used equally well for radio signals or structure vibrations. With the exception of those stands devoted to conventional microscopes, almost the whole of the exhibition had some application to the radio and associated industries.

Materials

An interesting development, which was shown by Salford Electrical Instruments, is the production of magnets and cores by moulding iron dust of extremely small particle size, namely that of the domains. Such material can be produced with a variety of magnetic properties, including permanent magnets of 0·5 to 1·0 × 10⁶ gauss-oersted, and low-loss high-resistivity coil cores. Scarce materials are saved, and production facilitated. The rectangular loop of Permalloy 'F', a new core material for magnetic amplifiers, was demonstrated by Standard Telephones. Plessey showed the usefulness of their Caslam cores in reducing the size of suppression inductors in the band 200–5,000 kc/s, and also Caslode conductive ceramic material as absorbers and attenuators of microwaves. Unlike other materials used as dummy loads, Caslode has stable properties up to 400°C and is not permanently damaged by 1,000°C. Another example of the saving of scarce materials was seen in Telconal, by Telegraph Construction and Maintenance; this copper-manganese-aluminium alloy has properties similar to Eureka but contains no nickel. Under the name Thessconite, the Sheffield Smelting Co. showed a large range of electrical contact materials and forms.

Components, including Valves and Rectifiers

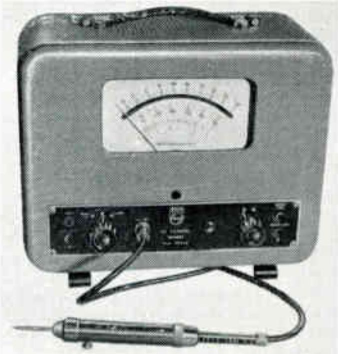
The demand for more and more robust components, stimulated by Service needs, was illustrated by British Electric Resistance rotary rheostats, embedded in vitreous enamel. The smallest size, similar to potentiometers usually rated at 3–5 W, was no less than 25 W. The same firm exhibited wire-wound resistors the production of which avoids the high temperatures of vitrifying, as a result of which resistances up to 0·25 MΩ are available to close tolerances. Plessey showed a number of resistive controls, including moulded-track and sub-miniature types, the latter being suitable for deaf aids, etc. Precision potentiometers for servo and measuring equipment were shown by Salford Electrical Instruments, and a new range of silvered-mica capacitors (type C.154, 5 pF – 0·25 μF to close tolerances) by Johnson, Matthey. A relay by Ericsson Telephones had the exceptionally high sensitivity of 12 gm contact pressure for less than 1 mW.

Londex coaxial relay.

Among the relays shown by Londex were coaxial types for controlling v.h.f. circuits. The same firm demonstrated a new type of constant-speed d.c. motor consuming only ¼ W. It employs a vibrating reed as the speed-determining device, flexibly coupled to the rotor, and is suitable for such duties as automatic radio signalling. A range of f.h.p. motors for servo mechanisms was shown by Evershed and Vignoles.

Among the new Ediswan valves were a number of types designed to avoid dollar imports. The ESU.77 is a high-vacuum rectifier with thoriated filament and tantalum anode, rated at 1·1 A peak anode current and 40 kV p.i.v. Some new thermal-delay switches of reduced size were included. A particularly interesting development is the cold-cathode decimal scaling valve, represented by the Ericsson Dekatron and the Standard Telephones Nomotron. Another interesting development, by Ferranti, is the substitution of ceramic for glass in certain valves. This material can be run at a higher temperature and has lower r.f. losses. The valves are for use in the 1,000-Mc/s band, and the running temperature is 200°C.

Research and development in the germanium rectifier field was evident on the stands of B.T-H., G.E.C., Marconi, Standard Telephones, and Westinghouse. Specimens of large whole crystals were shown, and examples of p-n interfaces. There were B.T-H. rectifiers of postage-stamp size with p.i.v. rating of 200 V and output 200 mA, representing a large saving in space and power. Besides a considerable range of germanium rectifiers, Westinghouse showed a new high-back-resistance selenium type ($< 1\,\mu$A at -20 V), and the well-known 16HT and 36EHT types hermetically sealed. Germanium triodes are still in the development stages, but as a matter of interest Standard Telephones demonstrated a gramophone amplifier with loudspeaker reproduction, using no other valves.



Philips h.f. voltmeter type GM.6006 covering 1 kc/s to 30 Mc/s.

Meters and Amplifiers

It is difficult to separate these two classes of equipment. For example, the Philips GM.6006 voltmeter is essentially a stable wideband amplifier, with a net voltage gain of 500 over the frequency band 1–30,000 kc/s. It can be used separately. There are 12 voltage ranges, from 1 mV to 1 kV full-scale, selected by a piston attenuator in the input probe. A built-in oscillator is provided for calibration. A companion instrument for a.f. is the GM.6007, with full-scale readings from 0·1 to 300 V over 5 to 10,000 c/s, also employing a built-in amplifier. The latest example of multi-range equipment on the AVO stand was the 98-range CT.38 Multimeter, designed to fulfil inter-Service requirements. Another electronic meter in Service dress was the Electronic Instruments CT.54—a development of the well-known battery-operated Micovac. Among other additions it has a top range of 2,400 V d.c. Although the British Physical Laboratories model VM.6351 valve voltmeter reads down to 10 mV it uses no amplifier; the detector is of the leaky-grid type. The Inter Electron valve millivoltmeter, on the other hand, uses an amplifier which, after negative feedback, has a voltage gain of 500, effective from 20 c/s to 2 Mc/s, and the ranges are from 1 mV to 300 V. A valuable practical feature is that the 6-in. square meter face can be tilted to the most convenient angle for reading.

Micovac valve voltmeter.

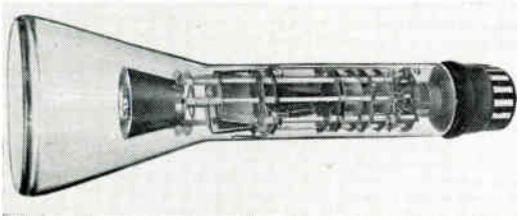
The Pye automatic pH meter was, perhaps, a pointer to the meter of the future. It has a servo-operated balance, using the Evershed motor already mentioned; and the place of the meter dial is taken by a counter which displays the reading in four figures. The d.c. amplifiers of Nagard are designed primarily for wide frequency range oscilloscopes; the beat-frequency type described last year now has a crystal frequency changer, to reduce noise. For the 0–10 Mc/s amplifier an input probe is available, containing a corrected cathode follower enabling rise times of the order of 0·01 μsec and amplitudes up to 100 V to be handled. A general-purpose amplifier was shown by Solartron, with a 15-W output from 50 c/s to 0·5 Mc/s, or a voltage output from 20 c/s to 3 Mc/s.

The Tinsley oil-filled shock-proof reflecting galvanometer appeared in an improved form, and Sullivan showed an entirely new portable galvanometer which it was claimed a 10,000% overload could not damage. It is obtainable either as a compact unit, or complete with lamp, scale, and Bloch optical magnifier giving the equivalent of a 1·5-m throw in a small box. Uniform in appearance with the Pye Scalamp galvanometer is a new electrostatic voltmeter, 5–18 kV, from 0–100 kc/s, covering present and prospective direct-viewing television e.h.t. voltages. The same firm showed a new type of amplifier operated by a galvanometer movement carrying a pair of differential coils in a uniform a.c. magnetic field. The voltage picked up is amplified and rectified with a phase-sensitive detector. The whole instrument is small, and full-scale reading is 4 μV.

Pye Scalamp electrostatic voltmeter.

Among other meters should be mentioned the 1½-in.

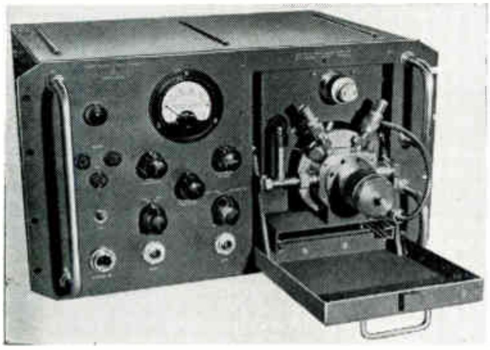
miniature moving-coil instruments, mains frequency meters using a synchronous-motor principle, and meters which can be set to close a contact at any desired deflection, without any mechanical obstruction of the pointer, the operation being photo-electric—all of these on the Pullen stand. A mains frequency meter employing two parallel a.c. bridges was shown by The Electrical Instrument Co., and the Sifam instruments included a totally-enclosed meter giving an audible signal when the current reaches a level set up by Braille touch. The range of 50-μA moving-coil instruments by Hivolt included e.h.t. meters from 15 to 50 kV using high-stability resistors.



20th Century Electronics polar co-ordinate c.r. tube.

Oscilloscopes and Recorders

A feature of the Show this year was the large number of data recorders. This is perhaps a slight reaction from the supremacy of cathode-ray equipment. For low speeds, mechanically-operated instruments are in general more convenient and economical. Considered in order of speed, there are, first, types which take time of the order of seconds to move from zero to full-scale, and are suitable for recording slow-changing levels over long periods. Of these, Sunvic showed a new example, servo operated, recording in ink on a wide paper roll. A very much smaller and simpler instrument by Standard Telephones, used for continuous recording of television radio-link signal strength, is capable of use with almost any pointer instrument, the record being made by spark as a black mark on inexpensive paper strip. The Evershed servo-operated recorder is capable of following frequencies up to 10 c/s. There were several examples in the moving-coil 50–100 c/s class: the Southern Instruments models, for which a 20-W amplifier is separately available, record with colourless fluid which leaves a black mark on treated paper and does not clog the pen; and the Ediswan and the Kelvin and Hughes types which both have a controlled ink system, the latter being particularly elaborate. The Ediswan recorder has one to four channels, and a suitable amplifier and stabilized power units are available. Finally, a very novel system used in the Ferranti recorder enables it to register complex waveforms with fundamentals up to 2,000 c/s. The record is made on Teledeltos paper by a 'comb' of 32 fixed styli, only one of which is energized at any one time, so that the record appears as a series of dots. The signal to be recorded is made to modulate the frequency of a carrier wave which is applied to a set of tuned circuits, each associated with a separate stylus. A visual indicator enables the amplitude of record to be adjusted without running off paper.



Wayne-Kerr test oscillator type XT108.

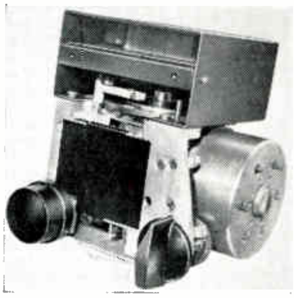
New developments in oscilloscopes have been directed mainly to the high-speed recording of transients. A new example, using a sanatron delay circuit, was shown by Langham Thompson, together with a seven-channel instrument using $1\frac{1}{2}$-in. tubes and arranged for photography of the traces. The delay circuit in the A. E. Cawkell high-speed oscilloscope is a phantastron. To increase the visibility of high-speed transients the Nagard L and M 103 models use post-deflection acceleration, as does also the Philips GM. 5653, an all-purpose instrument covering the wide band of 1 c/s to 7 Mc/s at 15 mV/cm. Another 'universal' oscillograph was that shown by Southern Instruments, with direct reading voltage calibration.

The post-deflection-acceleration tube used in the Nagard instrument is by 20th Century Electronics, who showed an example of their tubes made to special requirements—a polar co-ordinate c.r. tube, with conical deflector plates.

Allied Electronics peak-to-peak millivolter.

Oscillators and Signal Generators

At the lowest-frequency end, a useful little unit was shown by Allied Electronics. Strictly speaking it is not itself a generator, but an attenuator with metering circuit connected to the 50-c/s mains or other a.f. source for use as a voltage calibrator for amplifiers, oscilloscopes and the like, and variable from 100 μV to 100 V. On the same stand was a 5-c/s to 100-kc/s generator of square waves up to 100 V, having a rise time of 0·05 μsec. The supremacy of RC oscillators in the a.f. band was challenged by Wayne-Kerr and Industrial Electronics with beat-frequency models. Included among the examples of individualized instruments by Cawkell was a 10–10,000-c/s, oscillator designed for very high stability of amplitude, obtained by the use of a novel ambient-temperature-compensated thermistor. Also on this stand was a crystal-controlled decade frequency standard with built-in c.r.t. comparator and a receiver for checking accuracy against Droitwich 200 kc/s. Mullard showed an extremely high-stability crystal-controlled master oscillator with automatic frequency correction by Droitwich, suitable for the control of carrier waves in the band 0·5–1·5 Mc/s; and a local-oscillator unit for communications receivers, with a six-head coil turret covering 0·75–30 Mc/s, characterized by high stability, precise slow-motion drive, and a simple but very effective optical system for the frequency scale. The variable capacitor is the precision model shown last year.



Mullard local-oscillator assembly for communications receivers.

A television signal generator with a remarkably comprehensive specification was shown by Philips. Features include crystal control of sound and vision frequencies, 13 modulation patterns (obtainable separately or in combination) and built-in oscilloscope. For testing wideband networks, Elliott showed a pulsed signal generator, with pulse duration 0·1–0·5 μsec; carrier frequency up to 60 Mc/s. The waveform is visible on a built-in oscilloscope. In the same class, but employing a coaxial-line pulser, was the generator on the Atomic Energy Research Establishment stand.

Bridges and Standards

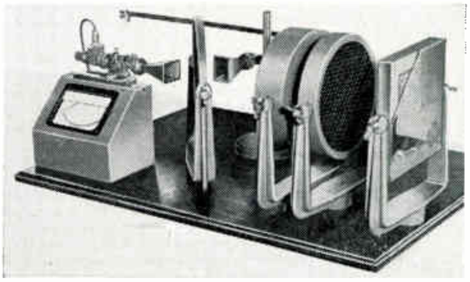
Most of these were of familiar types. A new general-purpose bridge was shown by Tinsley for measuring L, C, R, and Q with moderate precision over wide ranges. The a.c. source, a buzzer of special design for constant frequency and pure waveform, is built in. The Wayne-Kerr B.121 bridge is unusual among 50-c/s types in having six inductance ranges, from 20 mH upwards, as well as C and R ranges. The inductively-coupled ratio arms enable resistive and reactive parameters of paralleled components to be measured in situ. A direct-reading resistance tolerance bridge, covering 0·1 Ω to 1 MΩ, was shown by Doran. The Sifam Ohm-Master is a self-contained d.c. resistance bridge covering low resistances down to 0·001 Ω. In a new null system of voltage comparison, demonstrated by Pye, a high-speed (50 c/s) change-over switch connects the two voltages alternately to the input of an amplifier. The output, giving a reading proportional to the difference between the two voltages, enables them to be equalized very precisely.

Power Supplies and E.H.T. Test Gear

The automatic power-supply regulator previously shown by British Electric Resistance has now been improved, its dead-beatness being retained notwithstanding a higher speed of regulation. The supply requirements of klystrons are particularly exacting, and Airmec showed a stabilized unit (698B) for this duty, giving all the needed supplies, adjustable where necessary. A more elaborate source, using the Pound circuit for controlling supply voltage by klystron frequency error, was used by Marconi for their millimetre-wave demonstrations. The Hivolt stand was, as usual, devoted mainly to e.h.t. equipment, and included a 40-kV portable insulation tester for use by the Services. The r.f. coils used for units delivering from 3 to 22 kV are now of improved mechanical stability. The need for higher voltages for insulation testing has led to the latest Megger by Evershed and Vignoles—scaled up to 100,000 MΩ—being provided with a mains-driven unit giving up to 5 kV. The highest-voltage instrument shown was undoubtedly the N.P.L. attracted-disk voltmeter for absolute measurements up to 500 kV.

Microwave Apparatus

Apparatus in this group was very much to the fore this year. One of the most fascinating displays was that staged by Marconi, demonstrating properties of waves in the 9-mm band, especially the exploiting of polarization for duplexing (Common T and R), Doppler effect, and resolution of targets. Metal and dielectric lenses of various apertures and beam angles were also shown. Even shorter waves were demonstrated by Telecommunications Research Establishment with measurements of frequency and permittivity at 50 kMc/s (6 mm); also the Fabry-Perot interferometer. Another interesting demonstration was of an electronic attenuator by Ferranti, covering 0-50 db in the X band. It lends itself to automatic amplitude control systems. The calibration of attenuators was shown by Radar Research and Development Establishment in the 10-cm band and by Elliott in the 9-mm band. Both employed frequency-changer methods, but the latter was novel in reducing the extremely high r.f. to 220 *cycles* per second. This was done by using the signal source also as the local oscillator, the frequency difference being obtained by a mechanically-run phase changer. Waveguide test benches and various microwave techniques and equipment were shown by G.E.C., Metrovick, Standard Telephones, and Wayne-Kerr. The Standard Telephones exhibits included both laboratory and field equipment in the 7½-cm band used for the Manchester-Edinburgh television radio links. Progress in microwave technique was evidenced by the greatly increased precision claimed; for example, the commercially available S-band 0–40 db attenuator by Metrovick with a resetting accuracy of 0·01 db.

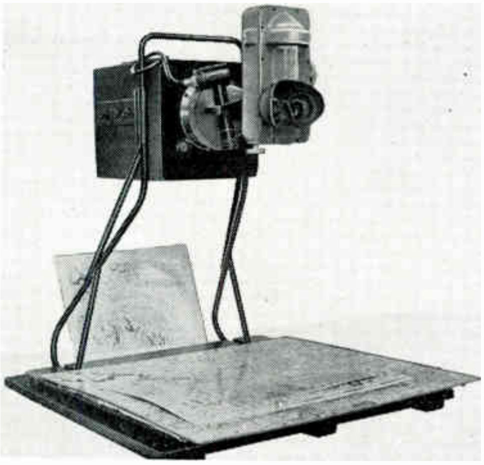


Marconi's Wireless Telegraph Co. duplexer for circular polarization.

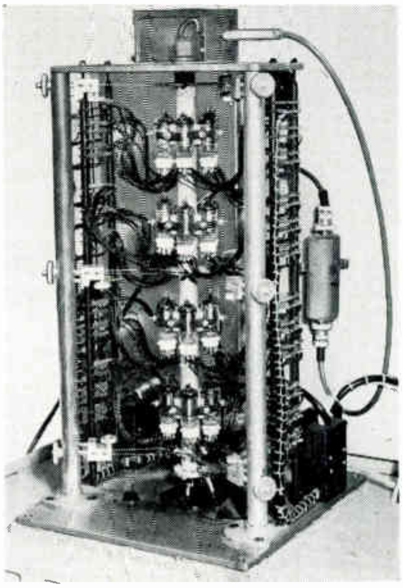
Miscellaneous Apparatus

Of the large amount and variety of counting and computing equipment shown there is space only to mention a few items. The binary scale remains the foundation of most of it, but the development of the cold-cathode decimal tubes already mentioned (Dekatron and Nomotron) facilitates the design of scale-of-ten equipment, examples of which were shown by Ericsson and Standard Telephones. The use of the magnetic drum for binary digit storage in the Manchester University computor has aroused interest in this method of storage. Among the T.R.E. exhibits were the type of 4-in. drum used in that machine, with a capacity of over 1,700,000 'bits', and a new 6-in. type rotated at 24,000 r.p.m. for extra-high-speed recording. A forerunner of the type of machine that may soon become normal laboratory equipment was seen on the Royal Aircraft Establishment stand: a general-purpose sequence-controlled digital relay calculator, made by Plessey.

Somewhat allied to computor technique was an interesting G.E.C. exhibit; a telemetering system for transmitting the readings of 10 meters over a single telegraph channel every four seconds. The readings were converted into a binary code of seven digits. Cold-cathode switching tubes were employed. A unit for automatically applying a sequence of 250 tests to Nomotron tubes was shown by Standard Telephones. The testing of servo mechanisms was demonstrated in a harmonic-response gear by Vickers-Armstrongs and a Nyquist-curve plotter by Plessey. Other interesting miscellaneous items were: a much simplified and more compact radar chart-comparison unit by Barr and Stroud; an electrolytic capacitor re-forming and testing equipment by Dawe; a demonstration of the use of Cinema-Television test-gear for examining filter characteristics; accelerated insulation-tracking tests by Admiralty Engineering Laboratory; a Nalder Bros. automatic earth-proving supply point, making it impossible for a portable tool to be energized unless the earth lead is intact; a relay-controlled unit for starting and stopping any ordinary stop-watch, by Allied Electronics; G.E.C. equipment for microscopic and oscillographic examination of valves while subjected to vibration of adjustable frequency and amplitude; and the Aviscope—a microscope employing the methods and equipment of television to obtain larger magnification of ordinary microscope specimens than by optical microscopes, combined with the flexibility of television screen presentation.



Barr & Stroud p.p.i. comparison unit.



General Electric valve vibration machine.

A normal 405-line raster is produced on a 'flying-spot scanning tube and is focused on the specimen in greatly reduced dimensions by a microscope type of optical system. The light from the specimen operates a photomultiplier tube and, after amplification, controls the brightness of the spot on the viewing tube, which can be of any size.

Research on cold-cathode tubes was demonstrated by R.A.E. with apparatus for the accurate measurement of diode characteristics, and by Birmingham University with apparatus for measuring de-ionization times in gas discharge gaps. On the latter stand one could also see a demonstration of magnetic flux density of the order of 10^6 gauss obtained by discharging an artificial line through a small solenoid. Another interesting research tool was that shown by Signals Research and Development Establishment: a magnetic field probe employing nuclear magnetic resonance in a small sample of water to give a resolving power better than five parts in 10^6 at 1,500 oersteds.

This establishment also showed an interesting development in magnetic technique. A mumetal core of E and I laminations in which the I-type are relatively few and widely spaced. The centre tongue of the E part of the core carries a winding which saturates the I part but not the E part. The I laminations carry individual windings and there is also a winding on an extension of the tongue of the E which encircles some only of the laminations. Current in these extra windings can unsaturate some of the I laminations by generating a bucking flux. It can, therefore, change the coupling between other coils wound on them; the device can thus operate as a switch. In addition, it can provide a 'memory' because of the remanence of the core material.

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.

