ELECTRONIC & RADIO ENGINEER

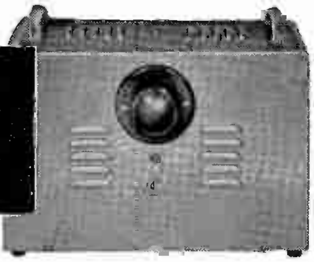
Incorporating **WIRELESS ENGINEER**

In this issue

Three shillings and sixpence

FEBRUARY 1957 Vol 34 *new series* No 2

A-C AUTOMATIC VOLTAGE REGULATORS
39 BASIC TYPES IN 6 DESIGN SERIES



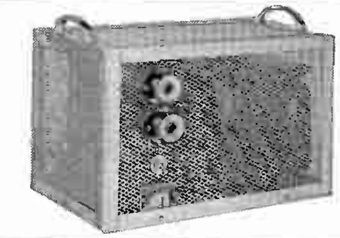
BMVR - 1725

WIDEST RANGE IN THE WORLD?

So far as we are aware, our range of A.C. Automatic Voltage Stabilisers is the largest in the World. We have a very wide range of standard models, single-phase patterns ranging from 200 VA to about 30 kVA (3-phase types up to about 90 kVA). There are 39 basic types, in six distinct design series, and all are available in standard form or as tropicalised instruments. We feel that on this account there can be few, if any requirements covering Stabilisers that we are not in a position to meet economically, efficiently and promptly.

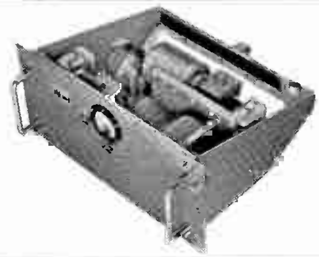
Here are very brief details of the six main series, in handy tabular form: cut this ad. out and use it as a Buying Guide; but please remember that if you do not see *exactly* what you require a written enquiry will probably reveal that we have a "special" to suit, or that the answer is under development. New stabilisers are regularly being added to our range. Several are at the very advanced development stage now—and we do design "specials". One such "special" (AM type 10D/20161) is illustrated (Illustrations not to scale). Nearly 100 have been supplied to Murphy Radio Ltd. for incorporation in equipment supplied by them to the Air Ministry for use on a chain of Radar Marker Beacons. 45 in slightly differing form are currently being made by us for the Air Ministry for another Radar Chain.

For complete data request our 20-Page Supplement Ref. V-549-S and its associated Special Price List, CLL Form VSP-56/16.

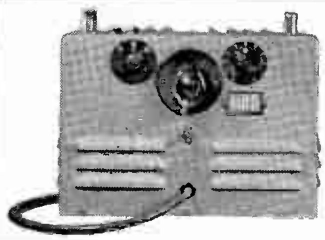


BAVR 1000 & BAVR - 1000 E

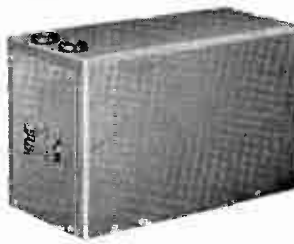
BMVR - 7000 - Series & TCVR - 7000 - Series



BMVR - 2750 - S58 (AM Ref. 10D 20161)



BMVR - 2750/VV & TCVR - 2750 VV



ASR - 1150 & ATC - 575.

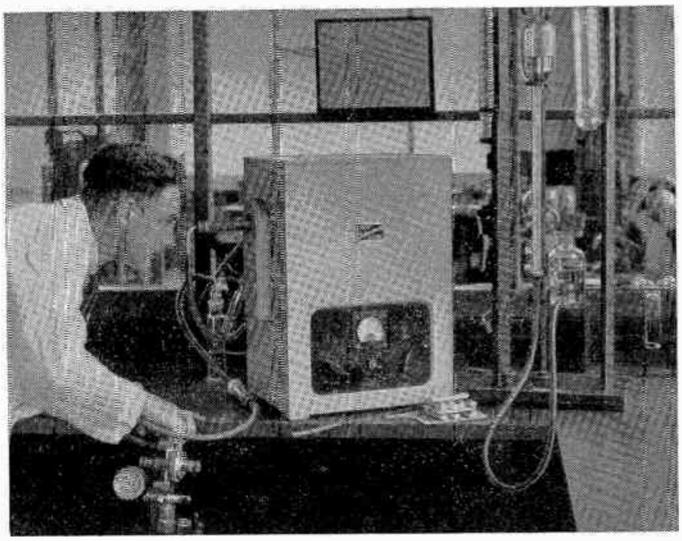
DESIGN SERIES	ASR	ATC	BAVR	BAVR-E	BMVR	TCVR
Input Voltage "Swing"	−10% to +5%	−20% to +10%	−10% to +5%	−10% to +5%	Depends on power: typical is from −19% to +8.5%	
Output Voltage Stability	±2½%	±5%	±0.15%	±0.15%	Usually ±0.5%	Usually ±0.5%
Change due to load (0-100%)	NEGLIGIBLE		±2.0%	±0.3%	NIL	NIL
Harmonics Generated	NIL	NIL	YES	YES	NIL	NIL
Response Speed	PRACTICALLY INSTANTANEOUS AVERAGING				1 V/Sec.	40V/Sec.
	2-3 CYCLES		1 CYCLE			
Power Ratings	1150VA 2300VA	575VA 1150VA	200VA 500VA 1000VA	200VA 500VA 1000VA	1600VA to 30kVA (18 models)	1600VA to 12kVA (11 models)
Basic Prices *	£24 to £34	£24 to £34	£50 to £79	£59 to £88	£75 to £237	£91 to £144

* From May 1st 1956, subject to 7½% increase.

Claude Lyons Ltd.

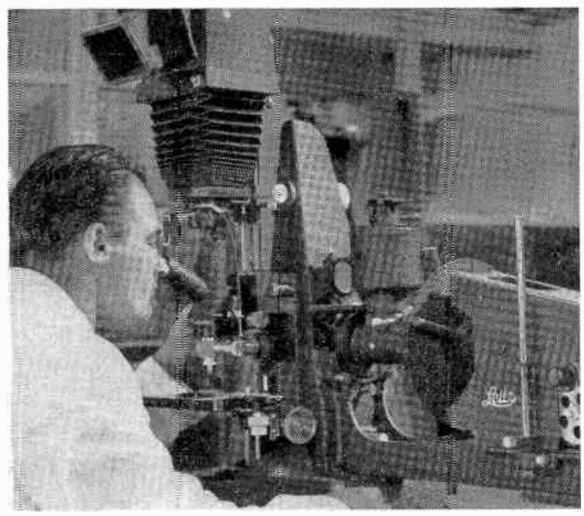
STABILISER DIVISION

HODDESDON · ENGLAND · TEL: HODDESDON 3007 (4 LINES) · 'GRAMS: MINMETKEM, HODDESDON



INSPECTION?

YES, BUT QUALITY CANNOT BE INSPECTED INTO A SCREW



Here we show you a very important part of our organisation. Inspection. The man at the top is calculating the carbon content of steel and on the right is a metallurgical microscope for examining material structure and grain flow. At Unbrako, quality control procedures are highly developed, we build quality into the product by controlling the materials and methods of production. We inspect the screws, too, but we cannot make good screws by inspection. We must inspect, control, ceaselessly check the materials, the tools, the machinery, the men. If these are right, the screws will be right, too.

UNBRAKO SCREWS COST LESS THAN TROUBLE

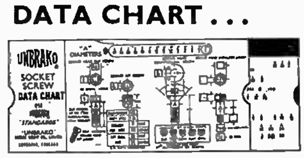
UNBRAKO

UNBRAKO SOCKET SCREW CO. LTD. COVENTRY

Every Unbrako screw is made from steel produced to a specification to suit the particular job it has to do. It is heat-treated and subsequently stress-relieved to give extra strength in the planes and positions that are going to be under the greatest strain in each kind of job. At the trouble spots under the head and at the root radius of the threads Unbrako incorporate fatigue-resisting fillets to make a strong screw stronger. The result? With Unbrako you can use fewer screws and smaller screws to take the same strain, use them with absolute confidence, too, because nowhere in the world are better screws made. May we send you some more details?

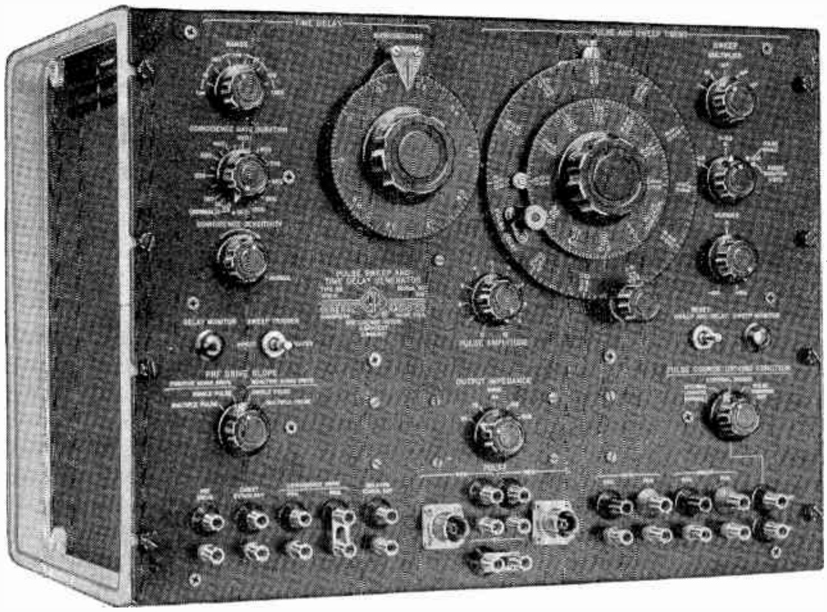
FREE

DATA CHART . . .



In the drawing office, in the toolroom or on production — you'll save valuable time and avoid costly guess-work with this free data chart, it cuts out all physical measurements or calculation.

An extremely versatile generator for time-domain measurements



GENERAL RADIO COMPANY GR

'GENERAL RADIO' TYPE 1391-A
PULSE, SWEEP AND TIME-DELAY GENERATOR

The new Type 1391-A Pulse, Sweep and Time-Delay Generator performs, individually and in combination, all the functions described by its title and performs them all well; its excellent performance results from a minimum number of compromises in design. Its wide ranges and complete flexibility of circuit interconnection make it a highly satisfactory pulse generator for laboratories engaged in time-domain measurements and waveform synthesis.

The transition times of the output pulses are compatible with most present-day oscilloscopes. The internal sweep circuit makes it possible to deflect an inexpensive oscilloscope by direct connection to the deflecting plates, to monitor the output pulse.

Among its many applications are measurement and testing in the fields of:

Echo ranging	Computers
Radio navigation	Telemetering
Television	Physiological research

DESCRIPTION The Pulse, Sweep and Time-Delay Generator consists of the following major circuit groups: (1) input synchronizing circuits, (2) delay and coincidence circuits, (3) sweep circuits, and (4) pulse-timing and pulse-forming circuits.

3 INSTRUMENTS IN 1

PULSE GENERATOR SWEEP GENERATOR TIME-DELAY GENERATOR

This is truly a *complete* Time-Domain Measuring Instrument, giving the best performance obtainable with ultra-modern techniques plus the finest obtainable materials and components, backed by over forty years manufacturing experience. A very well thought-out design, developed over several years, provides the pulse specialist with the equipment he has long been seeking.

SUPERIOR PULSE CHARACTERISTICS:
Excellent Rise and Decay Times: 0·025 ± 0·01 μsec. No Duty-Ratio or Frequency Restrictions on the Pulse.

HIGH BASIC TIMING ACCURACY:
Timing Scales are Linearly Calibrated, and accurate to 1%.

WIDE RANGES OF:

- PULSE DURATION: 0·05 μsec—1·1 sec.
- PULSE REPETITION RATE: 0-250 kc.
- TIME DELAY: 1 μsec—1·1 sec.
- DELAY REPETITION RATE: 0-400 kc.
- OUTPUT IMPEDANCE: 0-600 ohms.

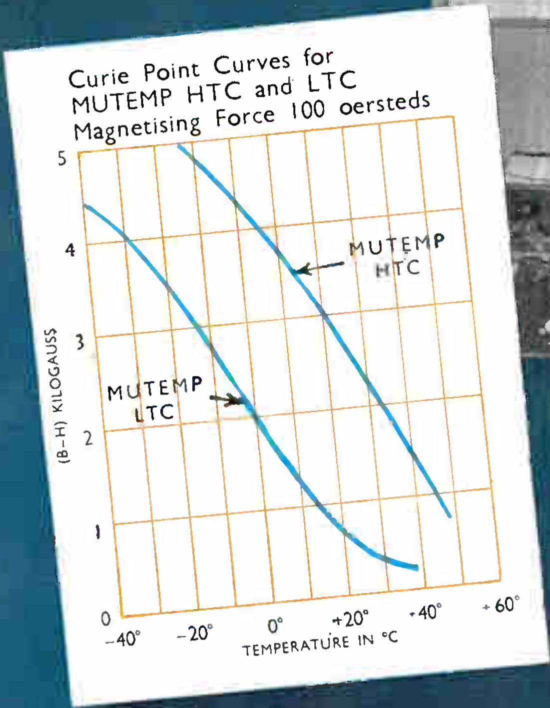
This is a large instrument, and it is supplied complete with its necessary power supply (not illustrated), arranged at choice for bench or rack operation. The Generator proper has thirty-six vacuum tubes. Considering its flexibility and completeness the price is reasonable —£1,047 net delivered (U.K. only). For complete data see the 13-Page article in "GENERAL RADIO EXPERIMENTER" for May 1956, (Vol. 30, No. 12) or request the latest "G.R." Catalogue '0' Send your written application to our nearest address, please.

Claude Lyons Ltd.

76 OLDHALL STREET · LIVERPOOL • VALLEY WORKS · HODDESDON · HERTS

Telephone: Central 4641/2 Telephone: Hoddesdon 3007 (4 lines)

CL26



Measurement of the change in characteristics with temperature.

Application of a MUTEMP compensator to a domestic kWh meter.

MUTEMP: a temperature-compensating alloy

This alloy, for use in electric instruments subject to wide variations in temperature, is now available in two distinct grades. The two grades ensure satisfactory coverage for a wide range of temperature change. It will be seen from the curves that MUTEMP LTC has characteristics suitable for the low temperature and HTC for the higher temperature ranges. MUTEMP is supplied in hot-rolled sheets up to 17 ins. wide and in thicknesses ranging from ·125 ins. to ·020 ins.

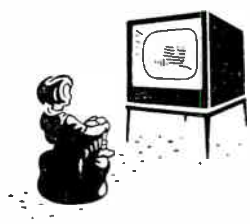
Full details may be obtained from our current catalogue, where its temperature characteristics are set out at three standard magnetizing forces, 2, 18 and 100 oersteds.

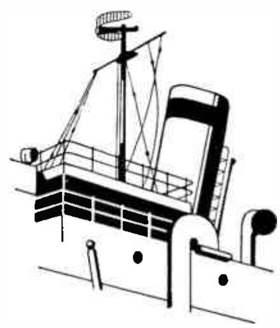
RICHARD THOMAS & BALDWINS LTD.

LAMINATION WORKS: COOKLEY WORKS, BRIERLEY HILL, STAFFS.
MIDLAND SECTION OFFICE: WILDEN, STOURPORT-ON-SEVERN, WORCS.
HEAD OFFICE: 47 PARK STREET, LONDON, W.1

Our Cookley Works is one of the largest in Europe specializing in the manufacture of laminations for the electrical industry.