Sharpness of Aerial Beam Cut-off

SIR,—The question of sharpness of beam cut-off below the half-power level and its variation with aerial aperture is frequently of importance. There does not, however, appear to have emerged, as yet, a simple formula connecting rate of cut-off (measured in db/degree) with the aerial aperture (measured in wavelengths), but it is possible to deduce one from fairly general considerations.

The method of Fourier Transforms enables us to calculate the radiation pattern resultant from any aperture field distribution.[1] It is well known that, in order to have a sharp beam, it is necessary for the phase to be uniform across the aperture, and we shall restrict ourselves to aperture field distributions of this character. The basis of sharpness of cut-off which we propose to employ is the angle required for the field distribution at infinity to fall from $1/\sqrt{2}$ of its value to $\frac{1}{10}$ of its peak value; i.e., for the gain to fall from $\frac{1}{2}$ to $\frac{1}{100}$ of its peak value. This is a drop of very nearly 17 db.

In Ref. 1 field distributions at infinity are given for a variety of different aperture distributions. In these the field distribution at infinity is plotted effectively against the quantity $q = (a \sin \theta)/\lambda$, where a is the total aperture and θ is the angular distance from the peak. As θ is small, we replace $\sin \theta$ by θ.

Now as we are not looking for exact values, but merely for a fairly simple general formula, it will be sufficient for us to read off the relevant values of q from the graphs. The results are as follows, the field distribution being $\psi(y)$ over $-a/2 < y < a/2$.

TABLE

x indicates the drop of the most important side lobe below the maximum of the main beam.

	$\psi(y)$	q		Difference	x
		Half power	Hundredth power	(Δq)	(db)
A	1	0·45	0·90	0·45	13·3
B	$1 - 2\|y\|/a$	0·65	1·25	0·60	26·6
C	$\cos \pi y/a$	0·60	1·30	0·70	23·0
D	$\cos^2 \pi/a$	0·75	1·65	0·90	31·7
E	$\frac{1}{3}+\frac{2}{3}\cos^2 \pi y/a$	0·55	1·05	0·50	25·7

On inspection of the above table it is clear that the loss of 17 db occurs over a Δq varying from 0·45 to 0·90. Now A has a very high side lobe, and D, although it has very low side lobes, has a comparatively broad main beam. We consider therefore B, C and E. It is clear that an assumption of $\Delta q = 0{\cdot}60$ is not far from the truth (in fact it is still of the same order of magnitude as the values for A and D).

The rate of cut-off is therefore defined by the statement:

As $q (= a\theta/\lambda)$ alters by 0·60, the power drops 17 db, hence as θ alters by $0{\cdot}60\ \lambda/a$ the power drops 17 db, and as θ alters by $0{\cdot}035\ \lambda/a$ the power drops 1 db.

Now θ is measured in radians and so the mean power drop per degree is given by $(a/\lambda)\ \{1/(0{\cdot}035 \times 57{\cdot}3)\} = a/2\lambda$.

It can thus be shown that, for a reasonable aperture distribution, the sharpness of drop in gain as we move away from the maximum is given in db/degree by half the aperture width in wavelengths. Clearly this relation cannot be taken literally as, if very low side lobes are required, the drop will be somewhat less, and if a very narrow main beam is required the drop will be somewhat greater. This is, of course, related to the fact that it is impossible to get exactly any radiation pattern without an infinite aperture. Because of the fact that it is not possible to keep phase exactly constant across an aperture, the rate of drop will be somewhat less.

While this analysis is of an empirical character, the aperture distributions considered do not greatly differ from the usual practical distributions and it is hoped that the resulting formula will prove useful in microwave-aerial design.

This work was carried out while I was at the Admiralty Signal and Radar Establishment and is published by permission of the Board of Admiralty.

LL. G. CHAMBERS.

Military College of Science,
Shrivenham, Wilts.
19th February, 1952.

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EXHIBITION OF ELECTRONIC DEVICES

The seventh annual exhibition of electronic devices organized by the North-West Branch of the Institution of Electronics will be held from 15th-18th July at the College of Technology, Manchester. In addition to the commercial section there is to be a scientific and industrial research section.

Admission is by ticket obtainable from the Secretary, N-W. Branch, 17 Blackwater Street, Rochdale, Lancs., and the hours of admission will be 12-9 p.m., 15th July; 10 a.m.-9 p.m. 16th and 17th July and 10 a.m.-5 p.m. 18th July.

MECHANICAL HANDLING EXHIBITION

An exhibition and convention dealing with Mechanical Handling will be held in the Grand and National Halls, Olympia, London, W.4. It will be open from 10 a.m. to 6 p.m. from 4th to 14th June and admission to the public costs 2s. 6d.

I.E.E. MEETINGS

14th May. "A Phototelegraphy Transmitter-Receiver Utilizing Sub-Carrier Frequency Modulation," by R. O. Carter, M.Sc.(Eng.), and L. K. Wheeler, B.Sc.(Eng.).

15th May. Annual General Meeting.

These meetings will be held at the Institution, Savoy Place, London, W.C.2, and will commence at 5.30.

BRIT.I.R.E. MEETING

7th May. "An Aerial Analogue Computor—An 'Instantaneous' Radiation Pattern Tracer and 'Design Apparatus' for Directional Arrays," by W. Saraga, D.Phil., D. T. Hadley and F. Moss, B.Sc., to be held at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, at 6.30.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

ACOUSTICS AND AUDIO FREQUENCIES

534.231 + 621.396.671 1179

The Representation of the Radiation Field of Two Radiators by means of Constant-Phase and Constant-Amplitude Curves.—Stenzel. (See 1201.)

534.231 : 534.121.1 1180

Effects of a Finite Circular Baffle Board on Acoustic Radiation.—T. Nimura & Y. Watanabe. (*Technol. Rep. Tohoku Univ.*, 1950, Vol. 14, No. 2, pp. 79–93.) Analysis of the field of a circular disk vibrating in a finite concentric circular baffle indicates that a baffle radius of about half the wavelength of the lowest frequency to be used gives a power increase almost equal to that for an infinite baffle. Experimental and theoretical results are in good agreement.

534.26 1181

Diffraction of Sound Waves at an Uneven Surface.—L. M. Brekhovskikh. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1951, Vol. 79, No. 4, pp. 585–588. In Russian.)

534.321.9 : 534.232 1182

Ultrasonic Generators and their Applications.—M. Alixant. (*Radio tech. Dig., Édn franç.*, 1951, Vol. 5, Nos. 5 & 6, pp. 271–278 & 299–325.) A survey paper with 165 references.

534.321.9 : 538.652 1183

Factors in the Generation of Ultrasonic Oscillations by means of Ferromagnetic Sediments.—H. H. Rust & P. Pilz. (*Z. angew. Phys.*, Oct. 1951, Vol. 3, No. 10, pp. 379–382.) Volume-magnetostriction measurements on a series of powdered materials are shown graphically and discussed. A hollow sphere of material with length-magnetostriction properties gives large volume variations for a relatively small applied magnetic field.

534.7 1184

Neuropsychological Relations between Phonation and Hearing.—R. Husson. (*Ann. Télécommun.*, Oct. 1951, Vol. 6, No. 10, pp. 273–277.)

534.7 1185

[Audible] **Objective and Subjective Resonance Effects with Short Trains of Pulses.**—O. Sala. (*Frequenz*, Sept. 1951, Vol. 5, No. 9, pp. 250–258.)

534.76 1186

Auditory Perspective — A Study of the Biological Factors related to Directional Hearing.—H. G. Kobrak. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1951, Vol. 57, No. 4, pp. 328–335.) The physiological aspects of stereophonic hearing are discussed. Properties of the sound signal significant for location are examined, and the role of the central nervous system in integrating the binaural stimuli is described. The influence of experience and training is stressed.

534.78 1187

Audio Problems in Aircraft Communication.—I. H. Bowker. (*Tele-Tech*, Oct. 1951, Vol. 10, No. 10, pp. 41–43..90.) High external noise levels and large variations of air pressure are the two major factors in reducing speech intelligibility in aircraft. The effect of altitude on speech production, on hearing, and on microphone and earphone performance is discussed and the design of special types of equipment to minimize noise effects and to increase speech intelligibility is considered.

534.84 1188

Notes on some Problems of Room Acoustics.—S. Sawade. (*Elektrotech. Z.*, 5th May 1950, Vol. 71, No. 10, pp. 245–246.) Introduction of the concept of 'reverberation radius', i.e., the distance from an omnidirectional source at which the pressures due to direct and reflected sound are equal, enables simple rules to be applied to the arrangement of loudspeakers and microphones, in particular for avoiding acoustic feedback; it also facilitates understanding of the significance of the experimentally found optimum reverberation time.

534.844.1 : 621.396.615.11 1189

Equipment for Acoustic Measurements: Part 2 — A Portable Tone Source Developed for Use in Room Acoustics.—Mayo & Beadle. (See 1382.)

534.846 1190

Influence of Chandeliers on the Acoustics of Theatres and Concert Halls.—L. Villard. (*Bull. tech. Suisse romande*, 8th Sept. 1951, Vol. 77, No. 18, pp. 243–245.)

E*

The subject is discussed in connection with the rebuilding of the Grand Theatre at Geneva. Many halls with good acoustics have in the past been illuminated by chandeliers, which provide a substantial amount of nonselective sound absorption and also act as sound diffusers; their replacement by modern lighting fittings may have an adverse effect.

621.317 : 621.395.813 **1191**

A New Evaluation of the Transmission Quality of a Telephone System.—G. Fontanellaz. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Oct. 1951, Vol. 29, No. 10, pp. 384–390. In German and French.) The C.C.I.F. has introduced a new criterion, the 'equivalent attenuation for intelligibility'. This is explained, and subjective tests are described for determining its value. The old criterion, 'reference equivalent', which took account only of loudness, is shown to be inadequate.

621.395.625.3 **1192**

A New Method for Measurement of the Speed of Magnetic Tapes.—P. H. Werner. (*Tech. Mitt. schweiz. Telegr-TelephVerw.*, 1st Oct. 1951, Vol. 29, No. 10, pp. 390–392. In French.)

621.395.92.001.4 **1193**

Testing of Components of Hearing Aids.—F. Müller. (*Funk u. Ton*, Sept. 1951, Vol. 5, No. 9, pp. 466–473.) Short description of methods of testing microphones, amplifiers, earpieces and bone-conduction devices. From these measurements the overall characteristics of a hearing aid can be determined. See also 994 of April.

AERIALS AND TRANSMISSION LINES

621.3.018.78† : 621.315.212 **1194**

Distortion of a Signal Transmitted by a Perfectly Homogeneous Coaxial Line.—R. Cazenave. (*Câbles & Transmission, Paris*, Oct. 1951, Vol. 5, No. 4, pp. 279–314.) For frequencies up to about 10 kMc/s the telegraphy equation represents coaxial-line propagation sufficiently closely, provided the coefficients are treated as functions of frequency. By considering separately the front and tail end of the received signal, corresponding respectively to the highest and lowest frequencies transmitted, an approximate solution is obtained, the total signal duration and the front-end curves for unit-pulse, unit-step and rectangular-wave signals being determined in the absence of and for small values of the leakage conductance. A numerical example illustrates the practical application of the results; a comparison of the performance of 2·6/9·4 mm and 5/18 mm coaxial cables operating over long distances clearly shows the superiority of the latter.

621.392 **1195**

Survey of Radio-Frequency Transmission Lines and Wave Guides.—E. S. Winlund. (*Proc. Radio Cl. Amer.*, 1951, Vol. 28, No. 2, pp. 1–64. Editor's remarks, p. 65.) Material published during the period 1919–1936 is surveyed; the majority of the 684 references given deal with later publications, up to 1951.

621.392.26 **1196**

The Relative Power-Carrying Capacity of High-Frequency Waveguides.—H. M. Barlow. (*Proc. Instn elect. Engrs*, Part III, Jan. 1952, Vol. 99, No. 57, pp. 21–27.) An assessment is made of this capacity, within the limits of electrical breakdown, for the wave modes commonly used inside waveguides of rectangular or circular cross-section, or outside a solid wire. This shows that for hollow guides the H modes are inferior to the E modes and both compare unfavourably with the TEM wave of a parallel-strip transmission line and with the waves supported by the solid-wire surface guide. The latter is particularly suitable for millimetre wavelengths.

621.392.26 **1197**

Diaphragms in Waveguides.—H. H. Meinke. (*Fernmeldetech. Z.*, Oct. 1951, Vol. 4, No. 10, pp. 431–435.) The application and exact quantitative treatment of basic types of diaphragm are demonstrated by referring their measured characteristics to their equivalent electrical circuits.

621.392.26 : 621.317.329 **1198**

Determination of Aperture Parameters by Electrolytic-Tank Measurements.—S. B. Cohn. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 33.) Correction to paper noted in 725 of March.

621.392.26 : 621.396.67 **1199**

Radiation from an Aerial located inside a Rectangular Waveguide.—M. Jessel. (*C. R. Acad. Sci., Paris*, 8th Oct. 1951, Vol. 233, No. 15, pp. 783–785.) The field radiated in this case is found from that radiated by the same aerial in free space by considering the radiation from the electrical images of the aerial in the walls of the waveguide. Radiation from slots can be calculated similarly.

621.392.5 : 681.142 **1200**

Magnetostriction Storage Systems for a High-Speed Digital Computer.—R. Millership, R. C. Robbins & A. E. De Barr. (*Brit. J. appl. Phys.*, Oct. 1951, Vol. 2, No. 10, p. 304.) A 60-μs delay line of the type described in 2107 of 1951 (Bradburd) consists of a thin Ni or Ni-Fe tape about 30 cm long, terminated to suppress reflections and threaded through a transmitting coil near one end and a receiving coil near the other. The advantages of this type of delay line over the mercury type when used in a storage system are: (*a*) greater simplicity and ruggedness; (*b*) smaller insertion loss; (*c*) availability of output at any point along the delay line.

621.396.67 + 534.231 **1201**

The Representation of the Radiation Field of Two Radiators by means of Constant-Phase and Constant-Amplitude Curves.—H. Stenzel. (*Arch. elekt. Übertragung*, Oct. & Nov. 1951, Vol. 5, Nos. 10 & 11, pp. 447–454 & 517–526.) The radiation process is represented by two vectors whose locus diagrams are hyperbolic spirals, position on which corresponds to distance from the respective radiator. By displacing the resultant vector and taking the readings on the graduated spirals the required curves can be drawn directly, without interpolation. The points of special significance on the curves are (*a*) the zero-amplitude points, (*b*) the phase crossover points and (*c*) the amplitude crossover points. The corresponding coordinates are given respectively by (*a*) the points of intersection of the spirals, (*b*) the points of contact of the common tangents and (*c*) the feet of the common normals. A set of equations is given for finding these points, and values are tabulated.

621.396.67 **1202**

A Dipole with a Tuned Parasitic Radiator.—R. King. (*Proc. Instn elect. Engrs*, Part III, Jan. 1952, Vol. 99, No. 57, pp. 6–14.) A more accurate determination is made of the electric field, the front/back ratio and the input impedance of an aerial with a single parasitic radiator, using recently derived approximate second-order self and mutual impedances. Theoretical curves for the field and front/back ratio are compared with the experimental data of other investigators, the apparent disagreement being explained by failure to coordinate correctly the measured and computed quantities. A method is outlined in which the theoretical requirements are closely approached in the experimental arrangement; good agreement is obtained between theory and experiment for the electric field and front/back ratio.

621.396.67 **1203**

On the Theory of Antennae with Discontinuous Thickness.—S. Uda & Y. Mushiake. (*Technol. Rep. Tohoku Univ.*, 1950, Vol. 14, No. 2, pp. 105–116.) Hallén's theory is extended to aerials with thickness discontinuities, such as a telescopic dipole, and approximate formulae for input impedance are derived. Experimental results showed qualitative agreement with theory.

621.396.67 **1204**

An Experimental Investigation of the Dielectric-Rod Antenna of Circular Cross-Section excited in the Dominant Mode.—C. W. Horton & C. M. McKinney, Jr. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1246–1249.) The radiation pattern and gain were measured at 9·275 kMc/s for four series of dielectric aerials of circular cross-section, constructed of polystyrene or lucite. Only one parameter in the rod geometry was varied in each series of measurements. The optimum working conditions for dielectric-rod aerials are deduced.

621.396.67 **1205**

A Broadside Dielectric Antenna.—G. E. Mueller. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 71–75.) An aerial is described which uses the properties of a nonuniform dielectric transmission line to produce a broadside directive pattern. Simple array theory is developed for prediction of the main features of the radiation patterns.

621.396.67 : 621.392.43 **1206**

Automatic Impedance Matcher.—True. (See 1224.)

621.396.67 : 621.396.619.13 **1207**

High-Power F.M. Antenna Design.—M. B. Sleeper. (*FM-TV*, Oct. 1951, Vol. 11, No. 10, pp. 11–12.) Description of the modified doughnut-type aerial and feeder system at station WMIT, on Clingman's Peak, N.C. Adjustable stubs replaced the flat plates previously used for tuning. Heating elements were added to prevent icing.

621.396.67 : 621.397.6 **1208**

Television Broadcast Antennas.—J. E. Keister. (*Gen. elect. Rev.*, Oct. 1951, Vol. 54, No. 10, pp. 19–22.) A review of the transmitting aerial systems at present in use for television broadcasting. Omnidirectional horizontal radiation and impedance matching over a wide frequency range are the general requirements. The sidefire helical aerial is a convenient radiator at u.h.f.

621.396.67 : 621.397.6 **1209**

Television in Buenos Aires.—(*Rev. telegr. Electronica, Buenos Aires*, Sept. 1951, No. 468, pp. 623, 636.) An account of the erection of the aerial system, which consists of eight symmetrical elements mounted one above the other at the top of a 50-m lattice mast, each element comprising three horizontal folded dipoles.

621.396.67.012.71 : 517.512.2 : 621.39.001.11 **1210**

Fourier Analysis and Negative Frequencies.—Shaw. (See 1422.)

621.396.677 **1211**

A Method for Calculating the Current Distribution of Tschebyscheff Arrays.—D. Barbiere. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 78–82.) The computation of the expressions for the current elements is reduced by a simplification, with no loss of exactness, of Dolph's equations for the optimum current distribution for a linear equispaced broadside array (2487 of 1946 and 2685 of 1947). A computation table for a 24-element array is given.

621.396.677 **1212**

Directional Antenna Arrays of Elements Circularly disposed about a Cylinder Reflector.—R. F. Harrington & W. R. LePage. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 83–86.) 1951 I.R.E. National Convention paper. "The general solution for the field pattern of a circular array is adapted to include the effect of a concentric reflecting cylinder. Two solutions are presented, one giving the field as a Fourier series, and the other as an infinite series of Bessel functions. The results are general, being applicable to any array dimensions and for arbitrary distribution of excitation. The solution is idealized to the extent of assuming a continuous current sheet, rather than discrete elements, and an infinitely long cylindrical reflector."

621.396.677.5 **1213**

Calculation of the Radiation Distribution for a Rhombic Aerial with Arbitrary Termination Impedance.—E. G. Hoffmann. (*Funk u. Ton*, Oct. 1951, Vol. 5, No. 10, pp. 518–525.) Calculation of the current distribution is based on that for a lossless two-wire line. The vector potentials in each arm of the aerial are calculated, and the resultant distant-field strength deduced as a function of reflection coefficient. This coefficient may be equal to or less than unity and can be chosen to give two equal side lobes of minimum amplitude. This is illustrated by a numerical example.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.015.7 : 621.387.4 **1214**

[Pulse] **Amplitude Selectors.**—R. Wahl. (*J. Phys. Radium*, Oct. 1951, Vol. 12, No. 8, pp. 67A–74A.) Selectors for one-channel, four-channel or ten-channel operation are obtained by using two, five or eleven identical selector units. Operation is independent of the shape, duration ($> 5 \times 10^{-8}$ sec) and time separation (> 12 μs) of pulses. Channel widths and threshold levels are adjustable.

621.3.018.78† : 621.396.619.16 : 621.392.52 **1215**

Pulse Distortion arising in F.M. Pulse Transmissions.—P. A. Mann. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 140–142.) The Dirac build-up function for an n-stage band-pass filter with critical coupling is expressed in terms of a Bessel function of order $(n - \frac{1}{2})$. From this the distortion of a unit pulse in passage through the filter can be evaluated. A 15-stage filter is taken as a numerical example, and graphs show that the time to reach the first maximum is practically independent of the frequency swing or of the phase linearity of the filter, but the tendency to overshoot is greater the greater the swing or filter nonlinearity.

621.314.2.012.3 **1216**

Transformer Iron Losses.—N. H. Crowhurst. (*Electronic Engng*, Oct. 1951, Vol. 23, No. 284, pp. 396–403.) Four charts are presented for application in a.f. transformer design. They are based on analysis of samples of ordinary-grade transformer iron and mumetal, and simplify the determination of all necessary design parameters.

621.314.6.011.1 **1217**

The Theory of the Linear R.M.S.-Value Rectifier.—O. Schmid. (*Arch. elekt. Übertragung*, Oct. 1951, Vol. 5, No. 10, pp. 459–463.) The operation of the circuit described by Boucke (687 of 1951) is analysed for inputs of any waveform. For alternating voltages that can be represented by algebraic functions a closed expression can be derived for the ratio of rectified voltage to peak voltage which is a function of the ratio of the charge and discharge time-constants. For inputs corresponding to transcendental functions the ratio rectified-voltage/peak-voltage is found by a graphical method. Curves are plotted from which the best time-constants ratio and the waveform errors of first and second type can be determined. See also 339 of February.

621.314.7 : 546.289 **1218**

Transistor Circuit Design.—G. Raisbeck. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 128–132, 134.) An explanation of the application of duality technique to the design of transistor amplifier, oscillator, modulator and multivibrator circuits, starting from the corresponding valve circuits.

621.316.86 **1219**

Nonlinear Resistors with Sintered-Semiconductor Base.—N'Guyen Thien-Chi & J. Suchet. (*Ann. Radioélect.*, Oct. 1951, Vol. 6, No. 26, pp. 291–298.) The resistors are made of a material with a sintered-carborundum base, have a low temperature coefficient of resistance and a voltage/current relation of the form $V = kI^{0 \cdot 2}$. Two types are available, type D (0·8-W rating) for operation at a few tens of volts and 1 mA current, and type H (15-W rating) at similar voltages and 100 mA current. They may be applied in the protection against breakdown of circuits containing mainly inductance, as shunts or multipliers in electrical instruments, and for voltage regulation.