RTB





High Speed Switching...

and the

Carpenter Polarized Relay

THE PROBLEM OF PRESERVING the correct time relationships in the operation of remote switches by short-duration d.c. impulses, is effectively solved by the Carpenter Relay which is highly sensitive and operates at high speed with the minimum of contact bounce.

It is equally efficient whether it is a question of operating the switch directly by closing a mechanical contact in the energizing circuit (as in the simpler remote control systems), or by the consecutive operation of many relays in complicated electronic switching units (as in the latest radar systems).

The ability of the Carpenter Relay to operate quickly on extremely short impulses has facilitated the development of electronic counting circuits (analogue computors) requiring a rapid change-over contact for comparing two different voltage levels—the construction of electronic stimulators for physiological treatment and biological research, requiring the availability of several electrical pulses with adjustable time relationships—and high-speed Telegraph and Teleprinter equipment.

If your project involves *High-Speed Switching*, details of the Carpenter Relay's performance cannot fail to be of value to you; and you will find much to interest you in our Brochure F.3516, "*Applications of the Carpenter Polarized Relay.*" Write us, or telephone, *now.*

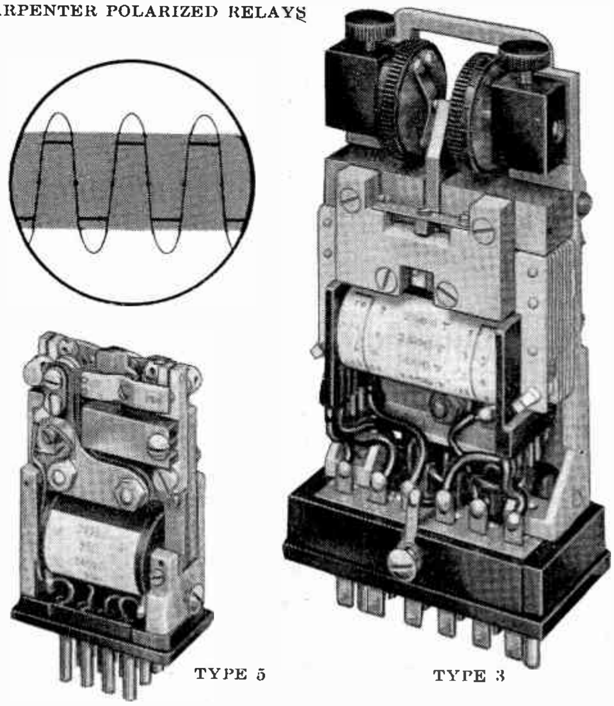
Manufactured by the Sole Licensees:

TELEPHONE MANUFACTURING COMPANY LTD

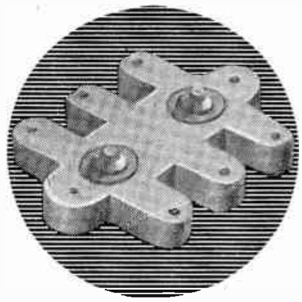
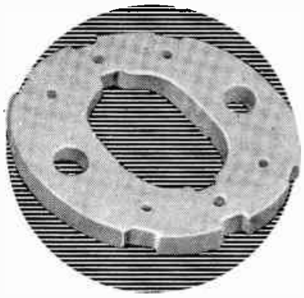
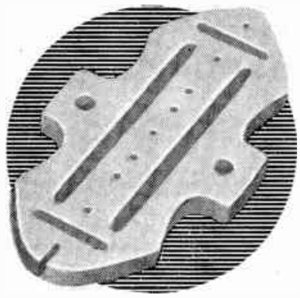
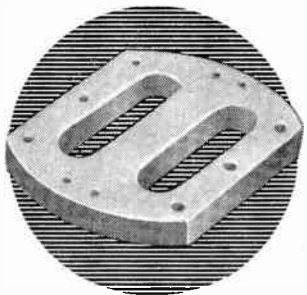
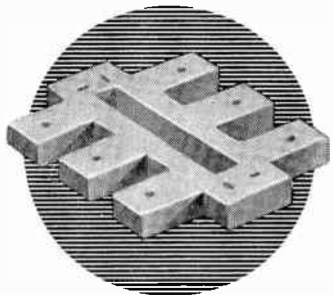
Contractors to the Governments of the British Commonwealth and other Nations.

HOLLINGSWORTH WORKS · DULWICH · LONDON S.E.21
TELEPHONE: GIPSY HILL 2211

CARPENTER POLARIZED RELAYS



TYPE 5 TYPE 3

E·M·I

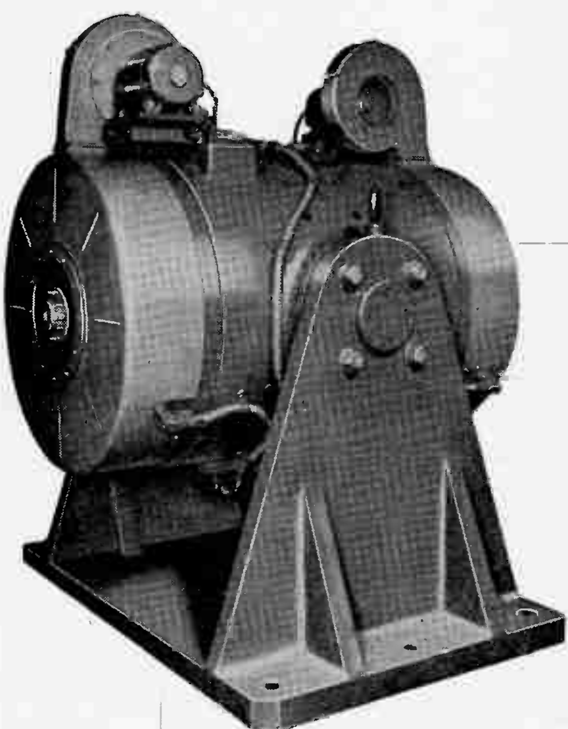
VIBRATION EQUIPMENT

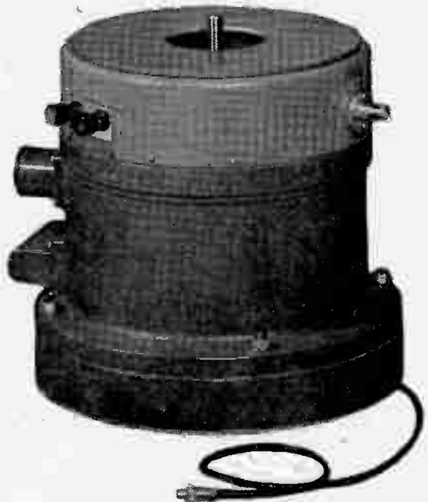
FOR HIGHLY SPECIALISED INVESTIGATIONS

Designed and manufactured by E.M.I., a company with many years' experience of vibration problems. This experience, gained in their own laboratories, has enabled E.M.I. to build equipments that fulfil the most exacting requirements in the field of vibration measurement.

- No re-magnetisation is required, with either model, since the field is electro-magnetic.
- The EMV 5 is trunnion-mounted and may be used in the vertical, horizontal or 45° position.
- Complete installation and instrumentation undertaken.
- Technical Advisory Service on vibration problems.

EMV 1 ▶
120 lb. Peak Thrust
5cps – 10kc/s for Max.Audio Power 1kW
Built in Accelerometer





◀ EMV 5
3000 lb. Peak Thrust
5cps – 1kc for Max.Audio Power 5kW
Excursion 0.9″
Built in Accelerometer

OTHER PRODUCTS

ELECTRONIC TACHOMETERS · PHOTO-ELECTRIC TRANSDUCERS · DYNAMIC BALANCING MACHINES
H.F. HEATING EQUIPMENT · STROBOSCOPES

E.M.I. ELECTRONICS LTD. INDUSTRIAL PRODUCTS DIVISION (DEPT. 20B) HAYES · MIDDLESEX · ENGLAND
Telephone: SOUthall 2468, Ext. 473
Part of the E.M.I. Group . . . Britain's Foremost Electronic Engineers
EE71

ELECTRONIC & RADIO ENGINEER

incorporating *WIRELESS ENGINEER*

HUGH S. POCOCK M.I.E.E. *Managing Editor*
W. T. COCKING M.I.E.E. *Editor*
Professor G. W. O. HOWE D.Sc., LL.D., M.I.E.E., Hon. M. Brit. I.R.E. *Technical Consultant*

CONTENTS

VOLUME 34 NUMBER 2 FEBRUARY 1957

Established 1923
Published on the fifth of each month

ANNUAL SUBSCRIPTION
(including Annual Index to Abstracts and References)
Home and Overseas £2 9s od
Canada and U.S.A. $7.50

PUBLISHED BY ILIFFE & SONS LTD. DORSET HOUSE STAMFORD STREET LONDON S.E.I
Telephone . Waterloo 3333 (60 lines) *Telegrams . Wirenger, Sedist, London*

BRANCH OFFICES AT BIRMINGHAM MANCHESTER GLASGOW

VOLUME 34 NUMBER 2

FEBRUARY 1957

ELECTRONIC & RADIO ENGINEER

incorporating WIRELESS ENGINEER

Transistor Amplifiers

AT radio-frequency, the transistor has still a long way to go, for its performance is considerably inferior to that of the modern thermionic valve. It is actually in a rather similar state to the valve of thirty years ago. Only triodes of low efficiency were then available and they required neutralizing to maintain stability. Stage gains were about 20–30 dB, which is about the same as the transistor of today.

Neutralizing made its appearance about 1925 and represented an enormous advance upon the previous technique of obtaining stability by reducing the stage gain, which was done by the application of positive bias to the grid! The neutralized triode was widely used until the screen-grid valve appeared but, by 1928, it had passed out of the average receiver.

In those years a great deal of work was done on neutralizing circuits and it was found that the most satisfactory were the ones reducible to a frequency-independent bridge. One of these, with bifilar-wound primary and neutralizing coils, was used in the famous "Everyman Four" (*Wireless World*, 28th July and 4th August 1926) and, in conjunction with efficient coils, enabled the then unheard of stage gain of thirty times to be obtained.

We feel that some transistor-amplifier designers would not find it a waste of time to browse in some of the literature of those far-off days. We, who remember them well, see many similarities between the old triode and the new transistor amplifiers. We see, too, attempts to use neutralizing circuits which were then discarded as being too tricky.

Anyone who does search the old literature will find that neutralized-triode amplifiers of more than two stages were very rare indeed. They were, in fact, exceedingly difficult to keep stable. We suspect, however, that this was nothing to do with the neutralizing. At that time, coils were usually unscreened and were air-core of 2–3 in. diameter; they were critically positioned for minimum coupling. Had it then been possible to make compact, efficient screened coils and had as much then been known as there is now about coupling in the wiring, we think that three or even four neutralized triode stages would have presented little difficulty.

It may be, of course, that, like the valve, the "triode" transistor as an r.f. amplifier is doomed to disappear and to be replaced by a "screened-base" transistor. Or it may be that, this time, neutralizing will be with us for good. If it is, we do not think that it will be a serious drawback to the transistor, merely an inconvenience.

Solenoids for Airborne Applications

By A. S. Gutman*

SUMMARY. *The design of solenoids for airborne applications, such as providing focusing fields for travelling-wave valves, is influenced by considerations of weight. The total effective weight depends on the equivalent weight of the equipment which generates power to energize the solenoid and the weight of cooling devices, as well as on the weight of the solenoid itself.*

A formula is derived for the optimum dimensions of a single-turn solenoid, taking account of its own weight and that of associated power-generating equipment. Various forms of practical multi-turn solenoids are considered, and foil-wound constructions are selected, because of their greater space efficiencies than wire-wound types. Consideration is then given to heat transfer with different forms of foil-wound equipment, and to coil design when the operating voltage is fixed. A wafer-type layer-wound coil is preferred to an edge-wound type because the ease of manufacture of the former offsets the slight power saving obtained with edge winding.

The fact that the weight of a solenoid of given field strength can be reduced if its power dissipation is increased is utilized in the design of solenoids for airborne applications. By adjusting the weight and the power dissipation, an analytical method is developed for designing an optimum single-turn solenoid.

The modification of the single-turn solenoid design for various types of multiple-turn solenoids is discussed.

The optimum operating temperature of solenoids can be determined from an overall systems analysis based on weight penalties for power consumption and for cooling air consumption. A high temperature solenoid has a higher power consumption for a given current due to the temperature coefficient of electrical conductors. A low temperature solenoid utilizes the cooling air inefficiently. This analysis determines the operating temperature that results in minimum overall weight penalty due to these two effects.

1. Basic Design Considerations

The magnetic field strength H of a solenoid of length l and current I is

$$H = \frac{4\pi n I}{25{\cdot}4 l} \quad \ldots \quad (1)$$

The power dissipation is

$$P = I^2 R \quad \ldots \quad (2)$$

where R is the resistance of the solenoid. The resistance is determined by the resistivity ρ of the conductor used, its length, and its cross-section A. For the purpose of this investigation, it is best to start with a one-turn solenoid with an inner diameter d_1 and an outer diameter d_2. See Fig. 1 (a).

The cross-section of the conductor is then

$$A = l\frac{d_2 - d_1}{2}$$

The average length of the current path is

$$L = \pi\frac{d_2 + d_1}{2}$$

and the resistance is

$$R = \rho\frac{L}{A}$$

Combining these equations,

$$R = \rho\frac{\pi}{l}\left[\frac{d_2 + d_1}{d_2 - d_1}\right] \quad \ldots \quad (3)$$

and the expression for the power dissipation becomes

$$P = I^2\rho\frac{\pi}{l}\left[\frac{d_2 + d_1}{d_2 - d_1}\right] \quad \ldots \quad (4)$$

The weight of the solenoid is

$$W = l\frac{\pi}{4}\,\delta\,(d_2 + d_1)\,(d_2 - d_1)$$

where δ is the density of the conductor.

The outer diameter and length of the device* to be placed in the solenoid determine its inner diameter and length. The outer diameter of the solenoid can be chosen by design considerations. Equation (4) shows that the power dissipation becomes minimum as the outer diameter approaches infinity. To determine d_2, a factor (α), which gives the equivalent weight of the power consumed, is required. If the solenoid is part of an airplane equipment, α is the weight of machinery and fuel required to generate 1 watt. In our case

$$\alpha = 0{\cdot}050 \text{ lb/watt.}$$

With this value of α, the total effective weight is

$$W_t = W + \alpha P$$
$$= l\pi\delta\,b^2 + l\pi\delta\,d_1 b + \frac{\pi}{l}\,\alpha\,I^2\rho + \frac{\pi}{l}\,\alpha\,I^2\rho d_1\frac{1}{b} \quad (5)$$

where the thickness $b = (d_2 - d_1)/2$, see Fig. 1 (a).

To find the minimum weight, we differentiate equation (5) with respect to b and equate to zero. Doing this, and writing $\lambda = 2\,b/d_1$, we get

$$\lambda^2\,(\lambda + 1) = \frac{\alpha\rho}{\delta}\left(\frac{2I}{ld_1}\right)^2 \quad \ldots \quad (6)$$

* *Sylvania Electric Products Inc., Waltham, Mass., U.S.A.*

* Such a device may be a travelling-wave valve.

it can be seen that

(a) for $\lambda \gg 1$,

$$\lambda_1 \approx \left(\frac{2I}{ld_1}\right)^{2/3} \left(\frac{\alpha\rho}{\delta}\right)^{1/3}$$

(b) for $\lambda \ll 1$,

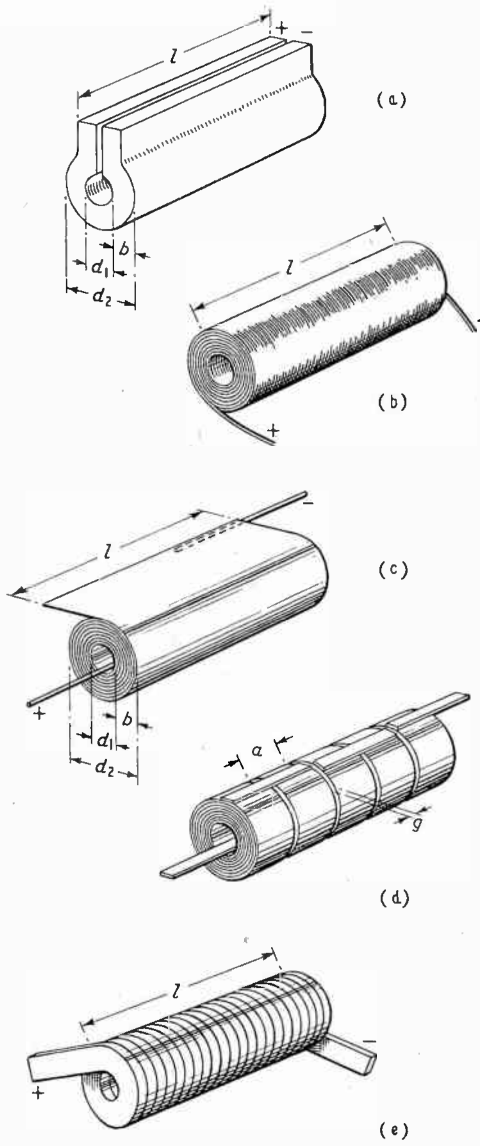
$$\lambda_2 \approx \left(\frac{2I}{ld_1}\right)\sqrt{\frac{\alpha\rho}{\delta}}$$

(c) if $\lambda \approx 1$, the value of λ_3 can be found by trial and error and lies between λ_1 and λ_2.

From the definition of λ we have $b = d_1\lambda/2$ and from Fig. 1 (a) it follows that $d_2 = d_1(\lambda + 1)$.

This determines the optimum dimensions of the one-turn solenoid. Such a solenoid would have to be operated at a high current and a low voltage. For practical purposes it is desirable to operate the solenoid at lower currents and higher voltages. This can be accomplished by using an ordinary multiple-turn wire-wound solenoid, as in Fig. 1 (b). However, because of the spaces between wires, the cross-section of a multiple-turn, wire-wound solenoid is different from that of the single-turn solenoid.

Fig. 1. This diagram shows various forms of solenoids: (a) single turn; (b) wire-wound; (c) foil-wound; (d) sectionalized foil-wound; and (e) edge-wound strip



If a solenoid is formed of flat foil, with negligible space between layers of foil, Fig. 1 (c), the resulting multiple-turn solenoid[1] will be equivalent to a single-turn solenoid in weight, power consumption, and magnetic field strength. To permit the use of still higher voltages and lower currents, the foil-wound solenoid can be divided into several sections, or wafers as in Fig. 1 (d). If the gaps between the wafers are neglected, the wafer-type, foil-wound solenoid is also the equivalent of the single-turn solenoid. Another method that can be used to obtain an equivalent multiple-turn solenoid is edge-winding,[2] illustrated in Fig. 1 (e).

The following conclusions can be reached before discussing the effects of heat transfer and insulation thickness:

(a) The space efficiency of wire-wound solenoids is poor compared with that of solenoids wound from conductors with rectangular cross-sections.
(b) There is no difference in space efficiency of foil-wound or edge-wound solenoids.
(c) The wafer-type foil-wound solenoid offers the best possibility for constructing high-voltage solenoids.

Insulation Thickness

In the previous section the thickness of the insulation between conducting layers has been neglected. However, since no electrical insulation with zero thickness exists, it must be taken into consideration in solenoid design.

Assuming n_1 layers of a conductor with thickness u, resistivity ρ_u, and density δ_u, separated by an insulator with thickness v and density δ_v, the average density of the coil is

$$\delta = \frac{u\delta_u + v\delta_v}{u + v} = \frac{\delta_u + \frac{v}{u}\delta_v}{1 + \frac{v}{u}} \qquad \text{(7)}$$

The average resistivity of the coil is

$$\rho = \rho_u\left(1 + \frac{v}{u}\right) \qquad \text{(8)}$$

Inserting these new values of ρ and δ in equation (5), the optimum solenoid dimensions can be calculated as before, for the solenoids illustrated in Figs. 1 (c) and (e). The foil-wound solenoid illustrated in Fig. 1 (d) requires a further correction for the gap width between the wafers. With a width a of one wafer and a gap g between wafers, one obtains for this case

$$\delta = \frac{\delta_u + \frac{v}{u}\delta_v}{\left(1 + \frac{v}{u}\right)\left(1 + \frac{g}{a}\right)} \qquad \text{(7a)}$$

[1] Sylvania Electric Products, Inc., has a patent on foil-wound coils, developed by T. Wroblewski and A. Zack, of Ipswich Lighting Division.

[2] This type of coil was developed by Sylvania Bayside Laboratories under Dr. A. W. Friend and associates.

$$\rho = \rho_u \frac{\left(1 + \frac{v}{u}\right)\left(1 + \frac{g}{a}\right)}{\frac{v}{u}} \quad \ldots \quad \ldots \quad \ldots \quad (8a)$$

Heat Transfer

Since heat generated in the conductor of the solenoid has to be dissipated, it is desirable to have effective heat transfer. This will result in lower operating temperatures, thereby:

(a) reducing deterioration of the insulation material,
(b) keeping the resistivity of the electrical conductor at a minimum.

One of the advantages of foil-wound over wire-wound solenoids is that a more direct heat transfer from the foil to the air is possible, because, in a wire-wound solenoid, much of the heat has to travel through several layers of electrical insulation before reaching a cooled surface. In a foil-wound solenoid the edges of each turn occur at cooled surfaces.

As the length of the solenoid is increased, the edge-wound has a better heat transfer characteristic than the foil-wound type, owing to the greater exposed surface area of the former. However, the wafer-type foil-wound solenoid can be designed to have as large a heat transfer area as the edge-wound with very little increase in wasted space.

This increase is $(a + g)/a$. The g can be kept very small compared to a, since a small gap serves as an excellent air duct, resulting in efficient heat transfer.

Tests show that solenoids designed for optimum weight penalty are not subject to high operating temperatures; therefore, heat transfer is not a major problem.

Design for a Voltage

For the initial calculations of the diameter d_2, only the ratios v/u and g/a have to be estimated. For the single-turn solenoid, the voltage is $E = IR$ with I obtained from equation (1) (with $n = 1$) and R obtained from equation (3).

In a practical design of a multiple-turn solenoid, the voltage is specified and is higher than the voltage of the single-turn solenoid. Therefore, it is necessary to decide on the subdivisions that should be used to convert the single-turn into a multiple-turn solenoid. Practical design considerations, such as the thickness of available foil, limit the number of sections used.

If the solenoid is divided into n sections and the n sections are connected in series, the resistance, current, and voltage of this new solenoid are

$$R_n = n^2R; \; I_n = \frac{I}{n}; \; E_n = nE$$

For edge-wound solenoids $l = n(u + v)$.
For foil-wound solenoids $b = n(u + v)$.

For the wafer-type foil-wound solenoid it is necessary to decide on both the number of layers and the number of wafers to be used. With n_1 layers and n_2 wafers

$$R_m = n_1^2 n_2^2 R; \; I_m = \frac{1}{n_1 n_2} I; \; E_m = n_1 n_2 E$$

Furthermore

$$n_1(u + v) = b \text{ and } n_2(a + g) = l.$$

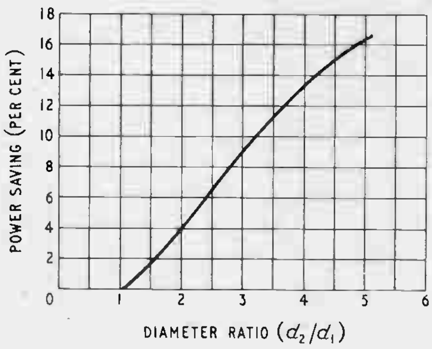


Fig. 2. *Effect of diameter ratio on power saving of edge-wound solenoid over a foil-wound one.*

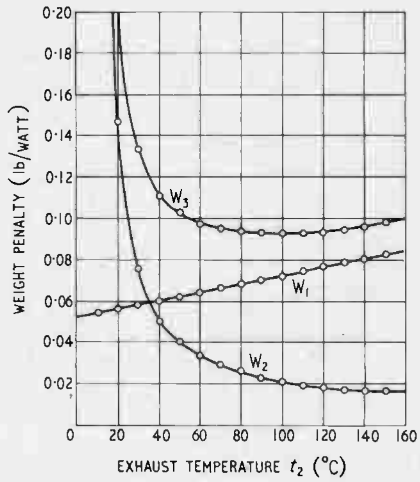


Fig. 3. *Weight penalties of the example calculated in the text; W_1 refers to the electrical power consumption; W_2 to the cooling air and W_3 to the two combined.*

Effects of Non-Uniform Current Densities

In layer-wound wire or foil solenoids, the current densities are almost uniform throughout any cross-section of the conductor. In edge-wound solenoids there is a tendency for the current to crowd along the inner circumference where the path length is shorter. The resulting higher current density at the centre of the solenoid produces a desirable effect.

This effect is analysed in the following paragraphs.

Layer-Wound Solenoids

Taking the inner and outer radii as r_1 and r_2 respectively, the average length of the conductor in a layer-wound solenoid is

$$L = \pi n(r_1 + r_2)$$

for n turns. Therefore, the resistance of the layer-wound one-turn solenoid is

$$R_1 = \frac{\pi\rho}{l} \cdot \frac{\frac{r_2}{r_1} + 1}{\frac{r_2}{r_1} - 1}$$

Edge-Wound Solenoids

For the edge-wound solenoid, the earlier equation for resistance can be restated as

$$\frac{1}{R_2} = \frac{1}{\rho}\int\frac{dA}{L}$$

where $L = 2\pi r$ and $dA = l\ dr$, which gives

$$\frac{1}{R_2} = \frac{l}{2\pi\rho}\int_{r_1}^{r_2}\frac{dr}{r} = \frac{l}{2\pi\rho}\log_e\left(\frac{r_2}{r_1}\right)$$

Power Consumption of Layer- and Edge-Wound Solenoids

For a given current the power consumption of a solenoid is proportional to its resistance. Therefore, the ratio of the power consumption of a layer-wound solenoid to that of an edge-wound solenoid is

$$\frac{R_1}{R_2} = \frac{1}{2}\,\frac{\frac{r_2}{r_1}+1}{\frac{r_2}{r_1}-1}\,\log_e\left(\frac{r_2}{r_1}\right)$$

The graph in Fig. 2 shows the percentage of power saved by using an edge-wound solenoid instead of a foil-wound solenoid with the same diameter ratio. For ordinary applications, the slight power saving of the edge-wound solenoid is more than offset by its difficulty of manufacture, and the use of a foil-wound solenoid is more practical.

2. Optimum Operating Temperature

When the solenoid is cooled by forced air convection, the heat carried away by the cooling air is

$$3{\cdot}41q = 60w \times c_p \times \frac{9}{5}(t_2 - t_1)\text{ B.Th.U. per hour.}$$

With $c_p = 0{\cdot}24$ B.Th.U. per lb. the cooling air flow is

$$w = 0{\cdot}13\frac{q}{t_2 - t_1}\text{ lb. per minute}$$

With a current I flowing in the solenoid, the power dissipation is

$$q = I^2R\,[1 + \gamma\,(t_3 - t_1)]\text{ watts.}$$

The weight penalty due to electrical power consumption is

$$W_1 = \alpha q$$
$$= \alpha I^2R\,[1 + \gamma\,(t_3 - t_1)]\text{ lb.} \quad \ldots \quad \ldots \quad (9)$$

The weight penalty due to cooling air consumption is

$$W_2 = \beta w$$
$$= \beta\,0{\cdot}13\frac{I^2R\,[1+\gamma\,(t_3 - t_1)]}{t_2 - t_1}\text{ lb.} \quad \ldots \quad (10)$$

There are two unknowns in equations (9) and (10); the solenoid temperature t_3 and the exhaust air temperature t_2. Since $t_3 > t_2$, we can set

$$t_3 = t_2 + \triangle$$

Referring the weight penalties to a solenoid that has a power consumption I^2R of 1 watt and substituting for t_3 in equations (9) and (10) gives

$$W_1 = \alpha\,[1 + \gamma\,(t_2 - t_1 + \triangle)]$$

and

$$W_2 = \frac{0{\cdot}13\beta}{t_2 - t_1}[1 + \gamma\,(t_2 - t_1 + \triangle)]$$

The combined weight penalty for the unit solenoid is

$$W_3 = W_1 + W_2$$
$$= \alpha\,(1 + \gamma\,t_2 + \gamma\triangle - \gamma t_1)$$
$$+ \frac{0{\cdot}13\beta}{t_2 - t_1}(1 + \gamma\,t_2 + \gamma\triangle - \gamma t_1)$$

Designing for minimum combined weight penalty as a function of t_2, we put $dW_3/dt_2 = 0$ and neglect $d\triangle/dt$, which is small compared to 1. This gives

$$\alpha\gamma + \frac{130\,\beta\gamma}{t_2 - t_1} - \frac{130\beta}{(t_2 - t_1)^2}(1 + \gamma t_2 - \gamma t_1 + \gamma\triangle) = 0$$

or

$$(t_2 - t_1) = \sqrt{\frac{130\beta}{\alpha}(1/\gamma + \triangle)}$$

Assuming the following numerical values,

$$\beta = 10\text{ lb/lb/min}$$
$$\alpha = 0{\cdot}050\text{ lb/watt}$$
$$\gamma = 0{\cdot}004\text{ per °C}$$
$$t_1 = 10\text{°C}$$
$$\triangle = 20\text{°C}$$

the exhaust air temperature for minimum combined weight penalty is

$$t_2 = 93\text{°C} = 200\text{°F}$$

Fig. 3 shows a plot of W_1, W_2 and their combination W_3 against exhaust temperature.

SYMBOLS

SECTION 1

A	Cross section of conductor	inches²
a	Width of wafer	inches
b	Radial thickness of solenoid $(d_2—d_1)/2$	inches
d_1	Inner diameter of solenoid	inches
d_2	Outer diameter of solenoid	inches
E	Voltage of solenoid	volts
g	Gap between wafers	inches
H	Magnetic field strength	gauss
I	Current	amps
L	Average length of conductor	inches
l	Length of solenoid	inches
n	Number of turns	
n_1	Number of layers of conductor	
n_2	Number of wafers	
P	Power dissipation	watts
R	Resistance at ambient temperature	ohms
u	Thickness of conductor	inches
v	Thickness of insulator	inches
W	Weight of solenoid	pounds
W_t	Weight penalty	pounds
α	Equivalent weight factor	lb./w.
δ	Density	lb./in.³
δ_u	Density of conductor	lb./in.³
δ_v	Density of insulator	lb./in.³
ρ	Resistivity	ohm-inches

SECTION 2

c_p	Specific heat of the air	B.Th.U./lb. °F.
I	Solenoid current	amps
q	Heat dissipation of the solenoid	watts
R	Solenoid resistance at temperature t_1	ohms
t_1	Ambient and inlet air temperature	°C
t_2	Exhaust air temperature	°C
t_3	Average solenoid temperature	°C
W_1	Weight penalty due to electrical power consumption	lb.
W_2	Weight penalty due to cooling air consumption	lb.
W_3	Combined weight penalty	lb.
w	Cooling air flow	lb./min.
α	Weight penalty for power consumed	lb./watt
β	Weight penalty for cooling air consumed	lb./lb./min.
γ	Temperature coefficient of the conductor	per °C

The B.B.C. Radio Microphone

POCKET F.M. TRANSMITTER

By F. A. Peachey, M.I.E.E. and G. A. Hunt, B.Sc.*

In broadcasting, both sound and television, there has been a long-felt need for a microphone that can wander with the artist free of connecting leads. In sound broadcasting the commentator sometimes does not wish his purpose to be noticed by those among whom he moves and in television there is usually every desire to avoid showing the microphone to the viewers. Indeed, it is this television aspect that has driven the designer to produce, for this purpose, apparatus so miniature that it can be hidden on the person.