621.318.435 : 621.3.015.3 **1220**

Transient Eddy-Current Phenomena of Saturable-Reactor Core.—T. Kikuchi. (*Technol. Rep. Tohoku Univ.*, 1950, Vol. 14, No. 2, pp. 94–104.)

621.318.572 : 621.385.8 .001.8 **1221**

Electron-Beam Switches.—F. Schröter. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 171–186.) A well illustrated review of various types and their applications.

621.319.4 **1222**

Capacitors with Ceramic Dielectric: Performance and Operating Characteristics.—A. Danzin. (*Onde élect.*, Aug./Sept. & Oct. 1951, Vol. 31, Nos. 293/294 & 295, pp. 342–356 & 406–412.) Detailed review based on official tests of capacitors for commercial and industrial use. Two groups are distinguished: (*a*) stable, with normal permittivity; (*b*) ferroelectric. The forms of construction adopted for various applications, particularly in receivers and transmitters, are described with illustrations.

621.319.45 **1223**

Tantalytic Capacitors.—L. W. Foster. (*Gen. elect. Rev.*, Oct. 1951, Vol. 54, No. 10, pp. 30–38.) Description of electrolytic capacitors using tantalum-foil electrodes. A capacitance of approximately 25 μF/in.³ at 150-V d.c. rating is obtained. The Ta_2O_5 insulating film can operate at an electrical stress of over 19 000 V/mil. Tantalytic capacitors are considerably smaller than corresponding ones of other types.

621.392.43 : 621.396.67 **1224**

Automatic Impedance Matcher.—V. True. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 98–102.) Description of equipment for matching a 35-ft whip aerial to a 50-Ω coaxial feeder over the frequency range 2–18 Mc/s. Matching is performed by a cantilever network in which the capacitance of one branch of the network is adjusted by a servomechanism controlled by a circuit which determines the phase angle between feeder current and voltage; the capacitance of the other branch of the network is similarly controlled by a circuit which measures the total load impedance of the feeder. The s.w.r. in no case exceeds 1·25. With minor circuit changes, the equipment can be adapted for different frequency ranges, power levels, types of load, and feeder characteristic impedances.

621.392.5 **1225**

General Input-Output Relations for Linear Networks.—L. A. Zadeh. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 103.) Outline of a method of analysis based on resolution of signals into a set of elementary components by means of a certain relation, which replaces that used for the resolution of signals into exponential components when using the Laplace or Fourier transform technique.

621.392.5 **1226**

Some General Theorems for Non-Linear Systems possessing Resistance.—W. Millar. (*Phil. Mag.*, Oct. 1951, Vol. 42, No. 333, pp. 1150–1160.) "In the case of a resistive network, the dissipation is divided into two parts—the 'content' and 'co-content'—which are duals of each other. The dissipation itself has stationary properties in linear but not (in general) in non-linear networks, but it can be shown that the 'content' and 'co-content' have stationary and additive properties in the non-linear case. The idea of 'content' is extended to reactive systems, and it is shown that the total content of any system in motion is an invariant." See also 1227 below.

621.392.5 **1227**

Some General Theorems for Non-Linear Systems possessing Reactance.—C. Cherry. (*Phil. Mag.*, Oct. 1951, Vol. 42, No. 333, pp. 1161–1177.) "The quantity called the co-energy (the dual of energy) is shown to possess stationary properties (maximum or minimum) and superposition properties; this is sufficient to establish the concept of an 'equivalent element' for any 2-terminal system of like elements (all-inductor, all-capacitor, all springs, etc.). The unfamiliar 'rectangle representation' of a circuit of linear resistors is explained and extended to the non-linear case, including reactive elements. It is shown that the equations of motion of a non-linear system, possessing reactance, may be expressed in Lagrangian form, thus emphasizing the importance of co-energy and also showing that the Principle of Duality is applicable. Finally, systems are considered possessing mutual inductance and moving magnetic circuits (as in rotating machines)." See also 1226 above.

621.392.5 **1228**

Conditions of Validity of Matrix Analysis for Quadripole Assemblies: Applications to Feedback Networks.—A. Kaufmann. (*Onde élect.*, Oct. & Nov. 1951, Vol. 31, Nos. 295 & 296, pp. 396–405 & 446–452.) The basic method of interconnecting two quadripoles so that they may be represented by a single matrix, and the representation of any 4-terminal network so that two matrices of order 2 are substituted for a matrix of order 3, are outlined. Impedance relations are derived which must be satisfied for the matrix calculation to be valid in the case of (*a*) parallel-parallel, (*b*) series-series, (*c*) series-parallel, and (*d*) parallel-series connection of input and output of two quadripoles. Particular examples of each case are noted. Different networks and their corresponding matrix relations are shown in a series of tables. The method is particularly useful for studying feedback networks; this is illustrated by examples.

621.392.5 : 519.241.1 **1229**

Note on "Correlation Functions and Power Spectra in Variable Networks".—B. D. Steinberg. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 103.) Extension of Zadeh's work (586 of 1951) to derive the correlation function of a system function in which the variables are separable. In this case the correlation function is the product of two others, relating respectively to the time-dependent and frequency-dependent parts of the system function.

621.392.5 : 517.755 1230

Hilbert Transforms and Bayard-Bode Relations.—F. H. Raymond. (*Ann. Télécommun.*, Oct. 1951, Vol. 6, No. 10, pp. 262–272.)

621.392.5 : 546.431.824-31 1231

Barium Titanate Delay Lines.—L. M. Orman & L. G. Callahan. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 224..248.) Mechanical vibration waves may be excited in $BaTiO_3$ ceramic by the application of an electric field, provided that the material between the electrodes has been previously polarized. The preparation of thin sheets of the substance for use in delay lines is outlined. Undesired reflections from the ends of the sheet may be damped out by coating the sheet with clay or paraffin wax.

621.392.5 : 771.4 1232

Electronic Delay System for Flash-Bulb Release.—J. P. Œhmichen. (*Toute la Radio*, June 1951, No. 156, pp. 151–153.) The flash bulb is operated by a thyratron energized from a cathode-coupled, double-triode 'flip-flop' circuit, the time constant of which is adjusted by a potentiometer with scale calibrated in seconds or microseconds.

621.392.5.029.64 1233

The Ferromagnetic Faraday Effect at Microwave Frequencies and its Applications — The Microwave Gyrator.—C. L. Hogan. (*Bell Syst. tech. J.*, Jan. 1952, Vol. 31, No. 1, pp. 1–31.) A new type of gyrator [see 301 of 1951 (Tellegen & Klauss)] dependent on the Faraday rotation of the plane of polarization of an e.m. wave has been developed. Analysis of wave propagation through a ferromagnetic material with dielectric and magnetic loss gives a formula for the Faraday rotation which indicates that in materials such as ferrites large rotations are to be expected and should be independent of frequency. Results of measurements on a MnZn ferrite, which gave a rotation of about 120°/cm, were in very good agreement with theory. Gyrators constitute low-loss wide-band devices with many possible applications, including one-way transmission systems, microwave circulators, microwave switches, electrically controlled variable attenuators, and modulators.

621.392.52 : 621.314.2 1234

The Transformer Properties of Choke Filters.—W. Taeger. (*Funk u. Ton*, Oct. 1951, Vol. 5, No. 10, pp. 526–535.) Certain low-pass arrangements, in particular choke filters, function near the resonance point very much like transformers. The ratio M/R (where M is the ratio of output voltage to input current on open circuit and R the actual load resistance) represents the transformation ratio u of the general quadripole and nearly corresponds to the mutual inductance of a transformer on open circuit. The ratio of output to input voltage of the choke filter, assuming losses are small, is u, the ratio of output to input current being $1/u$, but the phase difference between output and input voltages is only 90°. Doherty's modulation circuit makes use of the transformer properties of choke filters.

621.392.52 : 621.396.611.21 1235

The Maximum Bandwidth of Narrow-Band Quartz-Lattice Filters.—W. Rave. (*Arch. elekt. Übertragung*, Oct. 1951, Vol. 5, No. 10, pp. 455–458.) In filters comprising capacitors and crystals only, the highest attainable bandwidth depends almost entirely on the properties of the crystals. Numerical calculations are made for X-cut (frequency range 50–300 kc/s), AT-cut (frequency range 300 kc/s–6 Mc/s) and BT-cut crystals (frequencies over 6 Mc/s). The highest value of relative bandwidth, obtained at 50 kc/s, is 0·4%. Between about 800 kc/s and 6 Mc/s the bandwidth is $<$ 0·25%; above 6 Mc/s and at 300 kc/s the value is $<$ 0·125%. By including inductances in all the lattice arms the bandwidth can be increased to about 10%.

621.392.52.012.3 1236

Calculation Aids and Simple Formulae for the Approximate Determination of the Parameters of Two-Stage Band-Pass Filters.—E. William. (*Funk u. Ton*, Oct. 1951, Vol. 5, No. 10, pp. 545–554.) Tables and charts, developed from approximation equations, are presented from which the required data can be read off to within about 1%.

621.392.54† 1237

U.H.F. Oscillator Attenuator.—F. Reggia. (*FM-TV*, Oct. 1951, Vol. 11, No. 10, pp. 16–17, 23.) The construction, performance and applications are described of a linear attenuator in which an external magnetic field is used to alter the loss characteristics of a microwave-energy-dissipating material in a transmission line. An attenuator using similar principles has been described by Miller (337 of 1950).

621.395.645 : 621.395.97 1238

The Broadcasting-Network Amplifier Rack, Type 48, of the German Post Office.—E. A. Pavel, H. v. Schau & W. Schwenn. (*Fernmeldetech. Z.*, Oct. 1951, Vol. 4, No. 10, pp. 452–457.) Description of the high-fidelity line equipment for programme transmission on four incoming or outgoing lines.

621.396.611.21 1239

Quartz Crystal Vibrators as Circuit Elements.—H. E. Pearson. (*P.O. elect. Engrs' J.*, Oct. 1951, Vol. 44, Part 3, pp. 124–126.) Factors to be considered in the manufacture of quartz vibrators are discussed and values are given for the equivalent-circuit and other important parameters of types made by the British Post Office for operation in the range 1 kc/s–40 Mc/s.

621.396.611.3 1240

An Analysis of Triple-Tuned Coupled Circuits.—N. W. Mather. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 82.) Correction to paper abstracted in 2745 of 1950.

621.396.611.3.011.21 1241

Input-Admittance Characteristics of a Tuned Coupled Circuit.—R. A. Martin & R. D. Teasdale. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 57–61.) A steady-state analysis for a high-Q primary and low-Q secondary, with emphasis on the phase variation of admittance with frequency. Dimensionless curves of magnitude and phase illustrate the effect of varying the coupling and Q of the secondary.

621.396.611.4 1242

Representation of the Complete System of Natural Oscillations of Cylindrical Cavity Resonators with Horizontally Stratified Dielectric.—E. Ledinegg & P. Urban. (*Acta phys. austriaca*, March 1950, Vol. 3, No. 4, pp. 320–341.) Results previously obtained by Ledinegg (4 of 1943) for cavities with homogeneous dielectric are shown to be valid also when the dielectric is stratified parallel to the base of the cylinder. Explicit expressions are derived for the possible field distributions. The calculation is made first for a 'smooth' layer structure and is extended to incompletely smooth structures. Resonators of this type are of interest in measurement technique.

621.396.611.4 : 538.566 **1243**

Effect of Deformation of a Cylindrical Cavity Resonator on the Wave Numbers of the E_{010} and E_{011} Modes.—R. Müller. (*Z. Naturf.*, June 1950, Vol. 5a, No. 6, pp. 332–334.) The magnitude of the effect is calculated and its significance in relation to Essen & Gordon-Smith's measurements of the propagation velocity of e.m. waves (3488 of 1948) is discussed.

621.396.615.17 **1244**

Cathode-Coupled Pulse Generator.—F. A. Benson & G. V. G. Lusher. (*Wireless Engr*, Jan., 1952, Vol. 29, No. 340, pp. 12–14.) Positive pulses of amplitude about 30 V, duration about 1 μs and rise time slightly less than 0·5 μs are derived from a square-wave input by means of a flip-flop arrangement incorporating a highly damped oscillatory circuit.

621.396.645 **1245**

Review of British Amplifiers: Part 1 — General Constructional and Design Practises in the Better Amplifiers. Discussion of the Acoustical Amplifier.—J. Moir. (*FM-TV*, Oct. 1951, Vol. 11, No. 10, pp. 30–32, 40.)

621.396.645 **1246**

New Miniature Intermediate-Frequency Amplifier.—(*Tech. Bull. nat. Bur. Stand.*, Oct. 1951, Vol. 35, No. 10, pp. 143–145.) Description of the National Bureau of Standards Model VI, a 7-valve amplifier for the frequency range 20–100 Mc/s; construction is simplified by providing separate subassemblies for (*a*) all the inductors, (*b*) all the capacitors and (*c*) all the valve shields.

621.396.645 **1247**

The Series Amplifier.—E. L. Crosby, Jr. (*Radio & Televis. News, Radio-Electronic Engng Section*, Oct. 1951, Vol. 46, No. 4, pp. 12–13, 30.) Various amplifier units can be much reduced in size by the connection of valves in series. The anode of the first valve is connected through its load to the cathode of the second, and so on. Coupling capacitors and also the decoupling elements can then be omitted.

621.396.645.018.424 : 621.317.792 **1248**

Wideband Pre-Amplifier.—F. Horner. (*Wireless Engr*, Jan. 1952, Vol. 29, No. 340, pp. 19–26.) The amplifier was developed to increase the sensitivity of the aural-comparison method described by Thomas (169 of 1951). It is located at the aerial, away from the rest of the equipment, and operates unattended. Intermodulation between received signals is reduced by restricting the response to the required frequency band of 2·5–20 Mc/s, by careful design of the final cathode-follower stage and by making the voltage gain no greater than is necessary to achieve the desired sensitivity. The sensitivity is such that with a receiver of 10 kc/s bandwidth, and in the absence of atmospherics, a c.w. signal with a field strength of about 0·05 μV/m is intelligible in the presence of set noise only.

621.396.645.029.3 **1249**

A Tunable Shunt Selector-Rejector for Audio Amplifiers.—O. G. Villard, Jr. (*Rev. sci. Instrum.*, Oct. 1951, Vol. 22, No. 10, pp. 726–729.) Arrangements are described for adjusting the frequency response of an a.f. amplifier for experimental or other temporary purposes. An auxiliary valve with an appropriate RC feedback loop is shunted externally across the last voltage-amplifying valve of the amplifier. Design theory is discussed and illustrated by an example giving component values and measured performance.

621.396.645.029.3 **1250**

A Single-Ended Push-Pull Audio Amplifier.—A. Peterson & D. B. Sinclair. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 7–11.) 1951 I.R.E. National Convention paper. Describes a circuit which provides a direct output to a grounded load, and avoids the need for close magnetic coupling between the halves of the primary of an output transformer. Practical circuits and the application of negative feedback are discussed.

621.396.645.211 : 621.385.3 **1251**

High-Frequency Characteristics of Resistance-Coupled Triode Amplifiers.—J. W. Sauber. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 48–49.) A semi-graphical method of calculating the steady-state h.f. response, taking account of interelectrode capacitances.

621.396.645.35 **1252**

The Automatic Compensation of Zero-Drift Errors in Direct-Coupled Feedback Systems.—R. G. Lex : F. A. Summerlin. (*Proc. Instn elect. Engrs*, Part II, Oct. 1951, Vol. 98, No. 65, pp. 641–642.) Discussion on 1867 of 1951 and author's reply.

621.396.822 **1253**

Note on Resistance Fluctuations and the Flicker Effect.—M. Surdin. (*Physica, 's Grav.*, May 1951, Vol. 17, No. 5, pp. 548–550. In French.) Published experimental results on resistance fluctuations and flicker effect are reviewed. Macfarlane's theory (4087 of 1947) that flicker effect is due to fluctuations of potential barrier is shown to be compatible with van der Ziel's theory (3035 of 1950) that in oxide cathodes the effect is due to fluctuations of conductivity of the oxide layer, the mechanism involved being identical with that responsible for resistance fluctuations.

621.318.4 **1254**

Bauelemente der Nachrichtentechnik. Teil 3: Spulen. [Book Review]—H. Nottebrock. Publishers: Schiele & Schön, Berlin, 1950, 264 pp., 12 DM. (*Arch. elekt. Übertragung*, Oct. 1951, Vol. 5, No. 10, p. 485.) Gives practical information on coils (including transformers) for telecommunication applications.

621.396.615 **1255**

Theory and Design of Valve Oscillators. [Book Review]—H. A. Thomas. Publishers: Chapman & Hall, London, 2nd edn, 317 pp., 36s. (*Electrician*, 19th Oct. 1951, Vol. 147, No. 3827, p. 1207.) Five additional chapters have been included on u.h.f., v.m., RC, crystal, and magnetron oscillators, and a certain amount of rearrangement of the original important matter on frequency stabilization has taken place.

GENERAL PHYSICS

519.24 **1256**

The Best Method of Correcting for the Uncertainty involved in the Discrete, Discontinuous Nature of the Data in the Analysis of an Experiment.—P. Vernotte. (*C. R. Acad. Sci., Paris*, 1st Oct. 1951, Vol. 233, No. 14, pp. 735–736.)

534.111 **1257**

The Alternating-Current-Maintained Pendulum.—N. Minorsky. (*C. R. Acad. Sci., Paris*, 1st Oct. 1951, Vol. 233, No. 14, pp. 728–729.) The differential equations are developed and solved for the system comprising a pendulum carrying a piece of iron in the field of a coil carrying a.c. The excitation of the pendulum is of non-linear parametric type (1338 of 1951), no rational relation existing between the respective frequencies of the a.c. and the pendulum oscillations.

534.213.4 **1258**

Some Remarks on the Coupling of Two Ducts.—A. E. Heins. (*J. Math. Phys.*, Oct. 1951, Vol. 30, No. 3, pp. 164–169.) A mathematical treatment of the propagation of waves in two channels presenting different boundary conditions and coupled end to end.

535.361.2 **1259**

Scattering of Electromagnetic Waves from Two Concentric Spheres.—A. L. Aden & M. Kerker. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1242–1246.) "A solution is given for the problem of the scattering of plane electromagnetic waves from a sphere with a concentric spherical shell. The solution is general, and under appropriate conditions is reduced to the well-known solution for scattering from a single sphere."

535.37 + 537.311.33 **1260**

Radiationless Transitions of Electrons in Crystals.—F. Stöckmann. (*Z. Phys.*, 9th Oct. 1951, Vol. 130, No. 4, pp. 477–479.) A theory of radiationless transitions is advanced which depends on the fact that the effective radius of the Coulomb field of an impurity centre is equal to or greater than the free electron paths in valence crystals. Observations of luminescence and inhibition in phosphors and of conduction in semiconductors are adduced in support of the theory.

535.43 **1261**

Scattering of Plane Waves by Soft Obstacles: Part 2 — Scattering by Cylinders, Spheroids, and Disks.—E. W. Montroll & R. W. Hart. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1278–1289.) "Approximate closed-form analytical expressions are derived for the total and differential scattering cross-sections of cylindrical, prolate-spheroidal, and disk-shaped scatterers which subject scalar plane waves to only a small phase shift." Part 1: 2139 of 1951.

537/538 **1262**

General Solutions of the Equations of Electrostatics and Magnetostatics.—É. Durand. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1008–1010.) Solutions are derived directly from an identity which is the vector analogue of Green's scalar identity.

537.221 **1263**

Contact Potential Differences.—I. F. Patai & M. A. Pomerantz. (*J. Franklin Inst.*, Sept. 1951, Vol. 252, No. 3, pp. 239–260.) A historical survey of the subject, an outline of fundamental theoretical aspects of contact between metals, and a description of methods of measuring contact potentials. An extensive bibliography is given.

537.311.1 **1264**

On Electrostatic Plasma Oscillations in Metals.—J. A. Kok. (*Physica, 's Grav.*, May 1951, Vol. 17, No. 5, pp. 543–547.) Equations derived for plasma oscillations in a gas are applicable to conditions in metals, provided Fermi-Dirac rather than Maxwell statistics are used.

537.311.33 : 621.385.032.216 **1265**

***P-N* Transition of an Oxide-Coated Cathode.**—Ishikawa, Sato, Okumura & Saski. (See 1472.)

537.311.37 **1266**

A General Formula for the Conductivity of a Gas containing Free Electrons.—L. G. H. Huxley. (*Proc. phys. Soc.*, 1st Oct. 1951, Vol. 64, No. 382B, pp. 844–861.) Electron drift in gases is discussed in terms of the method of free paths, for constant and alternating electric fields with and without applied magnetic field; free-path distortion due to the electric field is taken into account. Formulae are derived for the drift velocity of the centroid of the electron group; the current density and gas conductivity are found directly from the drift velocity. The formulae are relevant to the theory of conduction in metals and semiconductors, the Hall effect and wave propagation in the ionosphere.

537.56 : 537.525 **1267**

Energy Losses of Charged Particles in a Very Strongly Ionized Medium (Ionic Plasma).—B. Kwal. (*J. Phys. Radium*, Oct. 1951, Vol. 12, No. 8, pp. 805–810.) Theoretical discussion of processes in electronic discharges in gases; conditions are probably similar in a large part of interstellar space.

537.58 **1268**

Thermal Ion Source for Negative Ions.—H. Hintenberger. (*Helv. phys. Acta*, 20th Sept. 1951, Vol. 24, No. 4, pp. 307–309. In German.)