The use of a small radio transmitter for broadcasting purposes is by no means new. The B.B.C. has used the 'pack set' type of transmitter for many years and, possibly as a result of experience gained with such equipment, there has been a natural reluctance to degrade the quality of such radio links appreciably in the cause of miniaturization. Unlike a transmitter set up on a permanent and properly chosen site, these small transmitters have to operate under the most adverse conditions. They are naturally limited in power output, cannot benefit from ideal aerial arrangements and have to operate in places where it is almost impossible to make a reliable pre-assessment of the local noise level.

Signal-to-noise ratio, apart from general reliability, is the main criterion by which such a link succeeds or fails. To a large extent it has to compete with the almost perfect conditions attained by the wired microphone, in fact a fade-over from the wired microphone to the radio-linked microphone must not normally be noticeable by either a change in quality or an increase in background noise.

It is imperative, therefore, that a transmitter for this purpose must have the maximum possible power output and should capitalize the technical advantages of frequency modulation.

In earlier models, attempts were made to attain these objectives by using a capacitance microphone to provide a very simple form of frequency modulation. In such an arrangement the capacitance of the microphone controls the frequency of the oscillator driving the transmitter. This provides an exceedingly simple circuit design and has, in fact, been so attractive from this point of view that several other broadcasting organizations

* *Designs Department, British Broadcasting Corporation.*

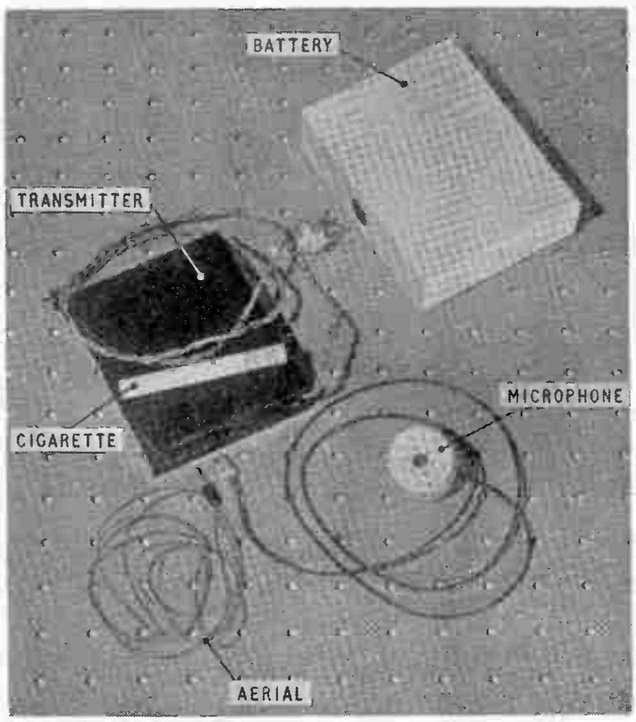


Fig. 1. *Peter Dimmock placing transmitter in his pocket (above) and the various units of the radio microphone (right)*

have adopted this system. It suffers, however, from two main disadvantages the foremost of which is the small amount of frequency deviation that can be attained by this method. Of lesser significance is the fact that, with this particular arrangement, it is difficult to have the high impedance circuit of the microphone far from the oscillator valve. This sometimes restricts the placing of the microphone on a convenient part of the clothing. Attempts have been made to increase the amount of frequency deviation by designing capacitance microphones which give an unusually large ratio change in capacitance when actuated by normal amplitude sound signals. The result seems to be a compromise between the amount of deviation and actual quality of reproduction; at the best, a deviation of about one part in ten thousand is attained before a noticeable degradation in frequency response occurs.

A transmitter has therefore been designed which largely overcomes these particular difficulties. Its specification is approximately as follows:

(a) Output power ¼ watt.
(b) Frequency modulated with a deviation of 75 kc/s.
(c) Operated from a detachable microphone and with sufficient audio gain so that various good grade microphones may be used.
(d) Operated continuously from the same battery for at least half an hour.
(e) So small that it may be slipped into any normal pocket or hidden under clothing. (The actual transmitter is the size of a packet of twenty cigarettes.)
(f) Operated at a frequency available to the B.B.C.; i.e., in the television transmitter range 50 to 70 Mc/s.

Fig. 1 shows the general external form of the transmitter and Fig. 2 the view of the inside of the transmitter unit. It has been designed around sub-miniature valves as, up to the present, suitable transistors are not available in this country. The replacement of valves by transistors will have the advantage, not of miniaturization, as the equipment is already small enough, but of improvement in the size and reliability of the battery supply. It may also enable the transmitter to be worked at a higher output power. With the present valves the overall

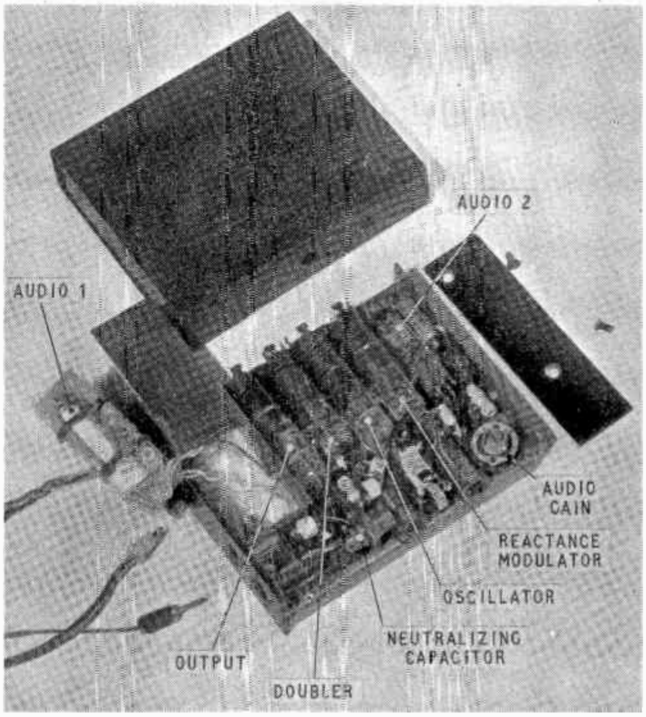


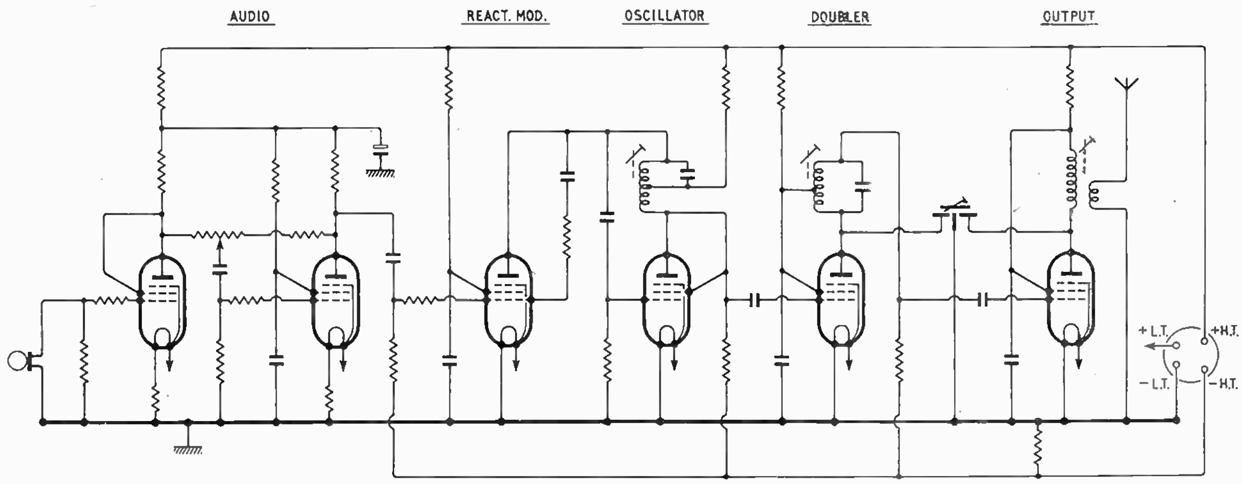
Fig. 2. *Inside view of transmitter*

power efficiency is about 16%. This means that, using valves, the transmitter casing has to dissipate about 1½ watts and, if the power is increased appreciably, a well-insulated pocket might get very hot indeed.

Neutralizing Circuit

The circuit of the transmitter is shown in Fig. 3 and is really conventional in every way, except possibly for the neutralizing arrangements on the output valve. For this purpose a variable capacitor with a very small minimum value was required. It has been devised as shown in Fig. 4 and comprises a metal plunger which may be screwed along a tube which carries the two 'fixed plates' of the capacitor with a metal screen interposed between them. If the plunger is one side or the

Fig. 3. *Circuit of radio microphone*



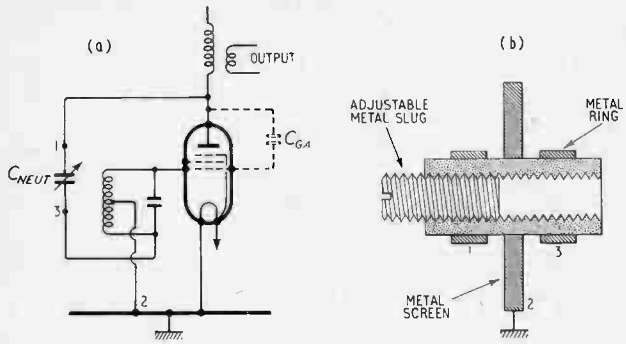


Fig. 4. *(a) Circuit arrangement for neutralizing the output stage; (b) neutralizing capacitor*

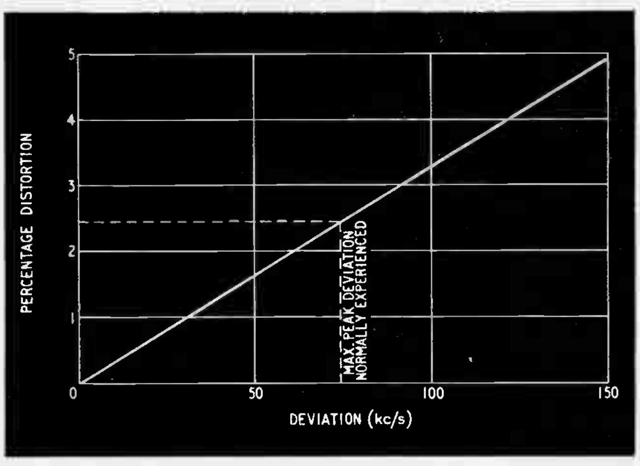
other of this metal screen, it will be seen that the capacitance between the two 'fixed plates' is very small indeed.

All programme transmissions radiated by the B.B.C. are controlled so that the best is made of the overall linkage from the studio to the listener's receiver. The modulation at the transmitting stations is monitored so that the listener receives a signal with the smallest noise interference consistent with inappreciable distortion due to overloading in any part of the system. This transmitter would be improved if some such control could be fitted.

Level Setting

Microphone levels vary enormously and are difficult to predict. A speaker will often increase the level of his voice when there is an audience present during the actual broadcast and so the gain settings found suitable at rehearsal no longer hold. It is usual, therefore, to set the transmitter gain controls so that the deviation approaches maximum but with some margin against unexpected heavy modulation which would cause distortion on both the transmitter and the local receiver. This tends to detract from the effective output power of the transmitter and increases the danger of local noise sources causing interference. To mitigate this trouble as far as possible, a receiver has been chosen which, over the normal range of modulation, does not add appreciably to the non-linear distortion of the transmitter. The receiver together with the receiving aerial is normally situated at the local outside broadcast control point and the size of apparatus, to reasonable limits, does not really matter. For this purpose, therefore, a good quality commercially-produced receiver has been chosen and modified to give the required characteristics. Over the normal range of modulation the non-linear characteristic of the complete link is therefore practically that of the transmitter shown in Fig. 5 and, on the type of programme material for which this link is normally employed, distortion is imperceptible. Beyond the normal peak deviation of 75 kc/s, the distortion from the transmitter not only increases as shown in Fig. 5 but the receiver distortion increases drastically and effectively limits the good quality transmission to a deviation of about 100 kc/s. The frequency response of the transmitter is shown in Fig. 6. This does not include the microphone characteristic. The small crystal microphone which may be pinned to the lapel, as shown in Fig. 1, has a rising response but correction is made for this in the base receiver.

Fig. 5. *Non-linear distortion due to transmitter*



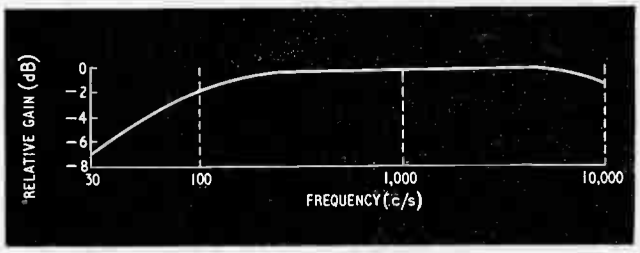


Fig. 6. *Frequency/amplitude response of transmitter*

Applications

This radio link, or 'radio microphone' as it is known in the B.B.C., has been in considerable use now for over a year and in many cases has proved extremely successful. On several occasions it has failed due to some breakdown, such as the battery not providing its expected life or the aerial being broken away from the set. In other cases it has failed because someone has tried to broadcast from the inside of a metal box or in some way has stretched the range of the equipment too far. It is intended merely to replace that short microphone lead but how tempting it is to wander when one is free to do so. On occasions it has been used over a distance of more than a mile but such usage is really unreliable for broadcasting, as any severe interference starting up within the neighbourhood of the receiver can spoil the whole transmission.

For such reasons the technical staff encourage the users to duplicate the equipment; e.g., if two people are talking to each other, each wears a transmitter so that if the one fails the other may satisfy the requirements of the two. Several transmitters may be used in the one broadcast in this way, care being taken to use frequencies sufficiently different from that of the local television transmitter. If it is necessary to extend the radius of operation, several aerials may be used and these may be switched to the receiver so that good reception conditions are maintained.

COLOUR AS A VECTOR

The obvious truth that a given set of vectors can have only one resultant, but that the reverse process is not unique because a given vector can be synthesized from components in innumerable different ways, has its counterpart in the field of colour reproduction. All our colour sensations result from stimulus by light of determinable intensity and wavelength. A given combination of spectral wavelengths gives a colour sensation that is unique; but the same sensation can also arise from any number of other combinations. I should like to explore this analogy as fully as can be done in a short article without, for the present, going too fully into the technical aspects of colour mixing.

This all has a bearing on colour television, but as a very general principle underlying the processes now developing. Excellent books such as G. G. Gouriet's " Introduction to Colour Television," and the fuller and more technical " Principles of Color Television " by the Hazeltine Laboratories Staff (John Wiley and Sons) will give you plenty to digest in the way of technical information. The latter, indeed, is quite magnificent on the physical optics side and, by going right to the heart of the matter, prompted these hoverings on the fringe. How far does the analogy between colours and vectors extend, and what do we mean by the vector representation of a colour ? If we do mean anything by it, why should it be possible, and what use can it be anyhow ?