537.581-13 : 537.566 **1269**

The Ionization in the Incandescent Gases of Jet-Propulsion Mechanisms.—C. Klein. (*Ann. Télécommun.*, Oct. 1951, Vol. 6, No. 10, pp. 287–298.) Anomalies observed in the guiding by radio of rockets with their engines working are attributed to thermal ionization of the incandescent gases ejected. The mechanism of this ionization and its influence on the propagation of radio waves is investigated. As in the case of the ionosphere, the electron concentration N and the mean collision frequency determine the course of the phenomenon. The method used by Eggert & Saha in 1920 for calculating N for stellar atmospheres is applied; values obtained are consistent with u.s.w. reflection but are very different from Goercke's experimental results (657 of March). Physico-chemical study of the combustion process shows that in most cases Saha's formula is inapplicable because thermal equilibrium is not attained; calculation based on Saenger's theory that ionization is due to molecular collisions prior to the establishment of equilibrium leads to results in better agreement.

538.12 + 538.65 **1270**

The Force and Torque acting on Magnetized Bodies in a Magnetic Field.—W. Döring. (*Ann. Phys., Lpz.*, 15th Oct. 1951, Vol. 9, Nos. 6/7, pp. 363–372.)

538.12 + 538.65 **1271**

Magnetic Field and Torque for a Magnetic Ellipsoid in a Permeable Medium and an External Field.—H. Diesselhorst. (*Ann. Phys., Lpz.*, 15th Oct. 1951, Vol. 9, Nos. 6/7, pp. 316–324.)

538.221 **1272**

The Mechanism of Discontinuities in Magnetization.—T. Hofbauer & K. M. Koch. (*Z. Phys.*, 9th Oct. 1951, Vol. 130, No. 4, pp. 409–414.) The effect of superposing on a main a.c. magnetizing field an auxiliary field of higher frequency is investigated experimentally. For a given value of the main magnetizing field the effect of the auxiliary field is to increase the value of saturation magnetization and remanence. The effect is related to that produced by h.f. biasing in magnetic sound recording.

538.221 **1273**

The Study of Ferromagnetic Resonance using the Complex-Permeability Diagram.—B. Pistoulet. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1015–1017.)

538.566 **1274**

Wave Packets, the Poynting Vector, and Energy Flow: Part 4 — Poynting and Macdonald Velocities in Dissipative Anisotropic Media.—C. O. Hines. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 535–544.) It is found preferable to replace the Poynting vector by Macdonald's to obtain physically suitable results, but even then the direction obtained for the energy flow differs from that found by wave-packet methods, which probably give the better results. Part 3: 2697 of 1951.

538.613 **1275**

Correlation of the Faraday and Kerr Magneto-optical Effects in Transmission-Line Terms.—C. H. Luhrs. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 76–78.) The Faraday effect is derived from phase considerations and the Kerr effect from impedance considerations.

530.145 **1276**

Quantum Mechanics of Particles and Wave Fields. [Book Review]—A. March. Publishers: J. Wiley & Sons, New York, 1951, 292 pp., $5.50. (*J. Franklin Inst.*, Sept. 1951, Vol. 252, No. 3, p. 270.) "The book provides a text which may help clarify the latest conceptions and mathematical formalism of the theory of fields and particles."

538 **1277**

Modern Magnetism. [Book Review]—L. F. Bates. Publishers: Cambridge University Press, London, 3rd edn, 506 pp., 30s. (*Electrician*, 19th Oct. 1951, Vol. 147, No. 3827, pp. 1207–1208.) "Much fresh material is incorporated, including new h.f. techniques developed during the last war and the very striking elaborations of the domain concept resulting from important work in America, England and France, and their bearing on the interpretation of the hysteresis cycle."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523 : 621.396.822 **1278**

Radio Waves and Astronomy.—H. H. Klinger. (*Funk u. Ton*, Sept. 1951, Vol. 5, No. 9, pp. 474–485.) An outline of the methods of radio astronomy and discussion of the r.f. radiation from the sun, the galaxy and extragalactic sources.

523.72 + 523.854] : 621.396.822 **1279**

New Data on the Radiation of Electromagnetic Waves from the Sun and the Galaxy.—G. G. Getmantsev. (*Uspekhi fiz. Nauk*, Aug. 1951, Vol. 44, No. 4, pp. 527–557.) A review of recent publications on the subject, including many Russian papers.

523.746 "1951.07/.09" **1280**

Provisional Sunspot-Numbers for July to September, 1951.—M. Waldmeier. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, p. 604; *Z. Met.*, Nov. 1951, Vol. 5, No. 11, p. 349.)

523.755 **1281**

A New Radio Method for Measuring the Electron Density in the Solar Corona.—K. E. Machin & F. G. Smith. (*Nature, Lond.*, 6th Oct. 1951, Vol. 168, No. 4275, pp. 599–600.) The suggested method uses the 'occultation' of the radiation from radio stars situated in directions near that of the sun. The solar radiation is prevented from masking the weaker radiation from the star by using an aerial system insensitive to sources subtending a comparatively large angle. The determination of the effective radius of the sun for this effect at a number of radio frequencies would allow the distribution of electron density with height to be deduced, for densities as low as 10^4 cm^3. Tests at frequencies of 210, 81·5 and 38 Mc/s, carried out during a period of abnormal sunspot radiation, gave no useful results. Aerials of greater resolving power will be used in future experiments.

523.78 **1282**

Observation of the Annular Eclipse of the Sun, 1st September 1951.—F. Bosson, É. J. Blum, J. F. Denisse, É. Leroux & J. L. Steinberg. (*C. R. Acad. Sci., Paris*, 22nd Oct. 1951, Vol. 233, No. 17, pp. 917–919.) Measurements are reported of the intensity of radiation on wavelengths of 3·12 and 178 cm received during the eclipse at a location close to Markala in the French Sudan. The observations on 3·12 cm confirm that the sun's radiation is more intense at the limb. The apparent diameter corresponding to radiation on 178 cm is 1·4 times the apparent optical diameter, and the coronal radiation on that wavelength constitutes half the total radiation.

523.8 : 621.396.822] : 522.92 **1283**

A Diffraction Theory of the Scintillation of Stars on Optical and Radio Wavelengths.—C. G. Little. (*Mon. Not. R. astr. Soc.*, 1951, Vol. 111, No. 3, pp. 289–302.) The refraction theory of scintillation at optical wavelengths requires excessive atmospheric density gradients, and fails to explain the observed scintillation in colour; also the physiological explanations are insufficient to explain all the observations. The effects may be explained by Fresnel diffraction at a nonhomogeneous atmospheric layer; this theory requires much smaller density gradients. A similar theory explains the observed intensity fluctuations of radio waves from discrete extraterrestrial sources.

523.8 : 621.396.822] : 535.42 **1284**

The Diffraction of Radio Waves in Passing through a Phase-changing Ionosphere.—A. Hewish. (*Proc. roy. Soc. A*, 8th Oct. 1951, Vol. 209, No. 1096, pp. 81–96.) Discussion of the diffraction by the ionosphere of waves from radio stars, and the resultant field at the earth's surface. It is assumed that the wave emerges from the ionosphere with constant amplitude but with lateral variations of phase. The cases of simple sinusoidal variation and random variation of phase are considered. Knowledge of the amplitude and phase variations at the ground enables the average magnitude of the phase deviations produced by the ionosphere, and their lateral extent, to be calculated. Comparison of results on different wavelengths enables an estimate to be made of the distance of the effective diffracting screen from the plane of observation. Experimental results indicate that the ionospheric irregularities have a lateral extent of the order of 5 km and cause phase deviations of 1 to 2 radians for radiation of wavelength 6·7 m.

523.852.32 : 621.396.822 **1285**

Radio Emission from the Andromeda Nebula.—R. H. Brown & C. Hazard. (*Mon. Not. R. astr. Soc.*, 1951, Vol. 111, No. 4, pp. 357–367.) Detailed account of work noted in 629 of 1951. The results indicate that extragalactic r.f. radiation accounts for about 1% of the total r.f. radiation reaching the earth.

550.38 "1951.04/.06" **1286**

International Data on Magnetic Disturbances, Second Quarter, 1951.—J. Bartels & J. Veldkamp. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 601–603.)

550.38 "1951.07/.09" **1287**

Cheltenham [Maryland] Three-Hour-Range Indices *K* for July to September, 1951.—R. R. Bodle. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, p. 604.)

550.385 "1951.04/.09" **1288**

Principal Magnetic Storms [April–Sept. 1951].—(*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 605–608.)

551.510.52 : 551.594.13 **1289**

Electrical Conductivity of Air in the Troposphere.—R. C. Callahan, S. C. Coroniti, A. J. Parziale & R. Patten. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 545–551.) Fair-weather measurements for widely separated areas in the U.S.A. indicate equality of positive-ion and negative-ion conductivity throughout the 35 000-ft altitude range investigated. The results are in agreement with those calculated from a formula based on Thomson's theory of volume recombination.

551.510.535 **1290**

The Absorption of Ultraviolet Solar Radiation and the Temperature of the Upper Atmosphere at a Height of about 100 Km.—J. Gauzit. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1048–1049.) The mean kinetic energy of oxygen atoms in the upper atmosphere at the instant of their creation by photodissociation corresponds to a high temperature which rises from 800°K to about 3 800°K between 90 and 130 km height.

551.510.535 **1291**

Some Phenomena of the Upper Atmosphere.—S. Chapman. (*Proc. phys. Soc.*, 1st Oct. 1951, Vol. 64, No. 382B, pp. 833–844.) A review of recent progress in knowledge of the height distribution of the temperature and constitution of the atmosphere, and of winds and tides in the upper atmosphere. Ionospheric phenomena observed near the magnetic equator are discussed, especially the abnormal intensification of electric current flow.

551.510.535 **1292**

A Quick Method for Analysing Ionospheric Records.—J. A. Ratcliffe. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 463–485.) A transparent scale carries families of calculated h'/f curves (h' is virtual height and f the frequency) for a series of values of layer thickness and critical frequency. Experimental h'/f records can then be matched with the calculated ones and the thickness parameters read on the scale. The method is applied to parabolic, linear, and square-root electron-distribution laws and provides a simple way of finding the total electron content in the F$_2$ region. Allowances for the effect of the F$_1$ layer are simply made.

551.510.535 **1293**

An Unusual Ionospheric Disturbance observed in Adélie Land.—M. Barré & K. Rawer. (*Ann. Géophys.*, Oct./Dec. 1950, Vol. 6, No. 4, pp. 309–317.) See 2997 of 1951.

551.510.535 **1294**

Some Regularities in the F$_2$ Region of the Ionosphere.—J. A. Ratcliffe. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 487–507.) Many of the anomalies of f_0F_2 values vanish when the total electron content per unit column (n) is considered instead. Records from Watheroo, Huancayo, and Alaska show that the value of n at noon is closely related to the sun's zenith angle over the whole range of values. The diurnal change in n does not show the 'bite-out' seen on f_0F_2 curves, and the change in n with magnetic dip shows no equatorial minimum.

551.510.535 **1295**

The Effective Midday Recombination Coefficient of the F$_2$ layer calculated from the Values of Critical Frequency observed during the Mögel-Dellinger Effect on 19th Nov. 1949.—W. Becker & W. Dieminger. (*Z. Naturf.*, June 1950, Vol. 5a, No. 6, pp. 308–311.) The value $1{\cdot}9 \times 10^{-10}$ is found as a lower limit; this is of the same order as previously published night-time values. The rate of production of charge carriers in the F$_2$ layer at the start of the disturbance was twice as great as normal.

551.510.535 : 537.56 **1296**

'Isanomalies' of F$_2$ Ionization.—O. Burkard. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 595–600. In German.) Discussion of the information which can be derived from sets of curves indicating places with corresponding F$_2$-layer variations.

551.510.535 : 551.557 **1297**

Winds in the Ionosphere.—(*Tech. Bull. nat. Bur. Stand.*, Dec. 1951, Vol. 35, No. 12, pp. 178–179.) A short explanation is given of the method of observation in which pulse signals from a central transmitter are received, after reflection from the ionosphere, at three stations located at the corners of a right-angled triangle. From records of the times at which fading of the signals occurs at the three stations, an estimate is made of the direction and speed of the ionospheric regions responsible for the fading pattern of the received signals. The N.B.S. transmitter at Sterling, Va., operates at 2·3 Mc/s and emits pulses of duration 0·2 ms, repetition rate 60/sec and peak power of 10 kW. Typical records of ionospheric wind velocities obtained at Sterling, Va., and at Cambridge, England, show close correlation, indicating that the ionospheric winds belong to a world-wide circulation system.

551.510.535 : 551.557 **1298**

Systematic Ionospheric Winds.—C. D. Salzberg & R. Greenstone. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 521–533.) Detailed account of the work referred to in 1297 above.

551.510.535 : 621.3.087.5 **1299**

Spot-Frequency Ionospheric Recording — A Combination of Sweep- and Fixed-Frequency Techniques.—H. W. Wells. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 613–615.) A panoramic recorder is used, but instead of photographing the complete h'/f trace, only three selected frequencies are recorded. The cycle is repeated at intervals of 25 sec and the photographic paper is moved on slightly after each frequency in the cycle. The resulting record is a combination of three h'/t records at different frequencies. Changes in structure with time are much more easily observed than on a series of full h'/f records.

551.510.535 : 621.396.11 **1300**

Contribution to the Study of the Electron Distribution in the Ionosphere and of the Absorption of Short Waves.—É. Argence, M. Mayot & K. Rawer. (*Ann. Géophys.*, Oct./Dec. 1950, Vol. 6, No. 4, pp. 242–285.) Based on a comprehensive survey of recently obtained data on the temperature distribution and the dissociation of O$_2$ in the atmosphere, a model for the D and E layers is proposed with parabolic distribution of temperature below 100 km and a rapid decrease of ionizable molecules above that height. The frequency variation of absorption due to collisions is investigated; approximate formulae are obtained assuming a stratified structure with parabolic distribution of μ^2 (where μ is the refractive index) for each layer and an exponential distribution of collision number. Special functions introduced in the theory are discussed and numerical values are tabulated.

551.510.535 : 621.396.11 **1301**

Group Velocities and Group Heights from the Magneto-ionic Theory.—Shinn & Whale. (See 1405.)

551.510.535 : 621.396.11 **1302**

Radio-Wave Propagation at Oblique Incidence including the Lorentz Polarization Term.—J. M. Kelso. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 87–97.) The true height of reflection, ray path, reflection coefficient, range and group path in the ionosphere, all of which depend only on the ionosphere, are first studied. Then, for both plane and curved-earth geometry, the ground range, group path, reflection coefficient as a function of ground range, and m.u.f. are examined. The ionosphere is considered as plane throughout the treatment, which has the following restrictions: all limitations on the use of the Chapman distribution hold; the earth's magnetic field is neglected; the angular operating frequency is assumed to be greater than the collision frequency; the absorption per vacuum wavelength is assumed to be small; ray theory is used.

551.594.21 **1303**

The Distribution of Electricity in Thunderclouds.—D. J. Malan & B. F. J. Schonland. (*Proc. roy. Soc. A*, 23rd Oct. 1951, Vol. 209, No. 1097, pp. 158–177.) Various independent methods of measuring the heights of origination of successive lightning strokes are discussed; the values obtained support the hypothesis of a columnar distribution of negative charge.

551.594.222 **1304**

Point-Discharge Currents and the Earth's Electric Field.—W. C. A. Hutchinson. (*Quart. J. R. met. Soc.*, Oct. 1951, Vol. 77, No. 334, pp. 627–632.) Measurements are reported of the current flowing to earth through a point set up at a height of 12 m, and of the electric field near the ground. Point-discharge current of either sign increases with the square of the field; the relation tends to direct proportionality for high values of field. The influence of local space charge on the field measurements is discussed.

551.594.6 **1305**

Recording of Atmospherics on board the *Commandant Charcot*, 1950-1951 Cruise.—R. Bureau & J. J. Vaury. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1049–1051.) The third antarctic cruise of the *Commandant Charcot* was followed by one across the Pacific, during which further centres of atmospherics were located. The apparatus was the same as that used on the second cruise [see 637 of 1951 (Bureau & Barré)]. The whole of the Pacific west of 120°W seems to be a diffuse source of atmospherics. A typical recording for a 24-hour period on 18th–19th April 1951 shows the approximately linear rise of the level of atmospherics starting at sunset. Maximum activity for the Pacific centres occurs at a later hour than for known continental centres, at 1 700–1 800 local time.

LOCATION AND AIDS TO NAVIGATION

621.396.9 **1306**

Radar Technique.—F. Michelssen. (*Frequenz*, Sept. 1951, Vol. 5, No. 9, pp. 258–259.) A brief historical note of developments in Germany during the prewar and early war periods.

621.396.9 : 621.396.822 **1307**

The Detection of Pulse Signals near the Noise Threshold.—R. E. Spencer. (*J. Brit. Instn Radio Engrs*, Oct. 1951, Vol. 11, No. 10, pp. 435–454.) Existing literature is surveyed, with emphasis on simpler and more intuitive physical considerations and their application to radar. The discussion is first in terms of a single pulse and then of repeated pulses. Matching the i.f. response to the frequency spectrum of the pulse is considered. The probability that the presence of a signal can be distinguished is shown to be independent of the detector law provided that it gives a monotonic increase of output with increased input. When signal and noise are of comparable magnitude, there is loss of performance if filtration is incorrectly distributed between the i.f. and video-frequency stages. Methods of presentation are discussed and the main practical conclusions are summarized.

621.396.93 : 621.396.812 **1308**

Disturbances caused by the Atmosphere in Aids to Navigation.—E. Vassy. (*Onde élect.*, Oct. 1951, Vol. 31, No. 295, pp. 379–383.) Sources of error in direction-finding systems are discussed generally, including the effects of tilts and asymmetry in the higher ionized layers, and of lateral refraction and diffuse reflection in the troposphere.

621.396.932.1/.2 **1309**

The Requirements for Radio Aids at Sea.—F. J. Wylie. (*J. Inst. Nav.*, Oct. 1951, Vol. 4, No. 4, pp. 327–344.) Radio aids to navigation are required as alternatives to astronomical and terrestrial fixing when these cannot be used, and the accuracy required is that obtained by the visual methods in good conditions. The extent to which shipborne and shore-based direction-finding equipment and loran, consol, Decca and radar systems satisfy the requirements is discussed. An account is given of the coverage obtained by existing systems, and possible lines of development are indicated.

621.396.932.1 **1310**

A New Shore-Based Radar Equipment.—E. Fennessy. (*J. Inst. Nav.*, Oct. 1951, Vol. 4, No. 4, pp. 345–350.) A general description of the Decca harbour radar equipment, its performance and applications. A method which has been developed for the radio transmission of information from the aerial and r.f. assembly to a remote display unit might be adapted to provide displays in vessels in the service area of the radar equipment.

621.396.933 **1311**

Hyperbolic Navigation Systems in Germany.—E. Roessler. (*Elektrotech. Z.*, 1st Oct. 1951, Vol. 72, No. 19, pp. 567–572.) Discussion of various systems, particularly Decca and its advantages over the single-frequency system. By a suitable linking of three hyperbola systems, both coarse and fine navigation facilities can be provided for an area greater than Germany, using only four frequencies.

621.396.933 **1312**

Long-Range Radar for Controlling Aircraft: Part 1—The Operation of London Radar.—D. W. Watkins. (*J. Inst. Nav.*, Oct. 1951, Vol. 4, No. 4, pp. 402–409. Discussion, pp. 413–414.) An account of early experiments, operational trials, the services at present available, with an outline of future developments. Part 2: 1313 below.

621.396.933 **1313**

Long-Range Radar for Controlling Aircraft: Part 2—Traffic Control at the Royal Aircraft Establishment.—G. G. Harris. (*J. Inst. Nav.*, Oct. 1951, Vol. 4, No. 4, pp. 409–413. Discussion, pp. 413–414.) Description of the radar control system at Farnborough, which is designed primarily for speed and flexibility. The approach control is the dominating control and extends in stages over the local or visual control as weather conditions deteriorate, providing talk-down facilities in the extreme case. Part 1: 1312 above.

621.396.933 **1314**

Radio Aids to Airways Navigation. The Australian Visual Aural Radio Range System.—H. White & F. B. Partridge. (*J. Instn Engrs Aust.*, Sept. 1951, Vol. 23, No. 9, pp. 167–181.) The basic aid adopted for use in Australia consists of a visual aural radio range (V.A.R.) in conjunction with distance-measuring equipment. The V.A.R., operating at about 120 Mc/s, is an adaptation of the American ρ–θ system (1158 of 1951) and provides four ranges, two with visual and two with aural presentation. A description is given of the general principles and ground equipment, and the radiation patterns are considered in detail. The airborne equipment is also described.

621.396.933 1315

Modern Radio Aids to Civil Aviation — The D.M.E. Project of the Department of Civil Aviation.—J. H. Gerrand. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1951, Vol. 12, No. 9, pp. 275–282.) "The history of the Australian D.M.E. project is reviewed and the main technical features of the equipment are briefly described. The choice of beacon sites is discussed together with the proposed programme of installation testing."

621.396.933(98) 1316

Radar as an Aid to Air Navigation in the Arctic.—K. R. Greenaway. (*J. Inst. Nav.*, Oct. 1951, Vol. 4, No. 4, pp. 399–401.) Summary of paper read at meeting of Canadian Institute of Navigation, Montreal, September 1950. The use of radar for the determination of drift and groundspeeds, and for pin-pointing, is discussed. The special difficulties encountered in the Arctic are considered. It is concluded that search radar ranks next in importance to astronomical navigation for flights in the Arctic.

MATERIALS AND SUBSIDIARY TECHNIQUES

534.321.9.001.8 : 621.315.615/.617 : 539.5 1317

Mechanical Properties of Polymers at Ultrasonic Frequencies.—W. P. Mason & H. J. McSkimin. (*Bell Syst. tech. J.*, Jan. 1952, Vol. 31, No. 1, pp. 122–171.) Different types of measurement methods are described for determining the reaction of polymer materials, in solid or liquid form or in solution, to longitudinal and shear waves over a wide range of frequencies. The relaxation frequencies are determined by a dispersion in the velocity, attenuation constants or characteristic impedance of the material. The various types of relaxation observed are explained by certain motions of the polymer chain or molecule which determine the toughness, impact strength and elasticity of the material.

535.37 1318

A Striking Difference in the Activation Susceptibility of Potassium- and Sodium-Halide Phosphors. — P. Pringsheim. (*Acta phys. austriaca*, March 1950, Vol. 3, No. 4, pp. 396–404.)