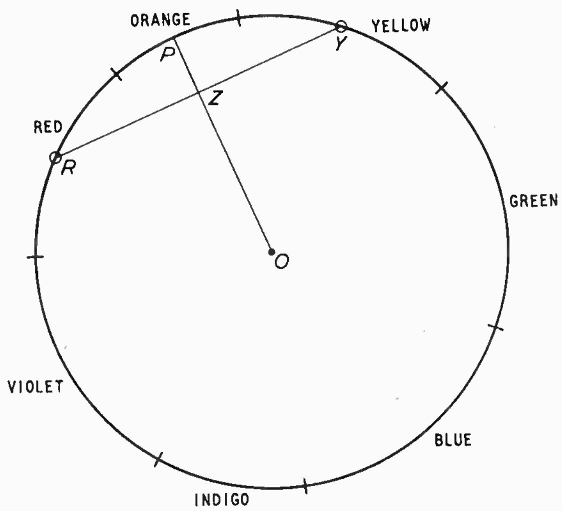
The simple facts about additive colour mixing are well known. The choice of three 'primary' lights suitably separated in the spectrum was suggested by Newton ; red, green, and blue-violet seem to have been selected by the Young-Helmholtz theory of colour-vision. These need not, indeed be pure spectral colours; while the C.I.E.* primaries R, G, B are in fact assigned definite wavelengths, the transmission of filters or the fluorescence of phosphors, which to the eye more or less match the prescribed wavelengths, work just as well. Clerk Maxwell devised an additive three-colour photographic process, which survives in the mosaic colour-screen methods for colour transparencies. For projection purposes, the Photochromoscope of H. E. Ives did things the hard way ; a separation camera using filters (R, G, B) gave, as positive prints, three monochrome slides which were projected on the screen each through the appropriate R, G, B filters and there superimposed. A correspondingly elaborate system, with most of the apparatus in triplicate, would of course operate for television; the little matter of substituting the right signals for the slides is only a problem in time-and-motion study; and, at the receiving end, of living-space. One of our questions can be answered at once; by properly organizing the information to be transmitted, this cumbersome arrangement can be simplified.

* *Commission Internationale d'Eclairage*

Let us go back to the colour-circle (Fig. 1) from the first book of Newton's "Opticks." To Newton, the spectrum comprised seven 'homogeneal lights,' which he called primary colours, though we do not use the term in that sense today. He likened these to the seven intervals of the musical scale, and drew them as arcs round the circumference of a circle, with orange and indigo like semitones with shorter arcs. Mixtures of spectral colours are represented by points within the circle, the centre O being white.

To find the result of mixing any two spectral colours, a mass representing the 'quantity' of each colour is placed at the mid-point of the arc. (By quantity we must nowadays understand power-flux per unit area.)

Fig. 1. *Newton's colour circle showing 'primary colours' as arcs around a circle*



The centre of gravity of the two masses, Z, is then found. This is, of course, simply a rule for dividing the line joining the centres of the arcs in inverse proportion to the quantities. Producing OZ to the circumference P locates the general hue of the mixture Z, and the distance OZ represents the saturation or 'distance from whiteness.' In order to have one word for the two attributes of Z, hue and saturation, we nowadays call

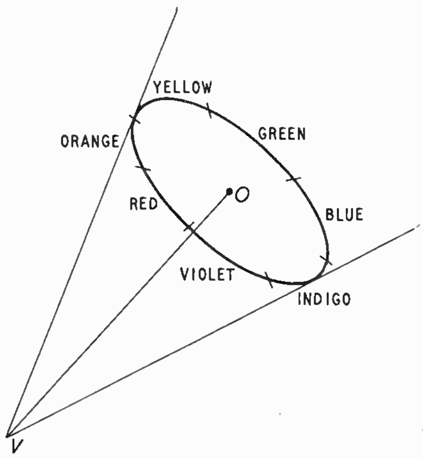


Fig. 2. *Colour circle extended into a section of a cone so that luminance can also be depicted*

it a 'chromaticity.' It follows that, starting with chromaticities within the circle and applying the same rule, the result of superposing Z and another mixture, Z' can be found.

Newton showed that by taking only three spectral colours, not all in the same semicircle, all colours within the triangle formed by joining the mid-points of their arcs could be synthesized ; the 'colour-triangle' will be referred to later. The modern chromaticity diagram retains the essence of Newton's circle—that of defining the chromaticity of a colour by a point in a plane. But in it the spectral colours are represented by a continuous range of wavelengths instead of an octave of seven intervals; and they are drawn along a curve called the spectral locus, which can be regarded as a circle which has been distorted to allow for the way in which the eye responds to equal power-flux per unit area in different parts of the spectrum.

In map-making terms, the chromaticity diagram is an isometric projection with respect to absolute power-measurement ; the colour-circle is a kind of Mercator's projection in which equal distances don't always mean the same thing in absolute terms. But I must not mix things up with three dimensions too soon, and this is a rough idea of the relationship between the two figures rather than a close analogy. Indeed, if it were more convenient, we could retain the circle and allow for the eye's behaviour by 'normalizing' (that is, doctoring the absolute powers by the correct factor for each wavelength) so that the spectrum sat neatly round it.

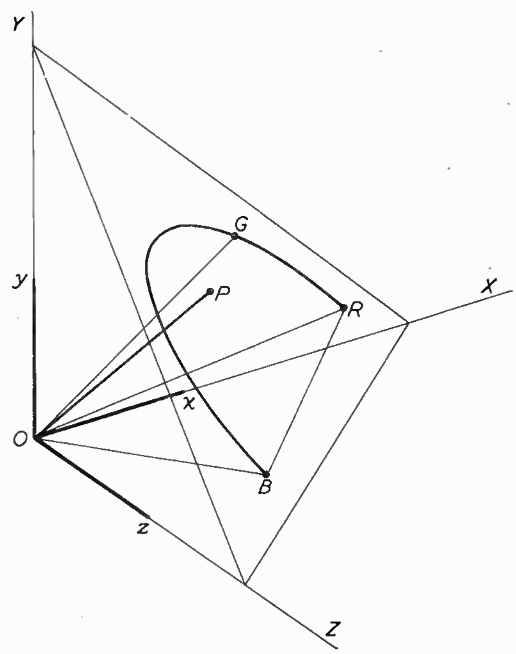
Newton realised that he had found the key to colour analysis. He said: "All Colours in the Universe that are made by Light, and depend not on the Power of Imagination, are compounded either accurately or very nearly according to the foregoing Rule." It might incidentally be mentioned that where the rules are waived, as for fine detail, we do indeed rely on either the power of imagination or the shortcomings of the eye. The terms 'hue' and 'saturation' so far used are subjective terms ; since OZ produced would cut the circumference at a definite wavelength if a continuous spectrum were described there, the objective term 'dominant wavelength' is used, and the objective term 'purity' denotes what we describe as 'saturation.'

Before going any further, let us consider what the representation of a colour by a point in a plane really means. It implies nothing more than two degrees of freedom, or two *completely independent* parameters. Newton's colour circle is simply a choice of polar co-ordinates in which the centre is taken as origin, purity (saturation) as r, and dominant wavelength (hue) as θ. In the colour circle, the vector OZ $(r\angle\theta)$ can equally well be represented in Cartesian co-ordinates, referred to axes through O, as $x + jy$. But if we do this, we then have to ask first what x and y represent, and secondly how we are to interpret negative values; and the answer in each case is that we have simply transformed things for possible convenience in algebra, and have at the end to convert back to the observable parameters chosen by Newton.

Why two parameters, for surely we use three in colour-mixing ? If we take three spectral colours, R, G, B at the vertices of a triangle which the circle circumscribes, any colour *within the triangle* is given by $C = rR + gG + bB$, where r, g, b are *coefficients* which represent relative power-quantities, and are all positive. But r, g, and b are not *independent*, for $r + g + b = 1$. Mathematically, this is equivalent to choosing homogeneous co-ordinates to specify a point in a plane in order to avoid negative values ; in practice we are forced to use this device as the ultimate addition is by the literal superposition of spectral lights at the eye. All that we finally present to the eye must be addable, because the eye can add but not subtract. But any technique for converting to x and y and performing subtractions during transmission of the information would free our hands to deal with only two variables in the intervening stages.

There is a third factor which has so far been left out of account *as a variable*. This is luminance (or, in subjective terms, what we call brightness). Luminance is the power-flux per unit area, not in absolute terms but doctored to take into account the eye's response. In the colour circle, or the triangle counterpart, it is assumed to be constant over the whole plane. Grassmann

Fig. 3. *Colour diagram in a framework of Cartesian axes*



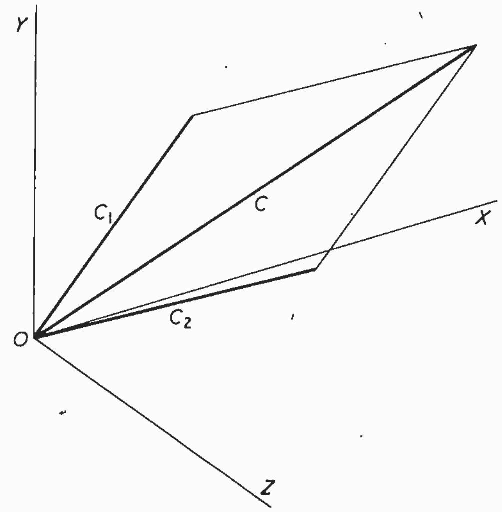


Fig. 4. *Resultant C of two vectors C_1 and C_2 in Cartesian co-ordinates X, Y, Z*

in 1854 stated that luminance is quite independent of the other two factors so far considered ; and indeed this is the only reason why the discussion has been able to get as far as this without mentioning it.

The proposition known as Grassmann's First Law says that the eye can distinguish only three attributes in a colour—dominant wavelength (hue); luminance (brightness); and purity (saturation)—and that these are independent of one another. To include luminance, (Fig. 2) we can extend the colour circle (or the modern equivalent) into three dimensions, as a circular section of a cone (or a diagram lying in that plane), the perpendicular *VO* from the vertex representing the luminance. A colour is then represented completely by a point in three-dimensional space ; one way of doing this would be simply to give the colour-circle co-ordinates and the length of *VO*. But symmetry suggests that now that we have three co-ordinates to consider, all of equal status since they are all independent, it may ultimately be much simpler to work in Cartesians, and in vector terms.

Let us put in a framework of *X*, *Y*, *Z* axes, and then see what the three co-ordinates mean after we have fitted the spectrum, at unit *power-flux*, into them (Fig. 3). Each colour can be represented completely by a point *P* (x, y, z), or by the vector *OP*, which may be written $\mathbf{i}\,x + \mathbf{j}\,y + \mathbf{k}\,z$, where **i, j, k** are unit vectors. We next put into the three-dimensional framework the points *R*, *G*, *B* corresponding to chosen spectral wavelengths at unit power-flux. The plane containing *R*, *G*, *B* is then that in which the whole chromaticity diagram for the "equal-energy spectrum" at unit power must lie. For other absolute power values, the figure has the same shape and lies in a parallel plane.

The argument has been presented in reverse, for quite obviously *R*, *G*, and *B* could not have been inserted before we had made up our minds about the nature of *X*, *Y*, and *Z* ; but one shrinks from starting off by saying " Take three non-existent colours," which is what they are. Now that the diagram is completed, it sounds less offensive to say that *X*, *Y*, and *Z* are abstract chromaticities which lie outside the chromaticity diagram; and that they have been so chosen to ensure that over the whole diagram only positive co-ordinate values occur.

Although spoken of as "abstract", in the sense that they are not readily available chromaticities, each of the C.I.E. primaries *X*, *Y*, *Z* can be represented by a definite spectral energy distribution; that of the *Y* primary is ingeniously chosen in such a way that the *Y*-component of any colour is proportional to the luminance of that colour. The axes are not usually shown drawn at right angles to one another in the books; I cannot understand why, unless it is that it would be easier to show a constant-luminance figure with oblique axes. But this point does not really matter for the present argument.

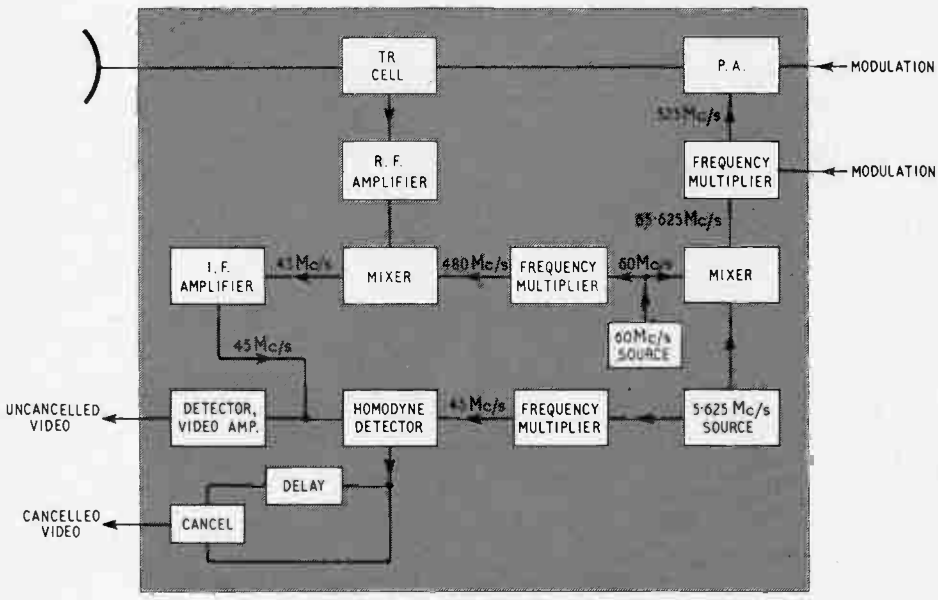
The real value of this three-dimensional 'colour-space' may not yet be apparent, but I am coming to it slowly. Grassmann also showed ("Grassmann's Third Law") that sources with the same colour parameters always produced the same effects in a mixture, regardless of their spectral composition. That is, when compounding colours we need only worry about their vector components. In the two dimensions of the colour-circle, $C_1 = x_1 + jy_1$ and $C_2 = x_2 + jy_2$ give $C = C_1 + C_2 = (x_1 + x_2) + j\,(y_1 + y_2)$. In three dimensions, $C_1 = \mathbf{i}x_1 + \mathbf{j}y_1 + \mathbf{k}z_1$ and $C_2 = \mathbf{i}x_2 + \mathbf{j}y_2 + \mathbf{k}z_2$ give $C = \mathbf{i}\,(x_1 + x_2) + \mathbf{j}\,(y_1 + y_2) + \mathbf{k}\,(z_1 + z_2)$. Or, rather more simply, the resultant can be found by drawing the diagonal of a parallelogram in either case (see Fig. 4). This means that we are not restricted to colours of a given spectral composition in choosing components for a colour-reproduction scheme; and, of course, people never have been in practice. But the important point emerging from all this is that the three pieces of information that must be conveyed by any means of colour reproduction are the three *independent* parameters: we can call them dominant wavelength, purity, and luminance ; we can represent them algebraically in terms of an abstract *X*, *Y*, *Z*, or geometrically by the corresponding vector line ; we can play about with the co-ordinates by transforming to other axes if we like; we can store them on separation-process slides, or convert them into electrical impulses ; and we can hand them over to the eye by projections in primary lights or patterns of glowing phosphors in three colours. In fact, so long as the three independent factors preserve their identity throughout, the actual vehicle of the information can be transformed in various ways—though at the end it must come out as an additive mixture of three lights C_1, C_2 and C_3.