535.37 1319

Size Effects in the Luminescence of ZnS Phosphors.—G. C. Wallick. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, p. 375.) Thermoluminescence measurements for crystals of 9ZnS.CdS-Cu and ZnS-Ag were made by saturation excitation at −160°C followed by a uniform increase of temperature to 100°C at a rate of 2°/min. Evidence is given of many more shallow traps in small crystals (average diameter 5·5 μ) than in large ones (average diameter 14 μ). The decay of phosphorescence with time was, however, found to be essentially independent of crystal size.

535.371.07 1320

A Fluorescent Cadmium-Iodide Screen under the Influence of Visible and Ultraviolet Radiation, Cathode Rays, α Rays and X Rays.—S. Schlivitch. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1023–1024.) A strongly luminescent phosphor is prepared by mixing lead nitrate and cadmium iodide. When used in a c.r. tube, the screen is luminescent for voltages over 600 V, the spectrum being in the region where the eye is highly sensitive.

537.311.33 : 538.214 1321

Magnetism of Free Charge-Carriers in Semiconductors.—W. Känzig & N. Maikoff. (*Helv. phys. Acta*, 20th Sept. 1951, Vol. 24, No. 4, pp. 329–331. In German.) Measurements of the magnetic susceptibility χ of grey semiconducting tin indicate an increase of χ with rising temperature proportional to the number of free charge-carriers.

537.311.33 : 538.221 1322

Resistivity of Ferrites of Zinc, Nickel, Cobalt, Magnesium and Copper as a Function of Temperature.—L. Bochirol. (*C. R. Acad. Sci., Paris*, 1st Oct. 1951, Vol. 233, No. 14, pp. 736–738.) Measurements on sintered ferrite disks over the temperature range 100°–700°C are reported and examined in relation to the theory of electronic semiconductors.

537.311.33 : 546.28 1323

A.C. Characteristics of Si p–n Junction.—S. Komagata, M. Hatoyama, M. Shibuya, W. Sasaki, T. Yamamoto & M. Kikuchi. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, p. 1290.) Graphs are given for the conductance and susceptance of p–n junctions in the frequency range 200 c/s to 100 kc/s, and for the resistance and capacitance, at various frequencies, as functions of bias voltage.

537.311.33 : 546.289 1324

The Effects of Pressure and Temperature on the Resistance of p–n Junctions in Germanium.—H. H. Hall, J. Bardeen & G. L. Pearson. (*Phys. Rev.*, 1st Oct. 1951, Vol. 84, No. 1, pp. 129–132.) According to Shockley's theory (379 of 1950), the low-voltage resistance of a p–n junction is proportional to $\exp(E_g/kT)$, where E_g is the energy gap. Measurements of the change with pressure of the characteristics of a junction in a Ge single crystal indicate a resistance change of 12·5%, corresponding to a change of E_g of about $3{\cdot}1 \times 10^{-3}$ eV, for a pressure change of 10 000 lb/in.^{2} Analysis of measurements made at temperatures between 16·5° and 20·5°C gives values of E_g averaging about 0·72 eV; these values are in agreement with those obtained from the change in intrinsic resistivity with temperature and pressure.

537.311.33 : 621.396.822 1325

A Theory of Electrical Fluctuations in Semiconductors.—M. Surdin. (*J. Phys. Radium*, Oct. 1951, Vol. 12, No. 8, pp. 777–783.) When a constant current is passed through a semiconductor filament or through a metal/semiconductor contact, the magnitude of the observed fluctuations across the terminals is greater by some powers of 10 than that to be expected from the thermal or shot effect. An explanatory theory is advanced based on the fluctuations of the number of conduction electrons in the case of filaments, and on the number of donor centres in the barrier layer in the case of metal/semiconductor contacts.

538.221 1326

The Frequency Dependence of Magnetic After-Effect in Powder Cores.—T. Einsele & F. Baur. (*Z. angew. Phys.*, Oct. 1951, Vol. 3, No. 10, pp. 373–376.) The complex permeability of a powder core is determined from the results of a series of bridge measurements at frequencies between 30 c/s and 100 kc/s on a coil surrounding the core. After subtracting the effect of eddy currents (determined by extrapolation of Q measurements), the extent of the magnetic after-effect alone on the complex permeability is determined. The after-effect has different characteristics at low and high frequencies. It is not connected with the increase of permeability with temperature. Core losses at small field strengths and at frequencies up to 100 kc/s are largely dependent on the after-effect.

538.221 1327

Ferromagnetic Resonance in Cobalt Ferrite at High Temperature.—T. Okamura, Y. Torizuka & Y. Kojima. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, p. 372.)

538.221 **1328**

Low-Frequency Dispersion in Ni- and Cc-Ferrites.—K. Kamiyoshi. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, pp. 374–375.)

538.221 **1329**

The Magnetic Properties of α-Ferric Oxide.—W. P. Osmond. (*Proc. phys. Soc.*, 1st Oct. 1951, Vol. 64, No. 382B, pp. 931–932.) Discussion and reconciliation of contending views advanced by Chevallier and Snoek (2731 of 1951) and Néel (3161 of 1949).

538.221 : 538.24 **1330**

The Value of the Spontaneous Magnetization of Binary Nickel Alloys as a Function of Temperature.—J. J. Went. (*Physica, 's Grav.*, June 1951, Vol. 17, No. 6, pp. 596–602.)

538.221 : 538.652 **1331**

Linear Magnetostriction of Homogeneous Nickel Alloys.—J. J. Went. (*Physica, 's Grav.*, Feb. 1951, Vol. 17, No. 2, pp. 98–116.) The magnetostriction was measured as a function of alloy composition, induction, and temperature; a comprehensive table of results is given and discussed.

538.24 **1332**

The Magnetization of Steels in Weak Magnetic Fields: Effects of Time, Stresses, Shocks, Transverse Magnetic Fields.—L. Lliboutry. (*Ann. Phys., Paris*, Sept./Oct. 1951, Vol. 6, pp. 731–829.) Full treatment. See also 2230 of 1950.

538.249 **1333**

The Temperature Dependence of the Magnetic Viscosity of Ferromagnetic Metals.—E. F. Kuritsyna. (*C. R. Acad. Sci. U.R.S.S.*, 11th July 1951, Vol. 79, No. 2, pp. 233–236. In Russian.)

539.234 **1334**

Notes on the Metallization of Surfaces by Evaporation in Vacuum.—L. Dunoyer. (*C. R. Acad. Sci., Paris*, 22nd Oct. 1951, Vol. 233, No. 17, pp. 919–921.) Details are given of (*a*) pretreatment of the surface, (*b*) choice of metal for heater, and (*c*) a method of increasing the hardness of the deposit, in relation to the deposition of Al on glass.

546.23 : 548.55 : 537.311.33 **1335**

Electrical Properties of Selenium: Part 2 — Microcrystalline Selenium.—H. W. Henkels. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1265–1278.) The electrical properties of selenium have been studied in their dependence on history of preparation, i.e., as functions of initial temperature of the liquid selenium, quench procedure, nucleation procedure, temperature of crystallization, and time of crystallization. Single crystals and also a microcrystalline matrix of these crystals were investigated. The effect of the addition of small quantities of sulphur, oxygen and iodine was determined. The frequency dependence of resistivity was also studied. Carrier densities and effective mobilities are estimated from data on thermoelectric power and resistivity. The results obtained, and their relation to other observations and to theories of semiconductors, are discussed. Part 1: 698 of March.

546.23.03 **1336**

Studies on Selenium and its Alloys: Report 1 — Physical Properties of Selenium.—T. Sato & H. Kaneko. (*Technol. Rep. Tohoku Univ.*, 1950, Vol. 14, No. 2, pp. 45–54.) Includes measurements of expansion coefficient, density, specific heat, melting and boiling points, dependence of electrical resistance on heat treatment, and resistance at high temperature.

546.28 : 537.534.9 : 621.314.6 **1337**

Properties of Ionic Bombarded Silicon.—R. S. Ohl. (*Bell Syst. tech. J.*, Jan. 1952, Vol. 31, No. 1, pp. 104–121.) The change of the rectifying properties of Si was studied as a function of ion velocity, intensity of bombarding current, length of time of bombardment, kind of gas (H, He, N, Ar), and the temperature of the specimen during bombardment. It was found that Si contaminated with B to the point where it shows little rectification can be modified by bombardment to make its rectifying properties better than those of most unbombarded materials.

546.289 : 537.312.67 **1338**

The Electrical Conductivity of Liquid Germanium.—R. W. Keyes. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, pp. 367–368.) The resistivity of liquid Ge near the melting point was found to be 60 μΩ. cm (about 1/15 that of solid Ge at the melting point), with a positive temperature coefficient of about 1 or 2 parts in 10^4 per 1°C. The purity of the Ge was stated to be over 99·9%.

546.321.85 : 621.3.011.5 **1339**

Difference between the Dielectric Constants of Free and Clamped KH_2PO_4 Crystals.—H. Baumgartner. (*Helv. phys. Acta*, 20th Sept. 1951, Vol. 24, No. 4, pp. 326–329. In German.) Measurements in the temperature range −155° to −120°C confirm the Curie-Weiss linear relation between the reciprocal of the dielectric constant and the temperature, both for a crystal effectively clamped by exciting it at its 201st harmonic (10 Mc/s) and for a free crystal excited at its fundamental frequency of 1 kc/s. The graph for the free crystal is displaced about 4°, toward higher temperatures, relative to that for the clamped crystal. The results are in complete agreement with Müller's theory.

546.431.824-31 **1340**

Ferroelectricity *versus* Antiferroelectricity in Barium Titanate.—M. H. Cohen. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, p. 369.) Discussion of an antiferroelectric state leads to the conclusion that the ferroelectric properties of $BaTiO_3$ cannot be explained by the simple dipole-dipole interaction model suggested by Slater (2188 of 1950).

546.431.824-31 **1341**

Theory of Barium Titanate: Part 2.—A. F. Devonshire. (*Phil. Mag.*, Oct. 1951, Vol. 42, No. 333, pp. 1065–1079.) The theory given in part 1 (663 of 1950) is extended, and expressions are obtained for the piezoelectric constants, the elastic coefficients for constant field and the dielectric constants for constant strain in terms of other physical constants of the material. These quantities are plotted as functions of temperature, and comparison is made with values found experimentally. The relations between the constants of the ceramic and those of the single crystal are discussed briefly.

546.431.824-31 : 621.3.011.5 **1342**

Is the Ferroelectric Transition of Barium Titanate at 120°C of the First or the Second Kind?—W. Känzig & N. Maikoff. (*Helv. phys. Acta*, 20th Sept. 1951, Vol. 24, No. 4, pp.343–356. In German.) Investigation of the effect of a biasing field on the permittivity of single-domain $BaTiO_3$ crystals in the range 20°–180°C confirms Devonshire's theory (663 of 1950). The transition at 120°C appears to be an adiabatic transition of the first kind.

546.817.221 : 621.314.63 **1343**

The Rectifying Properties of Lead Sulphide.—I. I. Adrianiva & I. L. Sokol'skaya. (*Zh. tekh. Fiz.*, June 1951, Vol. 21, No. 6, pp. 713–714.) According to modern theory, contact rectification takes place when the metal is positive with respect to the semiconductor. Experiments with PbS and a tungsten point indicated that if the applied voltage is increased up to 1–1·5 V the rectified current changes its direction. Also, if the rectifying contact is placed in vacuum, the current decreases and then changes its sign. An explanation of the phenomena is advanced.

546.824-31 : 621.315.612.4 **1344**

Electric and Thermoelectric Properties of Partially Reduced (Blue) Titanium Dioxide.—B. I. Boltaks, F. I. Vasenin & A. E. Salunina. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 532–546.) Experiments were conducted for determining, within a wide range of temperatures, the specific conductivity and thermoelectric e.m.f. of samples of TiO_2 at various degrees of reduction. The results obtained are explained from the standpoint of modern theories on the conductivity of semiconductors.

546.824-31 : 621.315.612.4 **1345**

Dielectric Properties of Various Preparations of Titanium Dioxide.—I. N. Belyaev, N. S. Novosil'tsev, A. L. Khodakov & M. S. Shul'man. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 547–551.) The effect of impurities on the dielectric properties of TiO_2 has been studied on six different samples. The results obtained are shown in curves and tables.

548.0 : 537.228.1 **1346**

Growing Piezoelectric Crystals.—H. Mosaner & M. Wurl. (*Arch. elekt. Übertragung*, Oct. 1951, Vol. 5, No. 10, pp. 463–467.) An examination is made of factors influencing the development of single crystals of commonly used types, grown from an aqueous solution whose temperature is reduced under controlled conditions. A constant rate of growth of only a few millimetres per day is desirable. The temperature reduction must be determined in relation to the rate of growth to give the required size.

548.0 : 538.114 **1347**

Interatomic Distances and Ferromagnetism in Spinels.—R. S. Weisz. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, p. 379.) Discussion with particular reference to the hypothesis that spin interaction is inversely proportional to the distance from a metal ion to a nearest neighbour (i.e., an oxygen ion) and thence to another metal ion.

621.315.612.6 : 537.311 **1348**

Breakdown and Electric Conductivity of Glass.—K. J. Keller. (*Physica, 's Grav.*, May 1951, Vol. 17, No. 5, pp. 511–530.)

621.315.616 **1349**

Synthetic Materials.—P. Domin. (*Fernmeldetech. Z.*, Oct. 1951, Vol. 4, No. 10, pp. 461–467.) Review of various plastics and their derivation. Mechanical and electrical properties are tabulated.

621.396.611.21 : 549.514.51 **1350**

Frequency Shift of Piezoelectric Oscillations of Quartz under High Pressure.—A. Michels & J. P. Pérez. (*Physica, 's Grav.*, May 1951, Vol. 17, No. 5, pp. 563–564.) Measurements are reported on two quartz resonators, an AT cut with frequency 942 kc/s and a BT cut with frequency 6·04 Mc/s at atmospheric pressure. The slope of the frequency/pressure curve is positive for the AT and negative for the BT cut.

666.1 **1351**

Technical Control in Glass Manufacture.—J. H. Partridge & E. Preston. (*G.E.C. J.*, Oct. 1951, Vol. 18, No. 4, pp. 212–220.) Descriptions are given of an automatic method of controlling the temperature of a large glass-melting tank furnace, a photoelectric pyrometer for measuring accurately the temperature of glass as it is fed to machines, and an instrument for measuring the diameter of glass tubing during the drawing process. The results of applying these controls are demonstrated.

MATHEMATICS

517.6 : 621.396.611.1 **1352**

The Impulse Integral, a Counterpart of the Duhamel Step Integral.—R. Lueg, M. Päsler & W. Reichardt. (*Ann. Phys., Lpz.*, 15th Oct. 1951, Vol. 9, Nos. 6/7, pp. 307–315.) If a time-variable disturbing force acts on a linear system and G is one of the system parameters, the function $G(t)$, representing the time dependence of G under the action of the disturbing force, may be represented by the Duhamel integral. It may also be represented in a much simpler way by an expression whose integrand differs from the Duhamel integral in that the effect of the step function (unit step) is replaced by the effect of a delta function (needle impulse). Hence the term impulse integral. It is the simplest form of many possible expressions, and leads, under stated conditions, to a multiplication law for finding Fourier components.

517.9 **1353**

On a Relaxation Method for Eigenvalue Problems.—S. H. Crandall. (*J. Math. Phys.*, Oct. 1951, Vol. 30, No. 3, pp. 140–145.)

517.9 **1354**

The Application of Relaxation Methods to the Solution of Differential Equations in Three Dimensions: Part 1 — Boundary Value Potential Problems.—D. N. de G. Allen & S. C. R. Dennis. (*Quart. J. Mech. appl. Math.*, June 1951, Vol. 4, Part 2, pp. 199–208.)

518.5 **1355**

The Logarithmic-Complex-Number Plane and the Complex-Number Calculator.—W. de Beauclair. (*Z. Ver. dtsch. Ing.*, 21st Oct. 1951, Vol. 93, No. 30, pp. 955–957.) The complex-number plane with rectangular- and polar-coordinate network can be so transformed that multiplication and division of complex numbers reduce to simple addition and subtraction. This forms the basis of a simple calculator.

681.142 **1356**

The Binac.—A. A. Auerbach, J. P. Eckert, Jr, R. F. Shaw, J. R. Weiner & L. D. Wilson. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 12–29.) A comprehensive description of a high-speed electronic digital computer. The Binac consists of a main computing section, input-output equipment, and a mercury delay line of 512-word capacity. It is a combination of a few basic circuits, classified as diode matrices, switching gates, and reshaping gates; the latter allow a 'pulse-envelope' representation of information. Crystal diodes are used in switching and gating. Crystal gates are used with electric delay lines to form a serial binary adder. Input data are supplied to the memory from a keyboard or magnetic tape through a synchronizer, which is also used to transfer data from the memory to magnetic tape or an electric typewriter.

681.142 **1357**

Logical Description of some Digital-Computer Adders and Counters.—H. J. Gray, Jr. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 29–33.) Description of some of the circuits incorporated in the EDVAC computer.

681.142 : 517.942.9 **1358**

A Three-Dimensional Electrical Potential Analyser.—S. C. Redshaw. (*Brit. J. appl. Phys.*, Oct. 1951, Vol. 2, No. 10, pp. 291–295.) A resistance network is used in an electrical-analogue method of solving problems involving the three-dimensional form of Laplace's equation.

681.142 : 621.392.5 **1359**

Magnetostriction Storage Systems for a High-Speed Digital Computer.—Millership, Robbins & De Barr. (See 1200.)

517.63 **1360**

Die zweidimensionale Laplace-Transformation, eine Einführung in ihre Anwendung zur Lösung von Randwertproblemen nebst Tabellen von Korrespondenzen (The Two-Dimensional Laplace Transformation, an Introduction to its Application in the Solution of Boundary Problems, with Tables of Transforms). [Book Review]—D. Voelker & G. Doetsch. Publishers: Birkhäuser, Basle, 1950, 259 pp., bound, 43 Swiss francs; paper-covered, 39 Swiss francs. (*Z. angew. Phys.*, Oct. 1951, Vol. 3, No. 10, p. 398.) "The book is written just as the scientific practising engineer requires it."

519.2 **1361**

Introduction to the Theory of Probability and Statistics. [Book Review]—N. Arley & K. R. Buch. Publishers: Chapman & Hall, London, 1950, 236 pp., 32s. (*Beama J.*, Oct. 1951, Vol. 58, No. 172, p. 340.) "The treatment given to the subject matter is clear and concise, wisely illustrated with actual fully worked examples, many of a numerical nature."

MEASUREMENTS AND TEST GEAR

389.6 **1362**

Recent Developments and Techniques in the Maintenance of Standards.—M. M. Postgate. (*Nature, Lond.*, 6th Oct. 1951, Vol. 168, No. 4275, pp. 594–597.) Report of a symposium at the National Physical Laboratory, 21st–22nd May 1951. Most of the standardizing laboratories of Europe, the Commonwealth, and North America were represented and also many research and industrial organizations in Britain. An outline is given of the various subjects discussed. The full proceedings are to be published shortly by H.M. Stationery Office.

529.78 **1363**

A Precision Radio Time-Signal System.—D. W. R. McKinley & B. E. Bourne. (*Canad. J. Technol.*, Oct. 1951, Vol. 29, No. 10, pp. 428–434.) Accurate 'seconds' pulses are produced from a 100-kc/s quartz-crystal frequency standard, coded, and radiated from a 220-Mc/s transmitter with line-of-sight coverage. The average error in the interval between two pulses is 10^{-7} sec at the source, or 10^{-6} sec as observed at distant stations. The system has been used for continuous automatic time recording at the various stations of a meteor-observation network.

621.317.31 : 621.396.645 **1364**

Reduction of Measuring Time of Low-Current Amplifiers without Reduction of Sensitivity.—J. Taieb. (*C. R. Acad. Sci., Paris*, 8th Oct. 1951, Vol. 233, No. 15, pp. 785–787.) The time constant of the amplifier input circuit is reduced by eliminating stray capacitance associated with a high input resistance; this is done by immersing the resistor in an appropriate electrostatic field. In one experimental arrangement the resistor was inserted through a pair of parallel plates of which one was earthed while the other was connected to a negative feedback circuit. Measuring time is so short that drift effects are eliminated. Some numerical results obtained with different values of input resistance are tabulated.

621.317.329 : 621.392.26 **1365**

Determination of Aperture Parameters by Electrolytic-Tank Measurements.—S. B. Cohn. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 33.) Correction to paper noted in 725 of March.

621.317.333.4.015.7 : 621.315.2 **1366**

Pulse Location of Line Irregularities.—C. Béguin. (*Câbles & Transmission, Paris*, Oct. 1951, Vol. 5, No. 4, pp. 315–324.) See also 3091 of 1950 (Béguin & Maugard).

621.317.335.3 + 538.569.4 **1367**

A New Abac for determining Dielectric Constant and Absorption at Centimetre Wavelengths.—S. Le Montagner & J. Le Bot. (*C. R. Acad. Sci., Paris*, 29th Oct. 1951, Vol. 233, No. 18, pp. 1017–1019.) A method differing from those of Benoit (935 of 1950) and Roberts & von Hippel (178 of 1947) is presented for the graphical solution of the equation $Z = z^{-1} \tanh z$ which is involved in the determination of dielectric constants by the method of standing waves in waveguides.

621.317.335.3 + 538.569.4] : 533.1 **1368**

U.H.F. Measurements of Dielectric Constants and Absorption Coefficients of Gases and Vapours.—A. Gennaoui. (*Helv. phys. Acta*, 20th Sept. 1951, Vol. 24, No. 4, pp. 333–334. In French.) Short outline of a cavity-resonator method of measurement, details of which are to be published later.

621.317.335.3.029.63 **1369**

The Coaxial Line as a Measurement Instrument in the Decimetre-Wave Band.—H. Jungnickel & H. Falkenhagen. (*Ann. Phys., Lpz.*, 15th Oct. 1951, Vol. 9, Nos. 6/7, pp. 341–356.) Theory and experimental determination of complex permittivity and permeability of materials.

621.317.335.3.029.64 **1370**

Measurement of the Electrical Properties of Highly Absorbing Dielectrics on Centimetre Waves by the 'Infinite Layer' Method.—N. V. Aleksandrov. (*Zh. tekh. Fiz.*, June 1951, Vol. 21, No. 6, pp. 647–651.) The dielectric is introduced into a cylindrical waveguide in which H_1 waves are propagated. Assuming no reflection from the far end, the dielectric constant and loss angle can be calculated from the distribution of the field in front of the dielectric. The theory of the method is given with experimental results.

621.317.335.3.029.64 : 546.217 **1371**

The Refractive Indices and Dielectric Constants of Air and its Principal Constituents at 24 000 Mc/s.—L. Essen & K. D. Froome. (*Proc. phys. Soc.*, 1st Oct. 1951, Vol. 64, No. 382B, pp. 862–875.) Full account of work noted in 1707 of 1951.

621.317.336.029.64 **1372**

Waveguide Measurement Sections for Centimetre Waves.—O. Macek. (*Fernmeldetech. Z.*, Oct. 1951, Vol. 4, No. 10, pp. 436–437.) Short account of two H_{11}-mode slotted cylindrical waveguide sections for impedance measurement at wavelengths of 5 cm and 3·2 cm.

621.317.34.092 : 621.397.24 **1373**

Measurement of Differences of Group Propagation Time on a Non-looped Line.—J. Selz & J. Iltis. (*Câbles & Transmission, Paris*, Oct. 1951, Vol. 5, No. 4, pp. 337–346.) Two a.m. waves are simultaneously applied to the cable, one of fixed frequency 100 kc/s modulated at 10 kc/s, the other varying from 250 kc/s to 10·5 Mc/s and modulated at 50 kc/s. The 10-kc/s modulation is obtained by division from the 50-kc/s modulation, so that there is a constant though unknown phase relation between them. The two carriers are separately demodulated at the receiving end, and the phases, after multiplication of the 10-kc/s frequency, compared. The choice of frequencies is based on minimum requirements for the transmission of high-definition television signals. The equipment, details of which are given, has an accuracy to within ± 0·02 µs for group-propagation time measurements, the sensitivity being 0·005 µs.

621.317.35 **1374**

Harmonic Analysis of Waves up to Eleventh Harmonic (Odd Harmonics only).—P. Kemp. (*Electronic Engng*, Oct. 1951, Vol. 23, No. 284, pp. 390–393.) Grouping of selected ordinates in the wave equations is applied, as in earlier analysis (465 of 1943), to obtain the coefficients of the sum and difference components. Tables are given by which a straightforward quantitative analysis of a wave can be effected. Numerical calculations are made for a square wave.

621.317.725 **1375**

'Stromdämmung' — a New [German] **Term for rating Voltmeters.**—E. Meyer. (*Funk u. Ton*, Oct. 1951, Vol. 5, No. 10, pp. 514–517.) The German word suggested for 'ohms per volt' is 'Stromdämmung' (literally, 'current reduction'), defined as the ratio of total meter resistance to voltage for full-scale deflection.

621.317.725 **1376**

Highly Stable V-T Voltmeter.—M. G. Scroggie. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 142 . . 224.) See 1041 of April.

621.317.76 **1377**

The Secondary-Standard U.H.F. Generator of the Compagnie générale de T.S.F.—M. Denis & H. Fovet. (*Ann. Radioélect.*, Oct. 1951, Vol. 6, No. 26, pp. 336–350; *Onde élect.*, Oct. 1951, Vol. 31, No. 295, pp. 384–395.) A 3·750-Mc/s quartz-crystal-controlled frequency is multiplied to 270 Mc/s (F_0) and applied to a Type-XM14 klystron multiplier. Modulation is applied to the klystron multiplier at a frequency $F_0/3$, so that integral multiples $pF_0/3$ are available, where $24 \leqslant p \leqslant 48$. Further subdivision is attained by interpolation, using a standard variable-frequency oscillator. The normal range of 2·160–4·320 kMc/s can be extended to 0·6–30 kMc/s by frequency-multiplication methods. Accuracy is within about 5 parts in 10^6, but can be improved to 1 part in 10^6. Auxiliary equipment available enables the meter to be used for calibrating wavemeters, for frequency measurement, and for estimation of the depth of parasitic modulation.

621.317.761 **1378**

Navy Primary Standard Frequency Meter.—J. M. Carroll. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 172 . . 192.) Description of the U.S. Navy model-LAM equipment for frequency measurements from 15 kc/s to 27 Mc/s with accuracy to within 1 c/s in 10 Mc/s. This equipment is used by frequency-measurement units at large naval radio stations on shore. The output of a high-grade crystal oscillator at 100 kc/s is divided down to 9, 10 and 11 kc/s, and harmonics of these three frequencies are generated. The difference frequency between the carrier to be measured and the nearest harmonic of each of the three frequencies is found in turn, using a calibrated a.f. interpolation oscillator. A triple check of each measurement is thus obtained. Additional equipment using a 50-kc/s crystal to provide check points for a very stable v.f.o. extends the measurement range to 160 Mc/s.

621.317.79 : 621.396.611.21.012.8 **1379**

Quartz-Crystal Measurement at 10 to 180 Mc/s.—E. A. Gerber. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 36–40.) A method is described for measuring the equivalent parameters of the main and spurious modes. The crystal is connected between the anode and cathode of an amplifier valve, and the voltage across it is recorded as a function of frequency. The required parameters can then be derived.

621.317.79 : 621.396.67.029.64 **1380**

Automatic Antenna Wave-Front Plotter.—R. M. Barrett & M. H. Barnes. (*Electronics*, Jan. 1952, Vol. 25, No. 1, pp. 120–125.) Description of equipment which scans a plane, 30 in. × 36 in., in front of a microwave aerial and plots either phase or amplitude contours.

621.317.792 : 621.396.645.018.424 **1381**

Wideband Pre-amplifier.—Horner. (See 1248.)

621.396.615.11 : 534.844.1 **1382**

Equipment for Acoustic Measurements: Part 2 — A Portable Tone Source Developed for Use in Room Acoustics.—C. G. Mayo & D. G. Beadle. (*Electronic Engng*, Oct. 1951, Vol. 23, No. 284, pp. 368–373.) Description of a unit which provides an adjustable a.f. output up to 20 db above 1 mW into a 600-Ω load. The effective incremental capacitance of the tuning capacitor in the variable oscillator is dependent on the circuit gain. This is varied by a signal from a transitron oscillator to effect a 10% warble at 7 c/s, with negligible amplitude modulation. A synchronous motor and gearbox effect a frequency sweep of 20 c/s–20 kc/s in 4, 8, 16 or 32 minutes. Detailed circuit diagrams and performance curves are shown.

621.396.615.12.029.51/.62 : 621.314.26 **1383**

Wide-Band Converter for Signal Generator.—D. M. Hill. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 118–121.) F.m. and a.m. signals are provided over the whole frequency range 100 kc/s–216 Mc/s by a v.h.f. signal generator operating in conjunction with a wide-band converter.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.766 **1384**

Self-Adjusting Timer for Bullet Photography.—J. Burlock. (*Rev. sci. Instrum.*, Oct. 1951, Vol. 22, No. 10, pp. 743–745.) A reference voltage is produced proportional to the time interval taken for the bullet to travel a given distance; this voltage is used to measure off a second interval equal to the first and immediately following it, at the end of which the light source is flashed. The system is useful where the velocity of the bullet is not known in advance.

538.569.2.047 **1385**

The Dielectric Behaviour of some Types of Human Tissues at Microwave Frequencies.—H. F. Cook. (*Brit. J. appl. Phys.*, Oct. 1951, Vol. 2, No. 10, pp. 295–300.) Measurements of the complex dielectric constant were made over the wavelength range 6·5–17 cm, using a coaxial-line method described by Roberts & von Hippel (178 of 1947). Results are discussed in relation to dielectric theory.

621-52 : 621.389 **1386**

An Electronic Process-Controller.—J. R. Boundy & S. A. Bergen. (*Proc. Instn elect. Engrs*, Part II, Oct. 1951, Vol. 98, No. 65, pp. 609–615. Discussion, pp. 615–618.) Fundamental principles of process control are discussed, and a method of converting the physical quantities into d.c. is described. Details are given of an electrical controller which operates an electro-pneumatic relay mounted on the control valve.

621.365 **1387**

A Review of Progress in Electric Furnaces.—D. M. Dovey & I. Jenkins. (*G.E.C. J.*, Oct. 1951, Vol. 18, No. 4, pp. 194–211.) Descriptions are given of both well known and novel types of furnace operated by r.f., arc and resistor heating.

621.384.6 **1388**

The Linear Electron Accelerator as a Pulsed Neutron Source.—B. T. Feld. (*Nucleonics*, Oct. 1951, Vol. 9, No. 4, pp. 51–57.)

621.385.833 **1389**

Study of Low-Power Electrostatic [electron] **Lenses: the Second Approximation.**—F. Bertein. (*J. Phys. Radium*, Oct. 1951, Vol. 12, No. 8, pp. 25A–31A.) Continuation of work noted in 3082 of 1951.

621.385.833 **1390**

An Independent Electrostatic [electron] **Lens with Minimum Elliptical Astigmatism.**—É. Regenstreif. (*J. Phys. Radium*, July/Sept. 1951, Vol. 12, No. 7, pp. 760–761.)

621.385.833 **1391**

Theory of the Elliptical Electrostatic [electron] **Lens for Transgaussian Conditions.**—É. Regenstreif. (*C. R. Acad. Sci., Paris*, 15th Oct. 1951, Vol. 233, No. 16, pp. 854–856.) The theory previously given (2793 of 1951) for gaussian conditions is extended to cover transgaussian ray paths (2314 of 1950). See also *Ann. Radioélect.*, Oct. 1951, Vol. 6, No. 26, pp. 299–317.

621.385.833 **1392**

Some Formulae of Electron Optics.—M. Bernard. (*J. Phys. Radium*, July/Sept. 1951, Vol. 12, No. 7, pp. 761–762.) Little-used formulae of geometrical optics, due to Cotes and others, are found useful for calculations on electron lenses.

621.385.833 **1393**

Gaussian Components in the Electrostatic Lens formed by Two Coaxial Cylinders of Equal Diameter.—P. Grivet & M. Bernard. (*C. R. Acad. Sci., Paris*, 8th Oct. 1951, Vol. 233, No. 15, pp. 788–790.)

621.385.833 **1394**

A New Mathematical Model of an Electron Lens.—P. Grivet. (*C. R. Acad. Sci., Paris*, 22nd Oct. 1951, Vol. 233, No. 17, pp. 921–923.) A formula is developed which expresses the axial variation of the field more correctly than Glaser's formula (2205 of 1941) for cases where the decrease of the field is due to screening.

621.385.833 **1395**

On a Magnetic Electron-optical System analogous to a Planoconcave Lens.—I. I. Tsukkerman. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 599–600.)

621.385.833 **1396**

Investigation of Field Distribution in Symmetrical Electron Lens.—J. R. Shah & L. Jacob. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1236–1241.)

621.387.4 **1397**

Relative Sensitivities of Windowless and End-Window Counters.—W. L. Graf, C. L. Comar & I. B. Whitney. (*Nucleonics*, Oct. 1951, Vol. 9, No. 4, pp. 22–27.)

621.387.4 : 549.211 **1398**

Some Aspects of the Counting Properties of Diamond.—G. P. Freeman & H. A. van der Velden. (*Physica, 's Grav.*, June 1951, Vol. 17, No. 6, pp. 565–572.)

621.387.424 **1399**

Geiger Counters with Xenon-Oxygen Filling.—O. Riedel. (*Z. Naturf.*, June 1950, Vol. 5a, No. 6, pp. 331–332.)

778.37 : 621.383.001.8 : 535.61-15 **1400**

The Performance of Image Convertors as High-Speed Shutters.—R. C. Turnock. (*Proc. Instn elect. Engrs*, Part II, Oct. 1951, Vol. 98, No. 65, pp. 635–641.) Characteristics of two types of image converter are discussed and an explanation of their operation as shutters is suggested. See also 2250 of 1951 (Hogan).

621.38.001.8 **1401**

Theory and Application of Industrial Electronics. [Book Review]—J. M. Cage. Publishers: McGraw-Hill, New York, 1951, 290 pp., 40s. 6d. (*Electronic Engng*, Oct. 1951, Vol. 23, No. 284, pp. 409–410.) "One of the well-known . . . Electrical and Electronic Engineering series edited by Terman."

PROPAGATION OF WAVES

538.566.2 **1402**

The Propagation of Electromagnetic Waves in an Atmospheric Duct.—T. Kahan & G. Eckart. (*Z. Naturf.*, June 1950, Vol. 5a, No. 6, pp. 334–342.) See 1465 of 1951.

621.396.11 **1403**

A Geometric Interpretation of the Π-Wave and Coupling Factor in Ionospheric Long-Wave Theory.—N. Davids. (*J. geophys. Res.*, Dec. 1951, Vol. 56, No. 4, pp. 611–612.) Analysis shows that the Π waves are simply the components of the normal mode along the principal axes of a system of rectangular co-ordinates in the complex plane. The coupling factor for the two normal modes of propagation corresponding to the c.w. solution of the Appleton-Hartree equations is found to represent the space rate of twist of the polarization axes.

621.396.11 **1404**

Spanish Method for the Prediction of Optimum Working Frequencies at Any Distance.—R. Gea Sacasa. (*Rev. Telecomunicación, Madrid*, Sept. 1951, Vol. 7, No. 24, pp. 3–13.) Paper presented before the C.C.I.R., June 1951. See 2614, 2615, 2877 and 2878 of 1950.

621.396.11 : 551.510.535 **1405**

Group Velocities and Group Heights from the Magneto-ionic Theory.—D. H. Shinn & H. A. Whale. (*J. atmos. terr. Phys.*, 1952, Vol. 2, No. 2, pp. 85–105.) The group velocity in the ionosphere above south-eastern England is calculated for the ordinary and for the extraordinary wave over a wide range of frequencies; results are presented in the form of curves. The number of values calculated is sufficient for group delays at vertical incidence to be computed. Corresponding values for various angles of dip are used to obtain the group-height/frequency curves for various magnetic latitudes, for the ordinary ray incident vertically on a layer with parabolic distribution of ionization. It is shown that estimates of layer thickness neglecting the magnetic field are correct for the magnetic equator but are too high for other latitudes by amounts rising to 53% at magnetic latitude 62°; estimates of height of maximum ionization neglecting the magnetic field are approximately correct. A new method of estimating these parameters is proposed. The effect of the field on oblique-incidence propagation is also discussed.

621.396.11 : 551.510.535 **1406**

Contribution to the Study of the Electron Distribution in the Ionosphere and of the Absorption of Short Waves.—Argence, Mayot & Rawer. (See 1300.)

621.396.11 : 551.510.535 **1407**

Radio Wave Propagation at Oblique Incidence including the Lorentz Polarization Term.—Kelso. (See 1302.)

621.396.11.029.6 **1408**

Tropospheric Propagation beyond the Horizon.—J. Feinstein. (*J. appl. Phys.*, Oct. 1951, Vol. 22, No. 10, pp. 1292–1293.) Recent calculations of the field strength of v.h.f. waves, based on a smooth-earth diffraction theory, give results far below the observed values in the shadow region, even when refraction produced by the standard atmosphere is allowed for. But in these calculations the contribution made by partial reflections, caused by the gradient of refractive index in the atmosphere, has been neglected. A mathematical treatment which accounts for these reflections is outlined, and results deduced from it are shown graphically.

621.396.11.029.62 **1409**

The Anomalous Propagation of Radio Waves in the 1–10-Metre Band.—F. H. Northover. (*J. atmos. terr. Phys.*, 1952, Vol. 2, No. 2, pp. 106–129.) Theory is developed according to which anomalous propagation in the 1–10-m band is satisfactorily accounted for by high-level subsidence inversions.

621.396.11.029.62 : 621.396.65 **1410**

Metre-Wave Links beyond the Optical Range.—L. Sacco. (*Poste e Telecomunicazioni*, Oct. 1951, Vol. 19, No. 10, pp. 465–471.) A comparison of various methods of estimating the performance of such links. Two main types of formulae are distinguished, (*a*) those based on diffraction at a sphere, and (*b*) those based on optical diffraction at an edge. These formulae are assembled in an appendix. Using data obtained from the Monte Cavo–Monte Serpeddi link, pairs of values of field strength and modified radius (R_{10}) of the earth are calculated. The distributions of R_{10} for all methods of type (*a*) are such that very favourable atmospheric conditions must be assumed, while those for methods of type (*b*) give much more probable results. Further evidence supporting this conclusion is adduced from results on the Grasse–Calenzana link, the attenuation calculated by type (*b*) methods being in much closer agreement with measurements.

621.396.11.029.64 **1411**

Measurements of the Parameters Involved in the Theory of Radio Scattering in the Troposphere.—C. M. Crain & J. R. Gerhardt. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 50–54.) A brief discussion of the recording apparatus used for measurements of the fluctuations of refractive index and temperature in the lower atmosphere, particularly over the height range of 10 in. to 50 ft above the ground, and discussion of the problem of atmospheric turbulence at such levels. Records of refractive index and temperature fluctuations for various atmospheric conditions are given.

621.396.812.029.64 **1412**

Volume Integration of Scattered Radio Waves.—A. H. LaGrone. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 54.) The general equation for radio scattering developed by Booker & Gordon (1757 of 1950) is extended to a volume-integral equation, which gives the total scattered-power density per unit cped at a receiver point relative to the power radiated per unit solid angle by an isotropic source. The propagation conditions assumed are stated. See also 2525 of 1951 (LaGrone et al.).

621.396.812.3.029.64 **1413**

Selective Fading of Microwaves.—A. B. Crawford & W. C. Jakes, Jr. (*Bell Syst. tech. J.*, Jan. 1952, Vol. 31, No. 1, pp. 68–90.) Propagation experiments over two line-of-sight paths 22·8 and 17 miles long were designed to reveal the processes which cause the fading observed on clear, calm nights. The incident wave fronts were explored with a narrow-beam scanning aerial to determine the angle of arrival of 24-kMc/s waves, and the transmission characteristics were observed by a frequency-sweep technique. It was concluded that severe fading is the result of multiple-path transmission in which several components may arrive at the receiver at angles up to about 0·8° above the normal day-time angle of arrival and with path differences up to about 10 ft.

621.396.812.3.029.64 : 621.3.015.7 **1414**

Propagation Studies at Microwave Frequencies by means of Very Short Pulses.—O. E. DeLange. (*Bell Syst. tech. J.*, Jan. 1952, Vol. 31, No. 1, pp. 91–103.) Pulses of 4-kMc/s radiation, of duration about 3 mμs, were transmitted over a 22-mile path to determine the effects of the transmission medium on the propagation. The results indicate that during fading periods transmission by two or more paths occurs, with path differences up to about 7 ft. The resulting distortion of the pulses puts a lower limit on pulse length and spacing in a pulse transmission system.

RECEPTION

621.396.621 **1415**

Radio without Valves.—(*Elect. Rev., Lond.*, 21st Sept. 1951, Vol. 149, No. 3852, pp. 599–600.) Ge triodes replace thermionic valves in a simple experimental G.E.C. receiver which combines robustness with sufficient output to operate a loudspeaker.

621.396.621 **1416**

A General Theory for Frequency Discriminators containing Null Networks.—J. L. Stewart. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 55–57.) Generalized theory is presented which is applicable to the design of discriminators including null networks in which, neglecting second-order effects, coupling capacitors, and the like, a phase difference of a multiple of π radians is maintained at all frequencies.

621.396.621.54 **1417**

Tracking of Superheterodyne Receivers.—(*Radio tech. Dig., Édn franç.*, 1951, Vol. 5, No. 5, pp. 243–270.) French adaptation of 482 of February (de Koe). 59 references.

621.396.621.54 : 621.3.015.7 **1418**

Pulse Response of A.M. Receiver.—R. Kitai. (*Wireless Engr*, Jan. 1952, Vol. 29, No. 340, pp. 15–18.) An analysis is made of the transient response of a simple superheterodyne receiver with inductive coupling to an open-ended aerial of effective height about 4 m. The magnitude of the response is shown to depend not only on the amplitude of the input pulses, but also on their duration in relation to the frequency to which the receiver is tuned; hence the receiver can be used to determine the duration of the pulses.

621.396.822 **1419**

Voltage Peaks of Fluctuation Noise.—V. I. Bunimovich. (*Zh. tekh. Fiz.*, June 1951, Vol. 21, No. 6, pp. 625–636.) The question, as to how frequently a random value such as a fluctuation noise voltage exceeds a predetermined level, is discussed under the following headings: (*a*) average number of peaks; (*b*) peaks of the amplitude envelope; (*c*) average duration of peaks; (*d*) average frequency and mean square frequency of the spectrum.

621.396.822 **1420**

Observed Groups of Peaks of Electrical Fluctuations.—V. I. Bunimovich. (*Zh. tekh. Fiz.*, June 1951, Vol. 21, No. 6, pp. 637–646.) In 1419 above separate random peaks were considered. In the majority of cases peaks occur in groups, and only as such can be observed on the screen of an oscilloscope. Formulae are derived for determining the average number of peaks and groups of peaks, and the average duration of peaks. In the derivation of these formulae it is assumed that the fluctuations have passed through a narrow-band filter, i.e. that the envelope of the fluctuation process is approximately sinusoidal.

621.396.828 : 621.396.619.13 **1421**

Reduction of Interference in F.M. Receiver by Feedback across the Limiter.—R. M. Wilmotte. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 34–36.) Vector analysis of the phase relations in a f.m. receiver with feedback across the limiter shows that interference from an unwanted signal, of intensity differing little from that of the wanted signal, can be substantially suppressed.