It is interesting to note that we have to have three primary colours in any case to present the result, because the eye cannot subtract ; but now we see that they may be made to carry their full share of information, each contributing to the three factors needed to reproduce their vector resultant completely. And the components into which the vector is resolved for transmission purposes need not be *X*, *Y*, *Z* ; any three signals of the form $S = \mathbf{i}x' + \mathbf{j}y' + \mathbf{k}z'$ which will conspire ultimately to reconstitute the vector can in principle be chosen, the co-ordinates referring to any other set of axes, X', Y', Z' in general. The sordid details of the calculations come a lot easier to networks and matrices and such things than they do to me. I salute the chaps with the soldering irons who know how to fix things, and the pundits who work out what goes where ; but my problem has been to see why it should be possible at all, rather than how the experts actually do it. The reason seems ultimately as simple as the plus-zero-minus code of the calculating machine; three separate kinds of information only have to be handled.

I confess that when I first met these ideas, in P. J. Bouma's "Physical Aspects of Colour," published by Philips of Eindhoven, their practical value did not seem obvious—but neither did that of the binary scale on first acquaintance with it in the arithmetic books. I thought then that considerable virtuosity was being expended on transformations of the kind that treatises on solid geometry throw in for good measure when the author is running out of meaty theorems. The light dawned (or perhaps I should say the clouds lifted a little) when I realised how directly they are applied in colour television. At the camera end the information is collected in terms of vectors C_1, C_2, and C_3. It is transformed to a luminance vector Y and the in-phase and quadrature components I and Q of a chromaticity or chrominance vector, and transmitted in these terms. Finally, it is transformed for reproduction back again to vectors C'_1, C'_2, and C'_3, which need not be the same as the original Cs, but must combine to give the same resultant or something acceptably like it. The transformations themselves are material for a whole article.

50-cm Doppler Radar

THE use of a carrier frequency of only 525 Mc/s, at which conventional amplifying valves can be used instead of magnetrons, has made possible an effective Doppler moving-target indicating system in the Marconi S.232 airfield radar, the aerial system of which is shown in the photograph. A 5·625-Mc/s crystal master oscillator is used to control the transmitter frequency which is, in fact, 8(60 + 5·625) Mc/s, the 60-Mc/s component being derived from another oscillator. The transmitted signal is pulse-modulated. The received signal is amplified, and frequency-changed to 45 Mc/s by beating against a harmonic of the 60-Mc/s source. After amplification, the 45-Mc/s i.f. (which is phase-modulated by Doppler effect when a moving target is encountered by the beam) is supplied to a homodyne detector controlled by a harmonic of the crystal master oscillator (8 × 5·625 = 45) Mc/s. The output is applied to an ultrasonic delay line and to a cancellation circuit in parallel. The delay is equal to one pulse repetition period, so that echoes received at any instant are subtracted from echoes received at the corresponding instant in the previous p.r.f. period. Static targets give equal echoes, which cancel, while the echoes from moving targets result in an output which is applied to a p.p.i. display. Since the master oscillator runs continuously and controls the transmitter and receiver, true coherent detection is possible.



Non-Linear Circuit Equation

By J. Irving, M.A., Ph.D. and N. Mullineux, B.Sc., Ph.D.*

SUMMARY. *Details are given of a way of solving non-linear equations by a perturbation method. A numerical method is also described and employed as a check.*

In a recent paper Liebetegger[1] considers the problem that arises when an inductive resistance, a capacitor and a diode valve are connected in series with a constant e.m.f., assuming that the valve has a non-linear resistance given by Child's law. He integrates the circuit equation numerically for a particular maximum value of the current. In this paper we give a perturbation method of solution, which is applicable even when the e.m.f. is not constant. The method yields an analytical solution involving the circuit constants in the form of two parameters and contains Liebetegger's problem as a particular case.

A numerical method which makes use of given initial values (in contrast with the tentative approach used by Liebetegger which starts from an assumed maximum value) is also described and used as an independent check on the perturbation method.

The Circuit Equation

The circuit is represented by Fig. 1, the resistance, inductance and capacitance being denoted by R, L and C, respectively; the charge on the capacitor at time t is q; the applied e.m.f. is e; the potential drop across the diode is $v = (i/k)^{2/3}$ by Child's law, i being the current.

The equation for the circuit of Fig. 1 has the form

$$L\frac{di}{dt} + Ri + q/C + v = e \qquad (1)$$

The cases for e constant and e time-dependent are now treated separately.

Case 1 : e = constant = E

This is the problem discussed in reference 1, where it is shown that equation (1) may be transformed to

$$\frac{d^2x}{d\theta^2} + \epsilon\left\{\frac{dx}{d\theta} + \left(\frac{dx}{d\theta}\right)^{2/3}\right\} + x = 0 \qquad (2)$$

where $x = \alpha R^3k^2(q - CE)$, $\theta = \alpha t$, $\epsilon = 2\mu/\alpha$ with $2\mu = R/L$ and $\alpha^2 = 1/LC$. For the initial conditions of zero charge, q, and zero current, i, it follows that $x(0) = -\alpha R^3k^2CE = a$, say, and $x'(0) = 0$.

If ϵ is small, the following perturbation method may be applied. We write $x(\theta)$ as a series expansion in powers of ϵ, namely

$$x(\theta) = x_0(\theta) + \epsilon x_1(\theta) + \epsilon^2 x_2(\theta) + \ldots \qquad (3)$$

and evaluate the terms $x_0(\theta)$, $x_1(\theta)$, . . . successively. It follows from (3) that

$$x'(\theta) = \frac{dx}{d\theta} = x_0'(\theta) + \epsilon x_1'(\theta) + \epsilon^2 x_2'(\theta) + \ldots \qquad (4)$$

so that

$$\{x'(\theta)\}^{2/3} = \{x_0'(\theta)\}^{2/3}[1 + (2/3)\{\epsilon(x_1'/x_0') + \epsilon^2(x_2'/x_0') + \ldots\} - (1/9)\{\epsilon^2(x_1'/x_0')^2 + \ldots\} + \ldots] \qquad (5)$$

From (2), (3), (4) and (5) we have

$$x_0'' + x_0 + \epsilon\{x_1'' + x_1 + x_0' + (x_0')^{2/3}\} + \epsilon^2\{x_2'' + x_2 + x_1' + (2/3)x_1'(x_0')^{-1/3}\} + \ldots = 0 \qquad (6)$$

(6) is satisfied if

$$x_0'' + x_0 = 0 \qquad (7)$$

$$x_1'' + x_1 = -x_0' - (x_0')^{2/3} \qquad (8)$$

$$x_2'' + x_2 = -x_1' - (2/3)x_1'(x_0')^{-1/3} \qquad (9)$$

etc.

Equation (7) is now solved subject to the prescribed initial conditions on $x(\theta)$, that is, $x_0(0) = a$ and $x_0'(0) = 0$. We readily find that

$$x_0 = a\cos\theta \qquad (10)$$

Then, from (8) and (10),

$$x_1'' + x_1 = a\sin\theta - a^{2/3}(\sin\theta)^{2/3} \qquad (11)$$

for which the initial conditions are $x_1(0) = 0 = x_1'(0)$. Using the Laplace transform and the 'convolution theorem'[2] the solution of (11), subject to its initial conditions, is

$$x_1 = \int_0^\theta \{a\sin\theta' - a^{2/3}(\sin\theta')^{2/3}\}\sin(\theta-\theta')\,d\theta'$$
$$= a\left[(\sin\theta - \theta\cos\theta)/2 - a^{-1/3}\left\{(3/5)(\sin\theta)^{8/3} - \cos\theta\int_0^\theta(\sin\theta')^{5/3}\,d\theta'\right\}\right] \qquad (12)$$

To find x_2 (12) is substituted in (9) and the resulting linear equation solved by the preceding method. A rather complicated expression is obtained, but for reasonably small values of ϵ, the contribution to $x(\theta)$ is negligible. The approximate solution of (2) is thus $x(\theta) = x_0 + \epsilon x_1$, where x_0 and x_1 are given by (10) and

* *University of Southampton.*

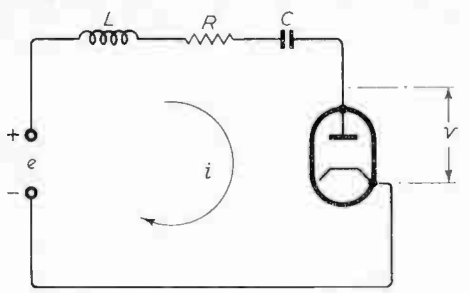


Fig. 1. *Diode valve circuit*

(12) respectively. The solution $x(\theta)$ contains the parameters a and ϵ, which depend on the circuit constants. The current is given by

$$i = \frac{dq}{dt} = (1/R^3k^2)\frac{dx}{d\theta} \approx (x_0' + \epsilon x_1')/R^3k^2$$

$$= -(a/R^3k^2)\Big[\sin\theta - (\epsilon/2)\,\theta\sin\theta + \epsilon a^{-1/3}\Big\{(3/5)\cos\theta(\sin\theta)^{5/3} + \sin\theta\int_0^\theta(\sin\theta')^{5/3}\,d\theta'\Big\}\Big] \quad \ldots \quad (13)$$

As a particular illustration we take the values $E = 340$ volts, $R = 10$ ohms, $L = 10^{-4}$ henry, $C = 10^{-10}$ farad and $k = 10^{-3}$, so that $2\mu = 10^5$, $\alpha = 10^7$, $\epsilon = 10^{-2}$ and $x(0) = a = -340 \times 10^{-6}$. From the first term of (13) the approximate value of θ for maximum current is $\theta = \pi/2$. The evaluation of (13) for $\theta = \pi/2$ gives $i(\pi/2) = 296{\cdot}5$ mA. (The evaluation of the integral is described in the Appendix.) Evaluating (13) in the neighbourhood of $\theta = \pi/2$, we obtain $i_{max} = 297$ mA for $\theta = 86°30'$ which corresponds to $t = 0{\cdot}151$ μsec. The corresponding value of x is $-46{\cdot}8 \times 10^{-6}$. The numerical solution of (2) for the above set of circuit constants is given later. Evidently the above formulæ for $x(\theta)$ and $x'(\theta)$ can be used for a wide range of values of the circuit constants.

Case 2: $e = F(t)$

The substitution $x = \alpha R^3k^2q$ then yields the equation

$$\frac{d^2x}{d\theta^2} + \epsilon\left\{\frac{dx}{d\theta} + \left(\frac{dx}{d\theta}\right)^{2/3}\right\} + x = \beta F(\theta/\alpha) \quad \ldots \quad (14)$$

where $\beta = \alpha R^3k^2C$.

From the foregoing perturbation theory the zero-order approximation gives in this case

$$x_0'' + x_0 = \beta F(\theta/\alpha) \quad \ldots \quad (15)$$

with $x(0) = 0 = x'(0)$, if $q(0) = 0 = i(0)$.

The solution of (15) may be written down immediately as

$$x_0 = \beta\int_0^\theta \sin(\theta - \theta')F(\theta'/\alpha)d\theta' \quad \ldots \quad (16)$$

i.e., $x_0 = G(\theta)$, say $\quad \ldots \quad (17)$

Hence from (8)

$$x_1'' + x_1 = -G'(\theta) - \{G'(\theta)\}^{2/3}$$

with $x_1(0) = 0 = x_1'(0)$, so that

$$x_1 = -\int_0^\theta \sin(\theta - \theta')\left[G'(\theta') + \{G'(\theta')\}^{2/3}\right]d\theta' \quad \ldots \quad (18)$$

The approximate solution of (14) is thus

$$x_0(\theta) + \epsilon x_1(\theta)$$

where $x_0(\theta)$ and $x_1(\theta)$ are given by (17) and (18), respectively. In particular, if $e = F(t) = E\cos\omega t$ with E constant, then

$$x_0 = G(\theta) = \{E\beta/(\omega^2/\alpha^2 - 1)\}\{\cos\theta - \cos(\omega/\alpha)\theta\} \quad \ldots \quad (19)$$

for $\omega \neq \alpha$.

x_1 in this case is then found from (18) with $G(\theta)$ given by (19).

Numerical Integration

The perturbation method for case 1 above is checked by a method of numerical integration of the differential equation

$$\frac{d^2x}{d\theta^2} + \epsilon\left\{\frac{dx}{d\theta} + \left(\frac{dx}{d\theta}\right)^{2/3}\right\} + x = 0$$

which has an advantage over the method of reference 1 in that it starts at the initial point and hence uses the prescribed initial conditions immediately. Liebetegger in his method, on the other hand, begins his integration at an assumed maximum and determines his initial conditions by integrating inwards to the origin. Consequently, for prescribed initial conditions, it is necessary in his method to carry out several trial integrations.

TABLE 1

θ	$x \times 10^6$	$x' \times 10^6$
0	− 340·0	0
0·1	− 338·3	33·30
0·2	− 333·4	65·52
0·3	− 325.3	96·51
0·4	− 314·1	126·1
0·5	− 300·1	154·0
0·6	− 283·4	180·0
0·7	− 264·2	203·9
0·8	− 242·7	225·4
0·9	− 219·2	244·5
1·0	− 193·9	260·9
1·1	− 167·1	274·5
1·2	− 139·1	285·3
1·3	− 110·1	293·1
1·4	− 80·6	297·9
1·5	− 50·7	299·7
1·6	− 20·7	298·5

We integrate equation (2), namely,

$$x'' + \epsilon\{x' + (x')^{2/3}\} + x = 0$$

with the initial conditions $x(0) = a = -340 \times 10^{-6}$, which corresponds to $E = 340$ volts with zero charge on the capacitor, and $x'(0) = 0$, corresponding to zero current initially.

The series solution of the equation is

$$x(\theta) = a\Big[1 - \frac{1}{2}\theta^2 - \frac{9}{40}\epsilon a^{-1/3}\theta^{8/3} + \frac{1}{6}\epsilon\theta^3 - \frac{9}{175}(\epsilon a^{-1/3})^2\theta^{10/3} + \frac{21}{220}\epsilon^2a^{-1/3}\theta^{11/3} + \frac{1}{24}(1 - \epsilon^2 - \frac{13}{175}\epsilon^3a^{-1})\theta^4 \ldots\Big] \quad \ldots \quad (20)$$

which gives accurate results for $x(\theta)$ and $x'(\theta)$ when

$\theta \leqslant 0{\cdot}3$. The values of $x(\theta)$ and $x'(\theta)$ for $\theta = 0{\cdot}1$, $0{\cdot}2$, $0{\cdot}3$, obtained from (20), are used as starting values in an iteration method[3]—which is self-checking—the integration being taken to just beyond the maximum of $x'(\theta)$. The results for $\epsilon = 10^{-2}$ are given in Table 1. The maximum value of x' is 300×10^{-6} and the corresponding value of x is $-47{\cdot}7 \times 10^{-6}$, showing that the perturbation results for x' and x have approximate errors of 1% and 2% respectively.

It should be noted that the iteration method of solution is most useful when ϵ is not small, in which case, of course, the perturbation method fails.

APPENDIX

The evaluation of the integral

$$I = \int_0^{\theta_0} (\sin\theta)^{5/3} d\theta$$

is fairly simple for θ_0 in the neighbourhood of $\pi/2$, and also for small values of θ_0. We have, with $u = \sin^2\theta$,

$$I = (1/2)\int_0^{\sin^2\theta_0} u^{1/3}(1-u)^{-1/2}\, du$$

so that I is an incomplete Beta-function. For θ_0, and consequently u, small, the integrand may be expanded as a power series in u, and the integral evaluated by term-by-term integration. For θ_0 in the neighbourhood of $\pi/2$, we write

$$I = (1/2)\int_0^1 u^{1/3}(1-u)^{-1/2}\,du - (1/2)\int_{\sin^2\theta_0}^1 u^{1/3}(1-u)^{-1/2}\,du$$

$$= (\sqrt{\pi}/2)\,\Gamma(4/3)/\,\Gamma(11/6) - (1/2)\int_0^{\cos^2\theta_0} v^{-1/2}(1-v)^{-1/3}\,dv$$

where $\Gamma(x)$ denotes the Gamma-function, which is tabulated. The second integral may be evaluated by expanding the integrand as a power series in v since $\cos^2\theta_0$ is small when θ_0 is in the neighbourhood of $\pi/2$.

We then have

$$\int_0^{\theta_0} (\sin\theta)^{5/3}\,d\theta \approx 0.841 - \left[\cos\theta_0 - \frac{1}{9}\cos^3\theta_0 - \frac{1}{45}\cos^5\theta_0 - \frac{5}{567}\cos^7\theta_0 - \;.\;.\;.\;.\right]$$

This result has been used to evaluate $x'(\theta)$ for θ in the neighbourhood of $\pi/2$.

REFERENCES

[1] Liebetegger, A., *Wireless Engineer*, 1956, Vol. 33, p. 24.
[2] Carslaw, H. S., and Jaeger, J. C., "Operational Methods in Applied Mathematics", 1941, p. 7. Oxford University Press.
[3] Hartree, D. R., "Numerical Analysis", 1952, p. 136. Oxford University Press.

New Dip-Soldering Technique for Printed Circuits

In conventional dip-soldering, printed-circuit boards (coated with liquid flux) are lowered on to the surface of the molten solder, rocked, and withdrawn. Several difficulties arise in applying the method. For instance, the mechanical movements which have to be imparted to the printed-circuit board are awkward to arrange and time accurately; the solder bath must be kept skimmed to remove oxide film; the surface of the solder in contact with the board is cooled by the evaporation of flux from the board, and this can lead to dry joints, or make necessary a higher working temperature.

A new method of dip soldering, devised by Fry's Metal Foundries Ltd., enables the soldering operation to be accomplished efficiently with a straight-line movement of the printed-circuit boards across the solder bath. The novel feature of this method lies in the creation of a stationary wave of solder (Fig. 1). The printed-circuit boards are passed over the crest of the wave, which makes contact with them. This system has many advantages in addition to its mechanical convenience. The solder wave is created by pumping solder from the bottom of the tank through a specially-shaped channel at a point below the surface, so there is no oxide film on the emergent wave. Since the solder in the wave is continuously flowing, wetting is good. The effects of surface cooling by flux evaporation are eliminated, since the wave is constantly replenished by hot solder from below the surface. The tangential track of the circuit board with respect to the solder reduces 'icicles' and 'bridging.' The latter is the factor which determines how closely conductors can be spaced. The turns of the printed inductor in Fig. 2 (left) are spaced about 0·017 in. With normal dip-soldering, bridging would occur with such close spacing and, to avoid it, close-spaced wiring would have to be masked-off in some way to prevent wetting, thus adding to production costs.

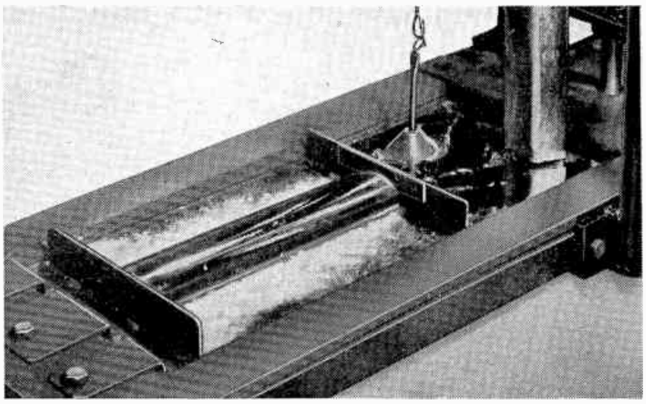


Fig. 1. *The solder wave has a smooth, clean surface*

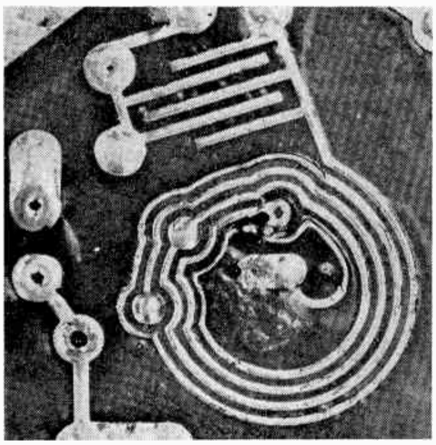


Fig. 2

Progress in Ferrite Materials

COMPUTER AND MICROWAVE APPLICATIONS

Since their introduction after the second World War, ferrite materials have been widely used to provide cores for inductors and transformers for operation at frequencies from a few hundred c/s to about 100 Mc/s. Various compositions of ferrite are available, each with an optimum frequency range. Typical applications include television line output-transformer and deflection-coil cores, high-Q filter inductors and wide-band transformers. More recently, some new properties of ferrite have greatly increased the range of applications, at the same time bringing out the need for new materials.

'Square-loop' ferrites, by virtue of their ability to store binary-coded information, have applications in computers and allied devices and in automatic telephony. Conventional ferrites can be used as non-reciprocal elements at microwave frequencies, and the design of isolators, circulators, attenuators, and non-reciprocal phase-shifters is well advanced. This article is a survey of applications, and draws heavily upon information contained in papers presented at the recent I.E.E. Convention on Ferrites.

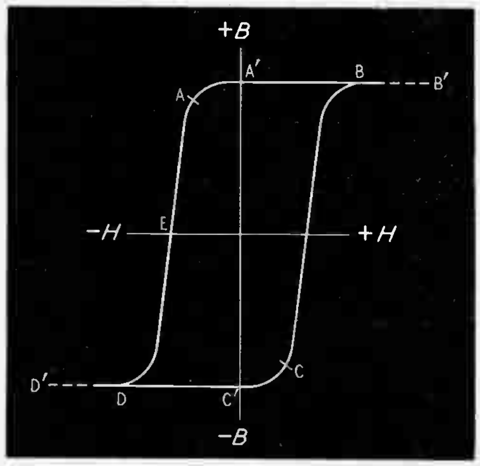


Fig. 1. *Near-rectangular hysteresis loop*

'Square-Loop' Ferrites

These have approximately rectangular B–H loops (Fig. 1). If such a ferrite is magnetized to the extent that H lies in the region B — B′ (i.e., beyond saturation) and the magnetizing field removed, the magnetic state of the material is given by A′ ; that is, there is appreciable remanent magnetism. Even if a demagnetizing force is applied so that the operating point moves to A, a large proportion of the original remanence persists. In computer applications, a piece of ferrite magnetized in this direction is deemed to represent, say, a '1'. If the working point lies on DC, it is deemed to represent a '0'. Thus, an array of pieces of square-loop material can be used to store binary numbers.

To change the state of a core from say, A′ to C′, the working point is moved along AED by applying a demagnetizing field, a small increase in B sufficing to switch the magnetism from A to D. In other words, once the ferrite is magnetized in a particular sense, it will stay in that condition, even though subjected to appreciable demagnetizing fields but, if a demagnetizing field above a certain critical value is applied, the state of magnetism will suddenly reverse. This behaviour is analogous to that of an Eccles-Jordan flip-flop with varying trigger-signal amplitudes.

In order to insert digits into a piece of ferrite, a coupling winding of some kind is used. To extract a digit, the ferrite is 'switched' and the resulting rapid change of flux gives rise to an output pulse. The conventional storage arrangement is shown in Fig. 2.

Here, the ferrite is in the form of small toroids (typically 2 mm diameter), each threaded by three wires. The wires which intersect at right angles carry currents for switching the cores, the wire common to all cores being a read-out wire. The wires are insulated. Application of currents to one vertical and one horizontal wire, each current amounting to half the value needed to switch a core, can cause switching of one core only, namely that at which the wires intersect. Such 'half-write' currents are individually insufficient to switch a core (i.e., they cannot shift its working point out of the regions AB′ or CD′). In practice, all the cores are initially switched to the '0' condition. Half-write currents are used to insert '1's in appropriate cores. The information is extracted by applying coincident 'half-read' currents in the reverse sense, cores which contain '1's then switching to the '0' state and giving output pulses in the read wire. Cores already in the '0' state do not switch and the pulses which appear in the read wire, when coincident half-read currents pass through a '0' core, are small.

Ferrite-core memory matrices have the advantage over magnetic-drum or tape recordings that information is immediately available. They are random access devices. The information is destroyed on reading out, however, and the physical size per bit is necessarily much greater, although matrices are small compared with some other devices. These characteristics suit the ferrite-core matrix to short-term storage applications. For example, information can be inserted at a random rate and withdrawn at a steady rate[1].

Two disadvantages of the matrix are the inconveniently large size of core-switching current required (about 500 + 500 mA), and the generation of small, but not negligible, output pulses when currents are applied to cores without changing their states. Such pulses may add in a read-out wire to form a larger pulse difficult to distinguish from a wanted pulse. If valves are used to generate half-read and half-write pulses, they must either be capable of delivering large currents (500 mA), or a transformer must be used. Fortunately, pentode valves in the 'bottomed' state (Fig. 3) can deliver large currents without large anode dissipations.

R_1 absorbs most of the power (the voltage drop across the matrix is small) and provides a measure of current stabilization. A negative-feedback voltage developed across R_2 reduces the sensitivity to changes in valve characteristics.

Valves with smaller current ratings may be used if the cores are fed from a pulse transformer[1]. Transformers with 10 : 1 ratio have been used in conjunction with miniature valves.

Transistors, being low-voltage, high-current devices, are inherently suitable for direct core switching, the only difficulty being the lack of a supply of transistors capable of delivering the necessary size of pulses with the short rise times (0·2 μs) necessary for high operating speeds. Temperature compensation[2] can be effected by the circuit of Fig. 4.

Two methods of dealing with the second difficulty (unwanted outputs) have been used[1]. The first consists of threading the read-out wire through the cores in such a way that spurious pulses from adjacent cores cancel. If the matrix has even numbers of rows and columns, only two uncancelled responses occur. The second[1] makes use of the fact that, when a core is subjected to a series of half-current pulses, the spurious output is largest during the first pulse[3]. The core of Fig. 5 will be magnetized to point A when a digit is written into it. The first half-read pulse moves the working point momentarily to B and, on cessation of the pulse, the working point becomes C. Subsequent half-read pulses only move the working point round the minor hysteresis loop BC. If, therefore, the output due to the first pulse can be discounted, the general level of spurious outputs is much reduced. In a practical system, a fourth wire threading all the cores in a matrix is automatically given a half-read pulse after each writing operation; so that, when the next reading operation takes place, only the residual responses occur.

Direct Selection Store

Another square-loop storage device is the direct selection[3] store. In this (Fig. 6), the problem of spurious outputs is bypassed by arranging that cores are not subjected to half-read pulses at all. Instead, it is arranged that each 'word' occupies one row of a matrix. When the 'word' is required, it is then extracted by applying a read pulse to the row wire. There is no read-out wire; instead, the column wires are employed, the output pulses for each of the digits in the word being passed to a read amplifier connected to the appropriate column. The resulting amplifier outputs might then, for example, be put into a shift register so that they could be extracted in order, for use in a computation. Writing is effected in the normal way, by applying a half-current pulse to the appropriate

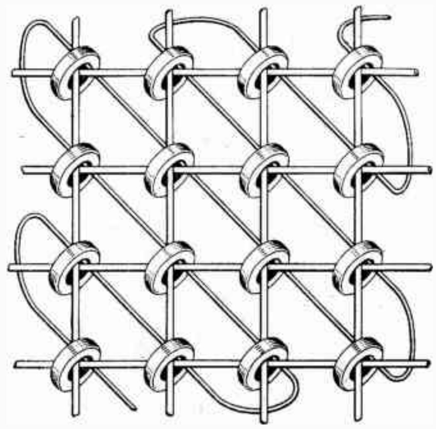


Fig. 2. *Ferrite-core memory matrix*

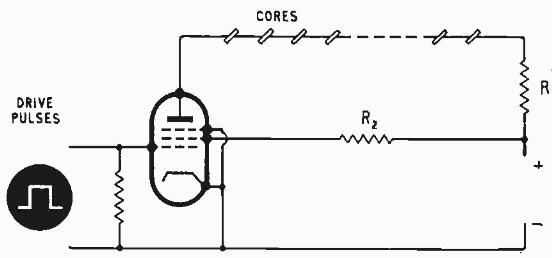
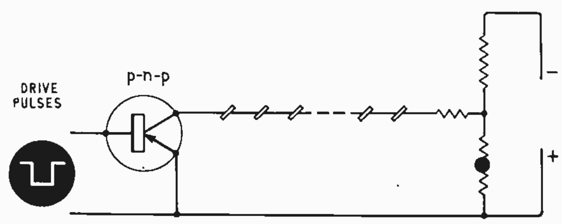


Fig. 3. *Matrix wire driven by pentode*

Fig. 4. *Matrix wire driven by junction transistor*



row via the access selector and to the appropriate column via a write amplifier and read/write gate. The occurrence of spurious outputs during writing is of no importance. The only spurious signals which now occur result from the application of the read pulse to cores which do not switch on reading (conventionally, cores which are in the '0' state). It is easy to neutralize these signals. A spare core is left in each row. All the spare cores are threaded by a column wire (compensation wire, Fig. 6). When a row is read, the compensation core, which is left permanently in the '0' condition, generates a spurious pulse equal in amplitude to that generated by any other core in the row which happens to contain a '0'. This pulse is amplified, inverted, and applied to all the column read amplifiers simultaneously. Spurious signals are thereby cancelled, but the amplitude of '1' signals, which is large, is merely reduced slightly, the overall discrimination between '0's and '1's being much improved.

Direct-selection stores can be made to work using material with a hysteresis loop rather less rectangular than that needed for random-access matrices. This has led to a new type of storage device, the 'magnetic cell'[4], which consists of a slab of square-loop ferrite with a hole through it, threaded by a pair of wires. The application of current pulses of appropriate amplitude to the wires sets the magnetic state of the material immediately adjacent to the hole. Material remote from the hole is not appreciably affected. Thus, another hole can be made in the same ferrite slab and used independently as a storage cell. Long bars of ferrite can be threaded by a number of holes to form the rows of a direct-selection store. Storage elements of this type have advantages over small toroids. The amount of energy required to switch a cell is only a quarter as great, and the output voltage is sufficiently large to make step-up transformers at amplifier inputs unnecessary. In general, the cells in a block of material

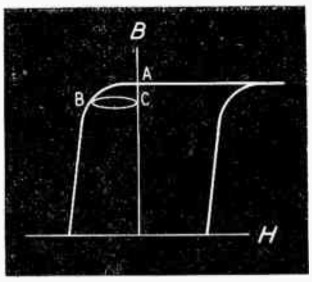


Fig. 5. *B-H loop showing conditions for 'disturbed' outputs*

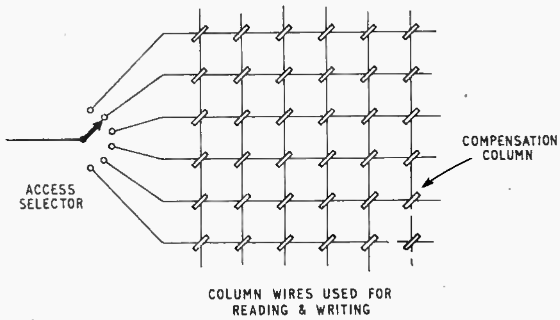
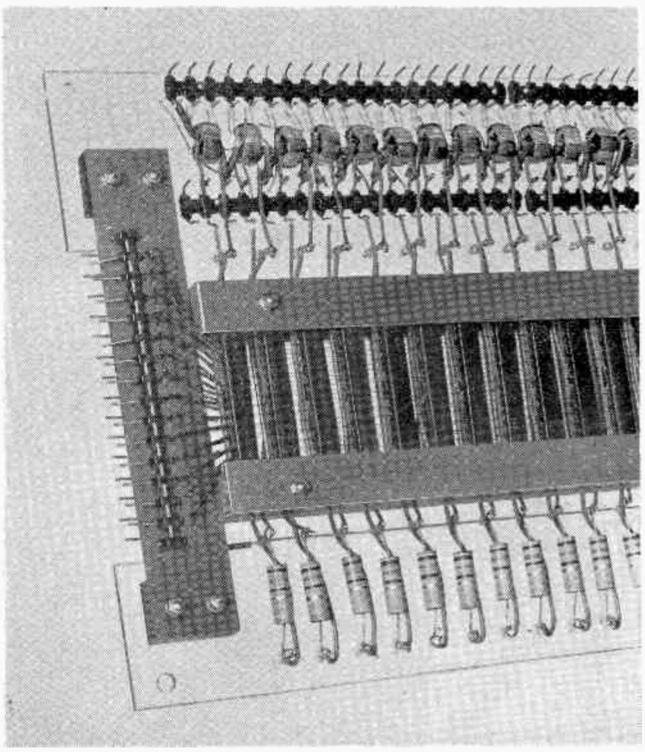


Fig. 6. *Direct-selection store*

will have uniform characteristics, so that accurate compensation of '0' outputs is possible. A direct selection store using magnetic cells is illustrated (Fig. 7).