STATIONS AND COMMUNICATION SYSTEMS

517.512.2 : 621.39.001.11 : 621.396.67.012.71 **1422**

Fourier Analysis and Negative Frequencies.—I. J. Shaw. (*Wireless Engr*, Jan. 1952, Vol. 29, No. 340, pp. 3–12.) The relation between the time function $f(t)$, expressing a fluctuation, and the frequency components $s(\omega)$ is examined; $f(t)$ is given by an integral in which ω ranges from $-\infty$ to $+\infty$. Neglect of the negative part of the spectrum leads in certain cases to errors in application of the modulation theorem of Fourier analysis. A graphical method is developed for obtaining the frequency spectrum of a finite wave train, in which the contribution of the negative frequencies is taken into account; simplification is achieved by introducing an auxiliary function with rectangular envelope. The method is applicable to the calculation of the polar diagram of aerials by Fourier analysis of the distribution of current across the aerial aperture; negative angles then take the place of negative frequencies.

621.39.001.11 **1423**

On the Definition of Information.—E. Reich. (*J. Math. Phys.*, Oct. 1951, Vol. 30, No. 3, pp. 156–161.) A definition of information is proposed which postulates an invariance under certain types of transformations. For a restricted class of admissible definitions these postulates imply that Shannon's formulation is the only possible one.

621.39.001.11 **1424**

Prediction and Entropy of Printed English.—C. E. Shannon. (*Bell Syst. tech. J.*, Jan. 1951, Vol. 30, No. 1, pp. 50–64.) A method of estimating the entropy and redundancy of a language is described, based on results of experiments in predicting the next letter of a text from knowledge of the preceding text. Some properties of an ideal predicting system are developed.

621.39.001.11 **1425**

The Concepts of Information and Transmission-Channel Capacity in Communication Engineering.—H. Weber. (*Bull. schweiz. elektrotech. Ver.*, 22nd Sept. 1951, Vol. 42, No. 19, pp. 749–754. In German.) A method is shown for calculating the quantity of information in a long text; the discussion is based on Shannon's method (1424 above) for deriving a text of reduced length which can be used for transmission and expanded to its original length at the receiver.

621.395.44 : 621.315.052.63 **1426**

British Developments and Applications of Carrier Current Principles for Operating Requirements of Power Utilities.—W. D. Goodman. (*G.E.C. J.*, Oct. 1951, Vol. 18, No. 4, pp. 229–236.) A.I.E.E. Summer General Meeting paper. Details are given of wideband coupling equipment for carrier-current working over power lines; the advantages of interphase coupling over phase-to-ground coupling are explained. S.s.b. operation is used in order to reduce noise. Recent British types of communication and relaying equipment are described.

621.396.619.13 **1427**

Investigations of Frequency [-modulation systems with] **Negative Feedback.**—J. Hacks. (*Arch. elekt. Übertragung*, Oct. 1951, Vol. 5, No. 10, pp. 441–446.) A discussion of the use of negative feedback to reduce distortion in f.m. transmitters and receivers. By confining consideration to small values of distortion the calculation can be simplified in comparison with earlier methods [see 3120 of 1939 (Chaffee) and 3548 of 1949 (Panter & Dite)] and phase shifts due to the finite group transmission time can be taken into account. The effect on the overall distortion of nonlinearities in the feedback loop is examined. A circuit for equalizing the feedback over the modulation-frequency range is described. With a feedback factor >2 a significant improvement can be obtained in the effective selectivity of a f.m. receiver.

621.396.65 + 621.396.97 **1428**

Bases of Calculation for the Design of Radio Communication Systems.—H. Herzan. (*Radio Tech., Vienna*, Oct. 1951, Vol. 27, No. 10, pp. 423–427.) The relative levels of signals and noise desirable for radio broadcasting, telephony and telegraphy systems are discussed. Graphs are reproduced showing noise spectra, ground-wave attenuation, aerial height factor, and space-wave absorption curves for medium and short waves. The use of a logarithmic distance/attenuation scale simplifies the application of the graphs.

621.396.65.029.6 **1429**

Nonlinear Crosstalk in Multichannel Systems during Transmission over U.S.W. F.M. Links, as compared with the Specifications for Cable Connections.—E. Kettel. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 163–168.) Modulation in carrier-frequency systems is considered, and the distortion in an u.s.w. f.m. installation is expressed in terms of crosstalk. F.m. u.s.w. links do not at present equal the performance of carrier-frequency cables, but can bridge useful distances while complying with C.C.I.F. requirements. A comparison between f.m. and time modulation shows the superiority of the former for a large number of channels from the point of view of signal/noise ratio.

621.396.65.029.62 **1430**

V.H.F. Radio Multichannel Carrier Telephone Circuits in Colombia.—L. C. Simpson, H. J. B. Nevitt & E. J. Eriksen. (*Ericsson Rev.*, 1951, Vol. 28, No. 3, pp. 62–72.) The main features are described of a triple link connecting Bogota and Medellin, distant 250 km apart. F.m. broadcasting equipment is used; the frequency range is 70–88 Mc/s.

621.396.65.029.63/.64 **1431**

The Planning of Beam Links in the Decimetre and Centimetre Wavebands.—K. O. Schmidt. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 129–139.) General considerations and expected future developments are enumerated, and planning details for the f.m. wideband 15-cm television link between Hamburg and Cologne are briefly considered. This link is expected to be in experimental operation early in 1952. The importance of relay-station tower construction and suitable power supply arrangements, in this case mainly wind-driven generators, is stressed.

621.396.65.029.63 **1432**

The IDA 22 Beam-Link Equipment.—G. Ulbricht. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 143–162.) A short survey of German wartime dm-wave links, which covered most of Europe and extended to North Africa, together with an account of the development of this new equipment. A 22-channel installation in experimental operation between Darmstadt and Frankfurt, with an intermediate relay station on the Feldberg, is described in detail. Pulse-phase modulation is used and the transmission frequency lies between 1 900 and 2 100 Mc/s. To avoid the effects of noise on the pulse flank, an auxiliary h.f. self-oscillator delivers a voltage low compared with the pulse voltage, but high compared with the noise voltage, to the transmitter. The pulse flank is thus modulated at the self-oscillator frequency but this frequency is rejected by the receiver. Alternative equipment for the modulation circuits uses Ge diodes. A map showing the dm-wave network of the German Post Office in 1951 is also included.

621.396.71 **1433**

The New Italcable Radio Transmitting Station of Torrenova.—M. Suppan. (*Poste e Telecomunicazioni*, Oct. 1951, Vol. 19, No. 10, pp. 473–481.) A general description covering the station lay-out and the equipment available.

621.396.97.029.62 **1434**

The B.B.C. Scheme for V.H.F. Broadcasting.—(*B.B.C. Quart.*, Autumn 1951, Vol. 6, No. 3, pp. 171–181.) The technical reasons for the proposal to plan a v.h.f. service are briefly outlined. Tests are described in which various forms of modulation and reception were compared from the point of view of noise and interference suppression. Laboratory experiments indicated that the level of receiver hiss and impulsive noise was markedly lower with f.m. than with a.m., either with or without a noise limiter. Similarly a survey of the quality of reception of transmissions from actual stations gave approximately twice the range for f.m. as compared with a.m. for the same quality of service. On this basis a f.m. broadcasting service has been planned for the United Kingdom; this is discussed with particular reference to common- and adjacent-channel interference and the requirements of suitable commercial receivers.

SUBSIDIARY APPARATUS

621-526 **1435**

Harmonic Analysis of Nonlinear Servomechanisms.—J. Loeb. (*C. R. Acad. Sci., Paris*, 1st Oct. 1951, Vol. 233, No. 14, pp. 733–735.) Continuation of work noted in 502 of February.

621.311.6 : 621.316.72.076.7 **1436**

Superregulated Power Supplies.—A. W. Vance & C. C. Shumard. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 109–113.) A description of apparatus giving supplies of 300 V at 20 A, 75 V at 6 A and −500 V at 3 A, all regulated to within 0·001%. Coarse regulation is obtained in stages using grid-controlled thyratrons, which precede fine regulators incorporating servo-stabilized d.c. amplifiers. A calibrator unit enables comparison of any voltage output with an appropriate reference voltage, and also direct measurement of hum on a c.r.o.

621.352 **1437**

Small-Size High-Voltage Battery.—P. Bristeau. (*J. Phys. Radium*, Oct. 1951, Vol. 12, No. 8, pp. 74A–78A.) Method of manufacture and main factors affecting operation are given for a Zamboni-type battery for low-consumption portable electronic apparatus. Diameter is 8 mm, length 60 mm and voltage 200 V.

621.396.68 **1438**

Power Supply.—The U.D.C. number 621.396.68 and its subdivisions, used hitherto for power supply, have been cancelled and replaced by 621.311.6 and subdivisions, which will be used in future in 'Abstracts and References'.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24 : 621.315.212 **1439**

Television Transmission Tests on Coaxial Cable.—P. Bréant & G. Fuchs. (*Câbles & Transmission, Paris*, Oct. 1951, Vol. 5, No. 4, pp. 325–336.) A brief description is given of the line and terminal equipment and of the equalization measures adopted for the coaxial-cable circuit between Brive and Montpon. 455-line tests were made over a 73-km and a 36-km loop in this circuit. The conclusion is that low-definition image transmission is feasible over the standard French coaxial cables, provided the transmission system is as nearly as possible linear and the signal/noise ratio is of the order of 5 N.

621.397.24 : 621.317.34.092 **1440**

Measurement of Differences of Group Propagation Time on a Non-looped Line.—Selz & Iltis. (See 1373.)

621.397.3 : 517.941.91 **1441**

A Mathematical Analysis of an Equivalent Scanning Circuit.—A. B. McFarlane & J. R. W. Smith. (*J. Brit. Instn Radio Engrs*, Oct. 1951, Vol. 11, No. 10, pp. 470–476.) A classical treatment of the switched LCR circuit by means of differential equations, which shows the effects of changes of the *Q*-factor of the circuit and leads to the formulae usually quoted. Energy fluctuations of the system in the oscillatory and non-oscillatory states are examined and a numerical example is worked out.

621.397.5 **1442**

The Present Position of Television [in Germany].—H. K. Ibing. (*Z. Ver. dtsch. Ing.*, 1st Oct. 1951, Vol. 93, No. 28, pp. 890–895.) Principal features of apparatus shown at the German Industries Exhibition, Berlin, 1951, are described.

621.397.5 **1443**

Electrical and Photographic Compensation in Television Film Reproduction.—P. J. Herbst, R. O. Drew & S. W. Johnson. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1951, Vol. 57, No. 4, pp. 289–307.) Defects in film reproduction due to limitations in existing television systems are discussed. Of available methods of compensation, area masking as described by Yule (*J. phot. Soc. Amer.*, March 1945, Vol. 11, No. 3, pp. 123–132) is recommended. A circuit equivalent for the photographic mask is described.

621.397.5 : 535.623 **1444**

A New Technique for Improving the Sharpness of Television Pictures.—P. C. Goldmark & J. M. Hollywood. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1951, Vol. 57, No. 4, pp. 382–396.) See 828 of March.

621.397.5 : 535.88 : 679.5 : 535.317 **1445**

Cast Plastic Lens.—(*Mod. Plast.*, Sept. 1951, Vol. 29, No. 1, pp. 188–189.) Description of the method of producing plastic lenses, up to 22·5 in. in diameter, for the correcting elements of Schmidt large-screen projection systems.

621.397.5(083.74) **1446**

Television Standards in Argentina.—(*Rev. telegr. Electronica, Buenos Aires*, Sept. 1951, No. 468, pp. 589–590.) These differ from U.S. standards in two chief respects, the number of scanning lines, which is 625, and the number of frames per second, which is 25. The vision signals are broadcast on 175·25 Mc/s, the sound on 179·75 Mc/s.

621.397.5 : 535.623](083.74) **1447**

Color Television — U.S.A. Standard.—P. C. Goldmark, J. W. Christensen & J. J. Reeves. (*J. Soc. Mot. Pict. Televis. Engrs*, Oct. 1951, Vol. 57, No. 4, pp. 336–381.) See 831 of March.

621.397.61.029.63 **1448**

U.H.F. Transmitter uses Beer-Barrel Cavity.—W. H. Sayer, Jr, & E. Mehrbach. (*Electronics*, Dec. 1951, Vol. 24, No. 12, pp. 125–127.) Describes a 700-Mc/s, 420-W experimental television transmitter incorporating an output stage consisting of six Type-2C39A valves in parallel used as grounded-grid amplifiers. The cathode-grid and anode-grid tuned circuits of the amplifier are coaxial-line cavities. The design is based on experience with a 600-Mc/s transmitter in daily use since March 1950. An illustration shows an assembly using 18 valves in parallel.

621.397.61.029.63 + 621.396.67 : 621.397.6 **1449**

Ultrahigh Transmitter and Antenna Design and Application.—R. G. Peters. (*TV Engng, N.Y.*, Oct. 1951, Vol. 2, No. 10, pp. 14–17, 29.) Description of the R.C.A. TTU-1B and TTU-10A television transmitters. together with the aerials and associated equipment, for the frequency range 470–890 Mc/s.

621.397.611.2 **1450**

Television Camera Tubes: Part 1 — Classification and Method of Operation of Camera Tubes.—H. Bruining. (*Tijdschr. ned. Radiogenoot.*, Sept. 1951, Vol. 16, No. 5, pp. 209–225.) An outline of principles of operation, with individual descriptions of the orthicon, image orthicon, vidicon, iconoscope and image iconoscope.

621.397.611.2 **1451**

Television Camera Tubes: Part 2 — Comparison of Characteristics of Camera Tubes.—P. Schagen. (*Tijdschr. ned. Radiogenoot.*, Sept. 1951, Vol. 16, No. 5, pp. 227–242. Discussion, p. 242.) The types of tube considered are the iconoscope, the image iconoscope, the orthicon and the image orthicon. Characteristics discussed include linearity, effective exposure time, generation of spurious signals, relative ease of operation, signal/noise ratio, spectral response. stability, depth of focus, possibility of black-level restoration, and sensitivity. For normal broadcasting operation, the relative sensitivities of the four types in the order given above are 1, 75, 25 and 325.

621.397.611.2 **1452**

Television Camera Tubes: Part 3 — Electronoptical Problems of the Image Iconoscope.—J. C. Francken. (*Tijdschr. ned. Radiogenoot.*, Sept. 1951, Vol. 16, No. 5, pp. 243–256. Discussion, p. 257.) Problems involved in the scanning and image-forming processes are discussed. Use of a high-emission cathode such as that described in 773 of 1951 (Lemmens, Jansen & Loosjes) helps to reduce defocusing of the scanning spot due to the inclination of the scanning ray to the target. The electron-image section using a long focusing coil is described; factors causing loss of definition of the electron image are mentioned and methods of reducing their adverse effects are discussed. By using a coil split into three sections and simultaneously varying the currents in these sections, it is possible to obtain continuous variation of magnification over a 1 : 2 range without rotating the image.

621.397.62 **1453**

Ultra-speed Theater Television Optics.—L. T. Sachtleben & G. L. Allee. (*J. Soc. Mot. Pict. Televis. Engrs*, Nov. 1951, Vol. 57, No. 5, pp. 425–433. Discussion, p. 433.) The general properties of a reflection system of the Schmidt type are discussed with reference to practical design considerations and application in the theatre. The relations between focal length, projection distance and screen illumination are demonstrated, and factors affecting resolving power and fine-detail contrast are examined. The design, material and application of the ogee correcting lens are also discussed.

621.397.62 **1454**

An Ultra-High-Frequency Television Converter.—B. F. Tyson. (*Sylvania Technologist*, Oct. 1951, Vol. 4, No. 4, pp. 78–80.) The design and performance are described of a simple, low-cost converter which enables transmissions in the band 475–890 Mc/s to be received on existing receivers designed for the band 174–216 Mc/s. Factors discussed are conversion efficiency, noise figure, frequency stability and possible interference from harmonics of the local oscillator of the v.h.f. receiver.

621.397.621.2 : 535.371.07 **1455**

Aluminium-Backed Screens for Cathode-Ray Tubes.—R. W. Dudding. (*J. Brit. Instn Radio Engrs*, Oct. 1951, Vol. 11, No. 10, pp. 455–462.) The ion-burn screen blemish associated with the electromagnetic c.r. tube can be prevented by depositing a thin Al layer on the back of the phosphor coating. The required characteristics of such layers, and methods of preparing them. are described. Further advantages of Al-backed screens are the prevention of screen voltage saturation effects, and improved brightness and contrast.

621.397.7 **1456**

The Holme Moss Television Transmitting Station.—D. B. Weigall. (*B.B.C. Quart.*, Autumn 1951, Vol. 6, No. 3, pp. 182–192.) A general description is given of the site and layout of buildings and equipment of the North of England television station, and comparison is made with a similar station at Sutton Coldfield [626 (Cork), 834 (Nind & Leyton) and 854 (Bevan & Page) of March]. The sources of power, vision and sound signals are described and also the methods of controlling the transmitters and monitoring the programme in the control room. The vision and sound transmissions are combined before passing up the 750-ft mast to the common aerial system. A radiated power of 45 kW is obtained on the vision frequency, the nominal carrier power of the sound transmitter being 12 kW. The corresponding powers of the standby transmitters are 5 kW (peak white) and 2 kW. A field-strength map of the service area is given and also details of the aerial system, which is basically similar to that at Sutton Coldfield. See also *Wireless World*, Nov. 1951, Vol. 57, No. 11, pp. 473–474.

621.397.81 **1457**

Fringe-Area Performance Predictions.—E. A. Slusser. (*TV Engng, N.Y.*, Oct. & Nov. 1951, Vol. 2, Nos. 10 & 11, pp. 18–19, 30 & 22–23, 29.) Based on data for effective transmitted power, propagation losses, receiving-aerial gain and height and receiver gain, nomograms are constructed for predicting the performance of television receivers in fringe areas.

621.397.828 **1458**

A Versatile TVI-less 40-Watt Transmitter.—S. Fisher. (*CQ*, Sept. 1951, Vol. 7, No. 9, pp. 11–20.) Precautions described against interference with television reception by a 10–160-Mc/s amateur transmitter include shielding and filtering arrangements for connection to the receiver.

621.397.828 : 621.365.5 **1459**

Curing R.F.-Heater Television Interference.—P. S. Rand, J. J. Lamb & A. J. Riley. (*Mod. Plast.*, Sept. 1951.

Vol. 29, No. 1, pp. 101–110.) A general survey of the problem, with a description of a sensitive wide-range wavemeter for measuring the frequency of stray radiation. Methods of preventing leakage from heating sets are described; careful attention to the design of the cabinet is necessary. Alternatively a screened room may be used for the equipment, with filter circuits in the power leads.

621.397.5 **1460**

Bases Techniques de la Télévision. [Book Review]—H. Delaby. Publishers: Eyrolles, Paris, 340 pp. (*Radio tech. Dig., Édn franç.*, 1951, Vol. 5, No. 5, pp. 293–294.) Companion volume to 'Principes Fondamentaux de Télévision' (1218 of 1949). Deals with all parts of the television transmission chain from the camera to the picture tube; recommended to radio engineers.

TRANSMISSION

621.396.61 : 621.397.97 **1461**

Description of a 40-kW Broadcast Transmitter.—A. G. Robeer & B. Swets. (*Commun. News*, Oct. 1951, Vol. 12, No. 1, pp. 16–32.) Detailed description of a transmitter for six preset frequencies between 6 and 24 Mc/s, incorporating 'instantuners' [click gear; 2941 of 1949 (Vervest)] for all tuning elements, continuously variable inductors, and triple contacts for heavy currents.

621.396.619.13 **1462**

On the Operating Conditions of Reactance Circuits for realizing Very Large Reactance Variations.—H. Fricke. (*Fernmeldetech. Z.*, Oct. 1951, Vol. 4, No. 10, pp. 458–461.) A pentode reactance valve is operated about a point of zero slope on the I_a/V_g characteristic. A suitable characteristic is obtained by applying a high screen voltage so that a space charge develops between screen and anode. With an EF14 valve, frequency deviations of ± 11·7% at 1·46 Mc/s and ± 7·9% at 27·5 Mc/s were obtained.

621.396.619.14 + 621.314.26] : 621.385.029.64 **1463**

The Travelling-Wave Valve as a Microwave Phase Modulator and Frequency Shifter.—W. J. Bray. (*Proc. Instn elect. Engrs*, Part III, Jan. 1952, Vol. 99, No. 57, pp. 15–20.) The principles of operation are discussed. It is shown theoretically and confirmed by measurement that phase modulation of about ± 2·5 radians can be achieved with a typical valve operating at 4 kMc/s, by injecting the modulating signal in series with the beam voltage. This principle when applied in a frequency shifter gives gain and power output only 6 db below those obtainable with the same valves used as amplifiers. Possible applications in the transmitters and repeaters of radio relay systems are outlined.

621.396.619.232 **1464**

High-Efficiency Grid Modulation.—L. A. Moxon. (*R.S.G.B. Bull.*, Oct. & Nov. 1951, Vol. 27, Nos. 4 & 5, pp. 144–147 & 193–196.) The Taylor and Terman-Woodyard grid-modulation circuits are analysed. The two systems share a common principle, the use of a quiescent valve to supply extra power during the positive half-cycle and at the same time to alter the load impedance seen by the power valve in such as way that the overall efficiency is high except during the negative half-cycle, for which ordinary grid modulation is used. An important difference between the systems is that in the Taylor circuit the quiescent valve has to supply all the power at the modulation peak, whereas, in the Terman-Woodyard system, impedance-inverting networks are used to bring about an equal sharing of the load between the two valves. Experiments carried out with both systems indicate that the Terman-Woodyard circuit is not only practicable, but is in no way inferior to the Taylor circuit. Tested with a lamp load, the Terman-Woodyard circuit gave the higher efficiency and also much better linearity. Circuit adjustments are not unduly critical.

VALVES AND THERMIONICS

537.525 : 621.396.822 **1465**

Determination of the Electron Temperature in Gas Discharges by Noise Measurements.—K. S. Knol. (*Philips Res. Rep.*, Aug. 1951, Vol. 6, No. 4, pp. 288–302.) The electron temperatures of discharges in He, Ne, Ar and Xe, as deduced from measurements of available noise power and from experiments using a probe, agree with values deduced theoretically from the gas pressure and the radius of the discharge tube. Precautions necessary to match the discharge to the waveguide are described.

537.525.92 : 537.533.7 **1466**

Nullification of Space-Charge Effects in a Converging Electron Beam by a Magnetic Field.—M. E. Hines. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 61–64.) Discussion of the conditions necessary for maintaining uniform convergence of a conical electron beam in the presence of space charge. Brillouin's focusing condition (3101 of 1945) is extended to conical flow. A converging magnetic field is found necessary.

537.533 **1467**

Theory of Electron Emission from a Metal in an Electric Field.—A. E. Glauberman & I. I. Tal'yanski. (*C. R. Acad. Sci. U.R.S.S.*, 1st June 1951, Vol. 78, No. 4, pp. 661–664. In Russian.)

621.383 : 546.289 **1468**

A Photovoltaic Germanium Cell.—B. J. Rothlein. (*Sylvania Technologist*, Oct. 1951, Vol. 4, No. 4, pp. 86–88.) Practical determinations of the photovoltaic characteristics of experimental cells are discussed. Factors affecting speed of response and sensitivity are shown to be related to the lifetime of the hole-electron pairs created.

621.385.029.62/.63 **1469**

Traveling-Wave Amplification by means of Coupled Transmission Lines.—W. E. Mathews. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, p. 64.) Corrections to paper abstracted in 867 of March.

621.385.029.62/.63 : 621.396.822 **1470**

Traveling-Wave Tube Noise Figure.—D. A. Watkins. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 65–70.) The optimum positions of the travelling-wave-valve circuit entrance with respect to the space-charge noise waves, and the corresponding minimum noise figures, are depicted graphically as functions of the space charge and the circuit loss. The noise figure is reduced if the electron stream is accelerated through a short non-resonant gap placed at a noise-convection-current minimum. A similar reduction is given by two velocity jumps, a deceleration at a noise-current maximum followed by an acceleration at a noise-velocity maximum. Measurements taken on an experimental valve of this type agree with the theoretical predictions.

621.385.032.216 **1471**

The Electronic Temperature of Oxide Cathodes: Interpretation of Experimental Results.—H. Dormont. (*J. Phys. Radium*, July/Sept. 1951, Vol. 12, No. 7, pp. 710–716.) Experiments reported by Champeix (2068 of 1950) indicating a difference between thermodynamic and electronic temperature are discussed. The results are consistent with the existence at the cathode surface of a potential barrier of step form; such a barrier would also account for the numerical value of the coefficient A in Richardson's equation.

621.385.032.216 : 537.311.33 **1472**

P-N Transition of an Oxide-Coated Cathode.—Y. Ishikawa, T. Sato, K. Okumura & T. Saski. (*Phys. Rev.*, 15th Oct. 1951, Vol. 84, No. 2, pp. 371–372.) *P*-type conduction was found for a (BaSr)O cathode in an oxygen atmosphere, as opposed to *n*-type conduction in vacuo. Hall effect and conductivity measurements for a wide range of oxygen pressures show that (BaSr)O has the characteristics of a semiconductor.

621.385.032.42 **1473**

The "Grip-O-Matic" Water Jacket for Large Water-Cooled Transmitting Valves.—A. G. Robeer & W. L. Vervest. (*Commun. News*, Oct. 1951, Vol. 12, No. 1, pp. 10–14.) Description of a water jacket designed so that no tools are required for mounting or demounting the valve.

621.385.3 **1474**

Theory and Calculation of the E. S. Penetration Factor of Planar and Cylindrical Triode Valves, assuming Two-Dimensional Potential Distributions.—M. Landsberg. (*Z. angew. Math. Phys.*, 15th Sept. 1951, Vol. 2, No. 5, pp. 375–393.) General formulae are derived, using the Weierstrass functions; the calculation leads to an infinite system of linear equations, which can be solved by using certain power series. The relation between the formulae deduced here and approximations previously derived is shown.

621.385.3 : 546.289 **1475**

Transistors.—The U.D.C. number 621.385.3 : 546.289 used hitherto for transistors will be replaced by 621.314.7.

621.385.8 : 621.318.572].001.8 **1476**

Electron-Beam Switches.—F. Schröter. (*Telefunken Ztg*, Oct. 1951, Vol. 24, No. 92, pp. 171–186.) A well illustrated review of various types and their applications.

621.385.831 **1477**

An Experimental High-Transconductance Tube using Space-Charge Deflection of the Electron Beam.—J. T. Wallmark. (*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 41–48.) 1951 I.R.E. National Convention paper. The valve uses a new principle, combining current-density and deflection control; a conventional grid controls the space charge, which produces a displacement of the electron beam. Transconductances of 25 millimhos have been obtained with only 3 mA output current, using an orbital-beam construction with one stage of electron multiplication. The measured equivalent noise resistance is about 900 Ω and the gain-bandwidth product about 320 Mc/s.

621.396.615.141.2 **1478**

The Electron Theory of the Planar Magnetron.—V. M. Lopukhin. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 505–515.) A theoretical investigation is presented of the interaction between the e.m. field and the electron currents in a magnetron. The presence of the electron stream causes a rise in the resonance frequencies. The necessary conditions for the excitation of the magnetron are considered.

621.396.615.141.2 **1479**

The Electron Theory of a Centimetre-Wave Decelerator.—V. M. Lopukhin. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 516–526.) The properties of a magnetron are considered for the limiting case when the spacing of the slots tends to equality with the slot width. This system, in the presence of an electron stream, acts as a complex filter with alternate pass and stop bands. Under certain conditions the direct wave passing through the system may be split up into three components, of which one will have an amplitude increasing exponentially with co-ordinate z. Thus the system can be used for amplification of microwave signals.

621.396.615.141.2 **1480**

Self-Excitation of a Decelerating System.—E. I. Vasil'ev & V. M. Lopukhin. (*Zh. tekh. Fiz.*, May 1951, Vol. 21, No. 5, pp. 527–531.) The decelerating effect of the split-anode magnetron is considered; discussion is limited to the case of π-oscillations with the electron stream occupying the whole space between cathode and anode (Fig. 1). An equation (6) is derived for determining the frequencies of oscillations. The solution of this equation gives the necessary conditions for the excitation of the system and also determines the variation of the frequencies depending on the parameters of the magnetron and of the electron stream.

621.396.615.142.2 : 621.3.012.8 **1481**

Equivalent Networks of Klystrons.—S. Uda & J. Ikeuchi. (*Technol. Rep. Tohoku Univ.*, 1950, Vol. 14, No. 2, pp. 117–129.) The induced current due to an electron stream flowing through a gap is calculated, taking account of the voltage which appears across the gap. From this the internal admittance of a klystron is deduced and equivalent circuits are derived for double-cavity and reflex klystrons, which assist in explaining their operation and also in their design.

621.396.615.142.2.029.64 **1482**

Ground-Transmitter Klystron for Air Navigation.—V. Learned. (*Electronics*, Jan. 1952, Vol. 25, No. 1, pp. 136 . . 165.) Description of a valve for operation at 9·3 kMc/s, with peak power of 7·5 kW and average power output of over 200 W. A permanent magnet is used for beam focusing.

621.385 **1483**

Radio Valve Data. [Book Review]—Publishers: Iliffe & Sons, London, 1951, 80 pp., 3s. 6d. (*Electronic Engng*, Oct. 1951, Vol. 23, No. 284, p. 410.) New edition of the *Wireless World* reference book giving the main characteristics of over 2 000 types of British and American valves, and over 100 c.r. tubes.

621.385.029.6 **1484**

Rundfunkröhren. Band 1951. Eigenschaften und Anwendung der neuen UKW-Röhren (Broadcasting Valves. 1951 Volume. Properties and Application of New U.S.W. Valves). [Book Review]—L. Ratheiser. Publishers: Regeliens Verlag, Berlin, 1951, 128 pp., 16 DM. (*Z. angew. Phys.*, Oct. 1951, Vol. 3, No. 10, p. 400.) Details of receiver valves and circuits; complementary to the earlier volume (1835 of 1950).

MISCELLANEOUS

061.3 **1485**

I.R.E.-U.R.S.I. Fall Meeting, Cornell University, Ithaca, N.Y., October 8-10, 1951.—(*Proc. Inst. Radio Engrs*, Jan. 1952, Vol. 40, No. 1, pp. 106–110.) Summaries are given of 43 technical papers presented.

621.39.001 **1486**

Post Office Research.—(*Electrician*, 5th Oct. 1951, Vol. 147, No. 3825, pp. 1017–1019; *Elect. Times*, 4th Oct. 1951, Vol. 120, No. 3126, pp. 609–610.) A brief account of the work undertaken at the Dollis Hill Research Station.

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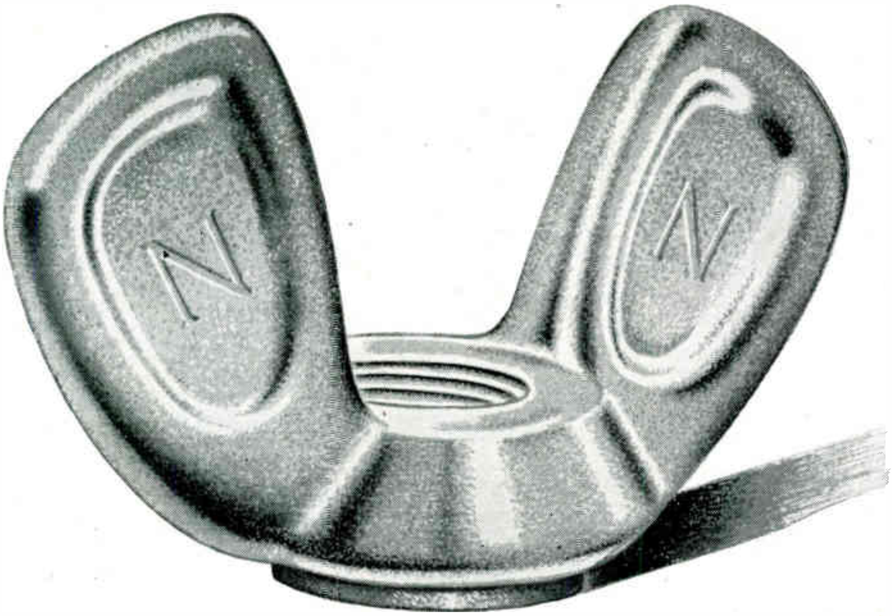

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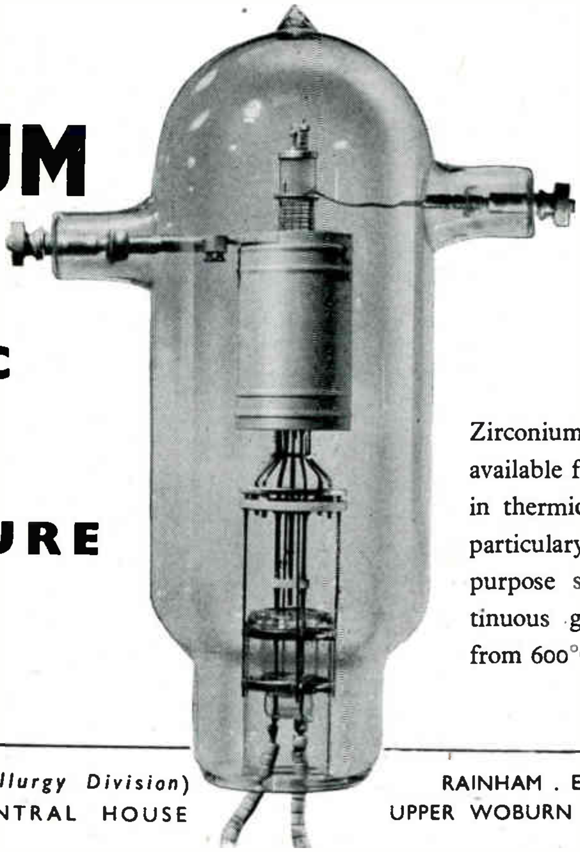

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The Board of Entry of the College invites applications from suitable candidates for the two-year course commencing in the Autumn of this year. Candidates should be of graduate standard, although the possession of a degree is not essential; a good Higher National Certificate is an acceptable qualification.

The College, a post-graduate institution, is devoted to the study of aeronautical science and engineering. The curriculum covers the five main subjects of Aerodynamics, Aircraft Design, Aircraft Electrical Engineering, Aircraft Propulsion, and Aircraft Economics and Production. Instruction in the first year is designed to provide students with a broad background of knowledge in all subjects, with opportunity for limited specialization in two or three subjects. In the second year students specialize more particularly, usually in one subject.

Experiments in the air are an important part of the work, both in the first year when all students take part in them and in the second year when they are linked to the specialist work of the departments.

Students who satisfactorily complete the course will receive the Diploma of the College.

Further particulars and details of the procedure for enrolment may be obtained on application to:

The Registrar,
The College of Aeronautics,
Cranfield,
Bletchley, Bucks.

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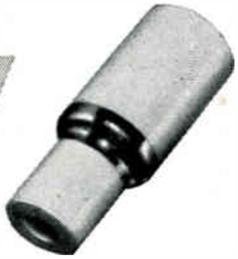

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APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order, 1952.

Belling & Lee. Ltd., Cambridge Arterial Road, Enfield, Middlesex, require research assistants in connection with work on electronic components, fuses, interference suppressors and television aerials. Applicants must be graduates of the I.E.E. or possess equivalent qualifications together with similar laboratory experience. Salary will be commensurate with previous experience: five-day week, contributory pension scheme. Applications must be detailed and concise, and will be treated as confidential.

S. Smith & Sons (England), Ltd., Bishops Cleeve, Cheltenham, require the following staff:—

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Development Engineers—for work on auto control and servo systems. Applicants with experience in low frequency electronic techniques, including the use of magnetic amplifiers. Preference given to those with previous experience in designing equipment for aviation requirements. Salary according to qualifications and experience. Ref. 3/EN.

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Brighton Education Committee—Brighton Technical College.
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Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience, and mentioning this paper, to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M.29184.B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.

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Apply at once by letter, stating age, full names in block letters and full particulars of qualifications and experience, and mentioning this paper, to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M.29100.B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.

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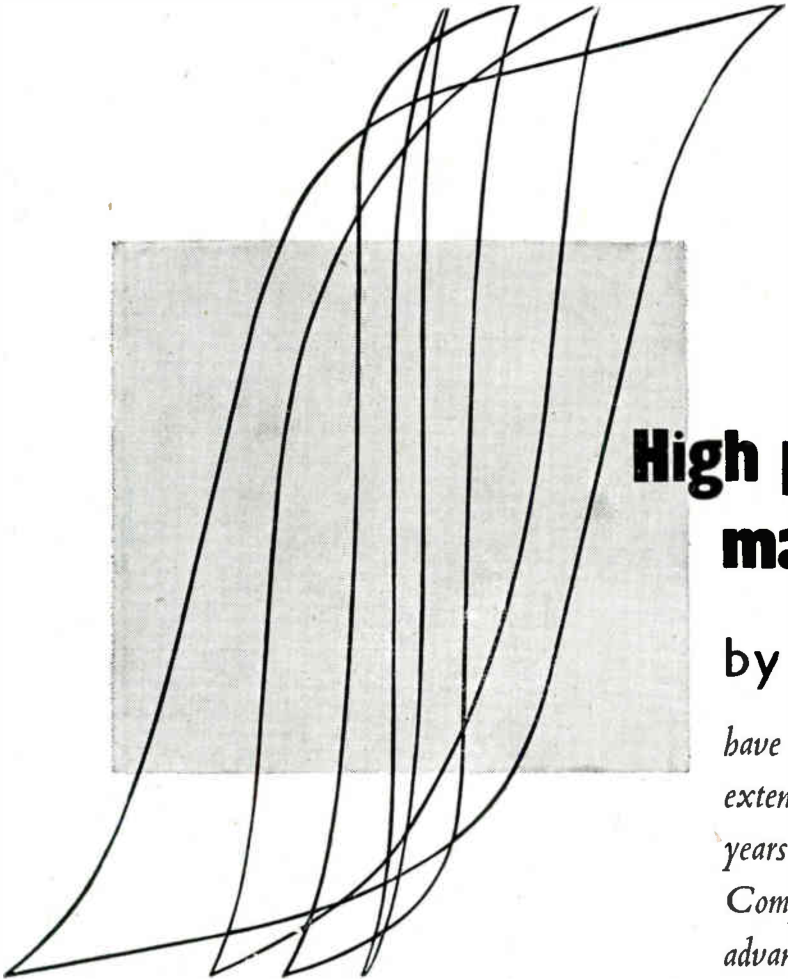

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Radio Engineers required for design work on aircraft radio systems Apply Employment Manager, Vickers-Armstrongs, Ltd. (Aircraft Section), Weybridge, Surrey.

Development Engineers required for Development Laboratory of light engineering factory in Stockport, experienced in circuit design for Radio, Test-gear, and Electronic Instruments. HNC, City and Guilds (telecommunications) Degree, essential. Write stating age and full details of experience and qualifications.—Box 7630, c/o *Wireless Engineer*.

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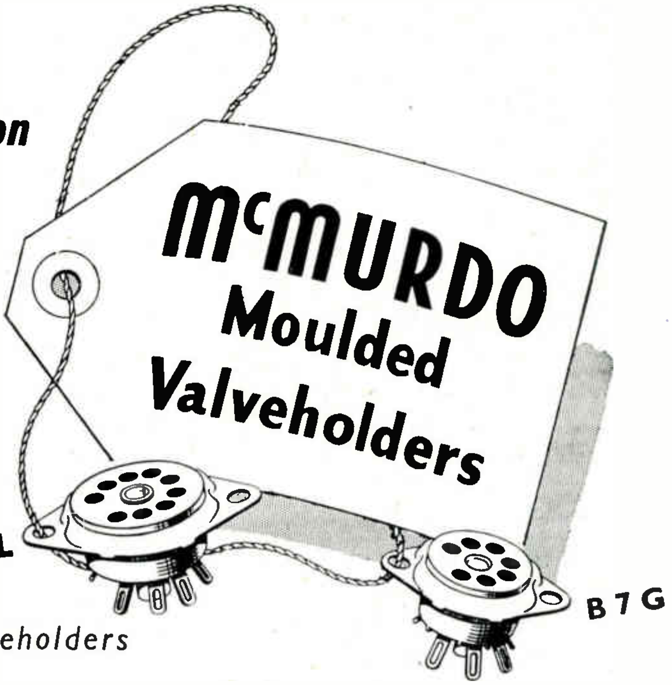

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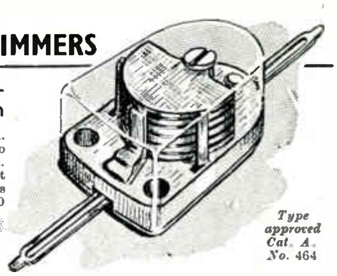

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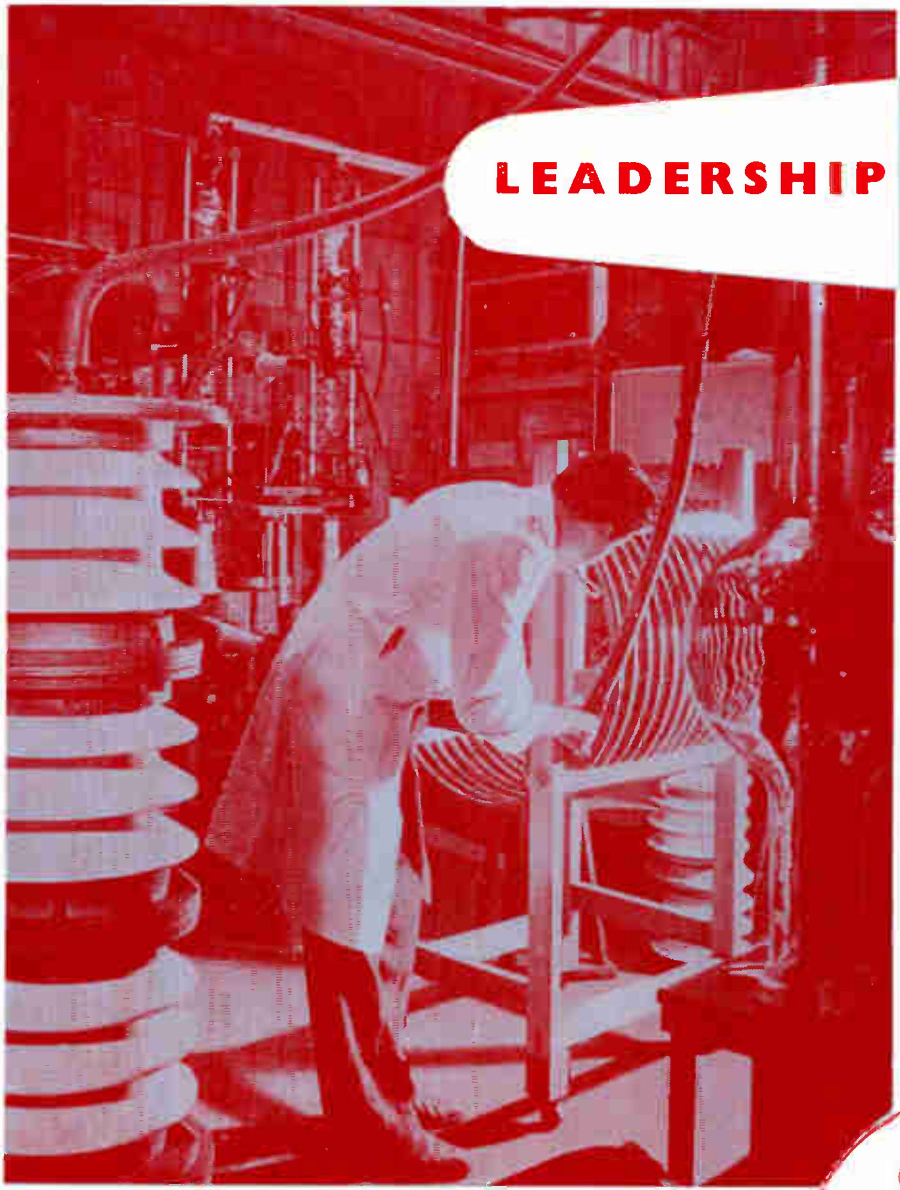

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