Fig. 7. *An assembled 'tray' containing 26 ferrite storage blocks, each having 28 magnetic cells. The information is inserted and extracted through 28 column wires, whose terminations are visible at the ends of the tray. The row of toroids (one for each block) forms part of the access selector*

(Photo by courtesy of Standard Telecommunication Laboratories Ltd.)



Although square-loop ferrite devices are used principally as fast-access stores, there are many other possible applications, particularly in automatic telephony and telegraphy[2,5].

Single cores also have their uses. Fig. 8 illustrates the operation of a coincidence gate circuit.

The core is initially set to '0'. If a half-write pulse is applied to either W_1 or W_2, the core will not switch, and only a small output will appear across W_3. If coincident half-write pulses are applied to W_1 and W_2, a large output is obtained from W_3.

Variable Magnetic Coupling

It is also possible to use a core as a variable coupling device (Fig. 9). If an increasing direct current is applied to the control winding, a point will be reached at which the core begins to saturate. Saturation will occur first round the inside circumference of the core where the magnetic circuit is smallest. As the control current is increased, the ring of saturated material will widen until eventually the whole core is saturated. In the saturated condition, the permeability of the core material in the neighbourhood of the windings A and B is at a minimum and, if small a.c. signals are applied to one winding, there is little coupling of energy to the other. Desaturation of the core results in maximum coupling. Thus, the degree of coupling between A and B can be controlled and the device can act as a gate, variable transformer, or modulator.

Microwave Applications

These depend on three physical phenomena:

1. Variation of permeability for left-hand and right-hand circularly-polarized waves.
2. Variation of permeability with applied d.c. field.
3. Absorption of microwave power with a critical applied d.c. field ('resonance absorption').

If a composite wave made up of left-hand and right-hand circularly-polarized waves impinges on a piece of ferrite in a waveguide, the relative speed of propagation of the two parts of the wave will vary, because permeability is one of the factors governing speed of propagation, and the permeability of the ferrite is different for the two components of the composite wave. On emerging from the ferrite, the two components combine to form a wave whose plane of polarization has been twisted with respect to the original wave. The amount of twisting depends on the variation in permeability and this, in turn, depends on the d.c. field applied to the ferrite, so the degree to which the plane of polarization is rotated can be controlled by this field. In the arrangement shown in Fig. 10, the input and output terminations are set at 45°. The d.c. field applied to the ferrite is set so that the plane of polarization of a wave propagating from left to right is rotated 45° in a clockwise direction, so that the emergent wave is accepted by the output waveguide. A wave travelling from right to left has its plane of polarization rotated 45° anticlockwise, looking in the wave direction, and so emerges with its plane of polarization at right angles to that which the left-hand waveguide will accept. A wave travelling from right to left is therefore reflected, and is absorbed by the resistive vanes. This device, known as a Faraday rotation isolator, is often used in conjunction with a rectangular waveguide system, since a plane-polarized wave can easily be split into two counter-rotating circularly-polarized waves by matching devices of the type shown in Fig. 10.

The same polarization-rotating element can be employed to obtain a circulator (Fig. 11).

Waves entering arm 1 travel to the right and are rotated 45°, thus they are accepted by arm 2 which is set at 45° to arm 1. Similarly, arm 2 couples to arm 3, arm 3 to arm 4, and arm 4 to arm 1 (with an extra 180° phase change).

The amount of rotation obtainable is not, of course,

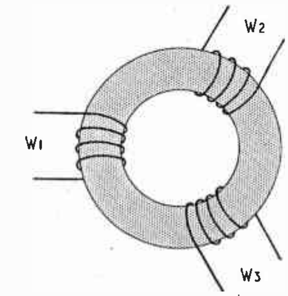
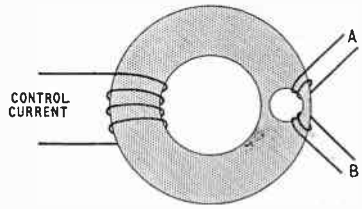


Fig. 8. *Ferrite-core coincidence gate*

Fig. 9. *Variable coupling device*



confined to 45°, and other angles can be utilized. For example, a waveguide system with a 90°-twist can be combined with a 90° Faraday rotator to obtain a phase-shift of 180° in one direction and zero in the reverse direction. The resulting device, called a gyrator, makes possible circulators of the type shown in Fig. 12.

Another group of devices used in rectangular waveguides makes use of the fact that the fields inside a waveguide are displaced in the presence of ferrite, waves for which it has a high permeability tending to concentrate in it. A waveguide containing two slabs of ferrite, one magnetized so as to have a high permeability for forward transmission and the other for reverse transmission, can be made to function as an isolator if resistive material is put near the second slab. Most of the 'forward' energy is concentrated near the 'forward' slab, so that the loss due to the resistive material is small (about 1 dB), but the reverse wave suffers a large loss (over 30 dB)[6].

A single slab of magnetized ferrite acts as a non-reciprocal phase-shifter like the Faraday rotator, and

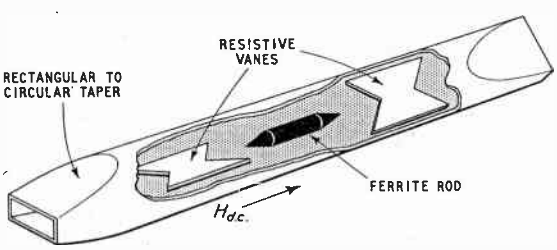


Fig. 10. *Faraday rotation isolator*

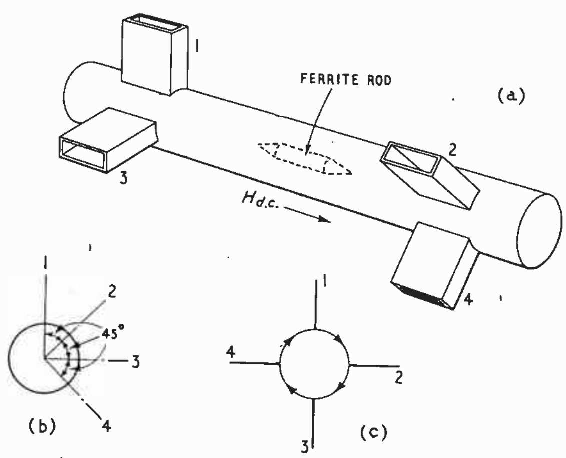


Fig. 11 (*right*). *Faraday rotation circulator: (a) mechanical arrangement, (b) angles between input and output waveguide parts and (c) couplings between parts*

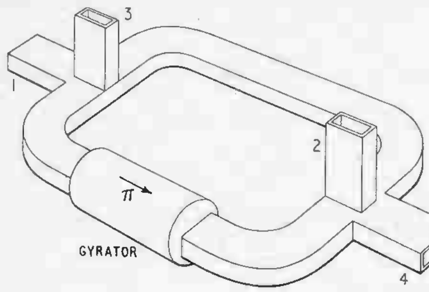


Fig. 12. *Hybrid-T circulator employing a gyrator*

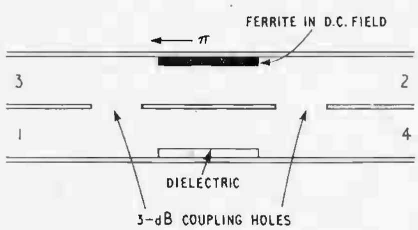


Fig. 13. *Circulator for rectangular waveguide*

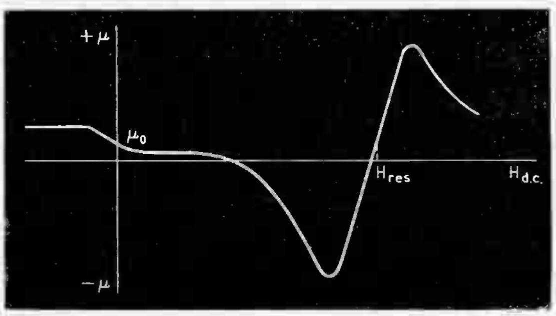


Fig. 14. *Variation of permeability with applied d.c. field*

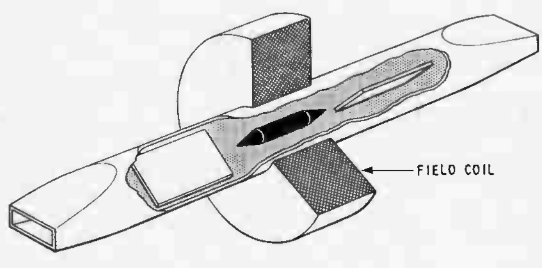


Fig. 15. *Resonance absorption isolator*

circulators have been designed which are similar in principle to those used in circular waveguide. A particularly simple one is shown in Fig. 13.

The purpose of the dielectric, which has the same dielectric constant as the ferrite, is to ensure that, for one direction of propagation, the phase-shifts in the two arms of the guide are equal. For the other direction, there is 180° difference in phase-shift due to the ferrite. For left-right transmission, the system behaves as if there were no ferrite. Energy entering at 1 leaves by 2, and 3 and 4 are similarly coupled. In the reverse direction, however, the extra 180°-phase-shift in the upper arm results in couplings between 2 and 3 and 4 and 1.

The third physical phenomenon, absorption of microwave power by the ferrite, makes possible a different kind of isolator. Reference to Fig. 14 shows that the permeability (μ) of ferrite fluctuates violently in the neighbourhood of a certain applied d.c. field H_{res}.

The interpretation of negative permeability is that it depends on the sense of circular polarization of an incident wave. It turns out that, for one sense (or one direction of propagation) the wave interacts with forces connected with electron spins in the ferrite in such a way that energy is transferred from wave to ferrite but, for the opposite sense, there is no interaction and no energy loss.

With isolators making use of this resonance absorption effect (Figs. 15 and 16) isolation ratios of 30–50 dB are obtainable, with forward losses $<$ 1dB. Unfortunately, the applied field required to produce absorption is very large and the device is, in this respect, inferior to the Faraday rotation isolator, in which the ferrite is subjected to quite low fields. It can be seen from Fig. 13 that useful variations in μ exist in the region around μ_0, where the field is below that required to saturate the ferrite. Faraday rotation devices operate in this region, whereas the field H_{res} necessary to produce absorption effects is much greater.

The effects used to make the microwave devices described above are frequency sensitive. This limits the bandwidth of a device. Methods of broad-banding are being investigated and quite respectable bandwidths have already been obtained[7]. Increase of Faraday rotation with frequency is probably due to increase in energy concentration in the ferrite. Materials with the same dielectric constant but no Faraday rotation have been positioned in relation to the ferrite components in a waveguide so as to counteract the effect, with considerable success. In one case, the Faraday rotation angle was constant from 10·7 to 11·7 kMc/s.

Dielectric material in contact with ferrite has the opposite effect; the concentration of energy is increased. This is of use in resonance isolators where, for some reason, the volume of ferrite must be small, since the greater energy concentration results in an increased absorption for a given applied field.

The range of frequencies over which microwave ferrite devices are useful extends from about 3 kMc/s to 35 kMc/s, but work is proceeding to extend it at both ends. Theoretical considerations[6] predict a lower frequency limit of about 500 Mc/s, while the upper frequency limit is fixed only by the materials available. Reciprocal resonance absorption has been obtained at about 50 kMc/s with *unmagnetized* 'Ferroxdure',* and the material has therefore possible applications in removing the second-harmonic output of transmitters operating at about 24 kMc/s, at which frequency it is loss-free. Ferroxdure, a hard black material widely

* Also known as 'Magnadur'

used for television focusing magnets, can be used to obtain Faraday rotation at 24 kMc/s, although it is not strictly a ferrite. (Since materials which produce rotation at optical frequencies are not ferrites either, this suggests that there may be other materials usable at microwave frequencies.) Faraday rotation produced by this material varies in the opposite way with frequency from that produced by ferrites, and this makes possible broad-band Faraday rotators using a combination of materials.

Power-handling capacity of ferrite devices is limited by non-linearity effects, which cause distortion of r.f. pulses passing through the material. The power-handling capacity depends on the nature and dimensions of the ferrite component. Commercial ferrite devices can handle some tens of kW.

Other Applications of Ferrites

It is not surprising that no very great advances have been made in the more conventional applications of ferrites as core materials. Here again, however, the need for new kinds of ferrite has made itself felt. In many applications, high Q is only of use if temperature stability is also high. With extant ferrites, it is often necessary to exchange Q for stability by putting a

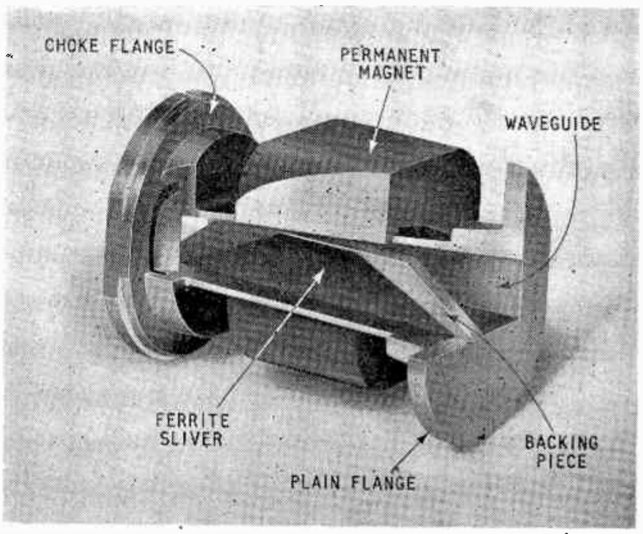


Fig. 16. *Cut-away view of commercial low-power resonance absorption isolator*
(Photo by courtesy of Mullard Ltd.)

large air gap in the magnetic circuit. Encouraging reports of new ferrite compositions suggest that, not only the dependence of permeability, but also that of the mechanical resonant frequency of a piece of ferrite on temperature are capable of reduction. This latter factor could result in the application of ferrites in electro-mechanical filters and resonators. At audio frequencies, ferrite would appear to have advantages over quartz crystals in that there is virtually no limitation on the physical size of a resonator. Mechanical Q values of several thousands are obtainable.

Another problem which is being attacked with success is that of increasing the saturation magnetization of ferrites. At present, this is so much lower than that of metallic-core materials that ferrites are only practicable in power applications at frequencies of about 2 kc/s and over. Ferrite power transformers are an attractive proposition by reason of the small core losses and the ease of assembly of bulk core parts compared with laminations.

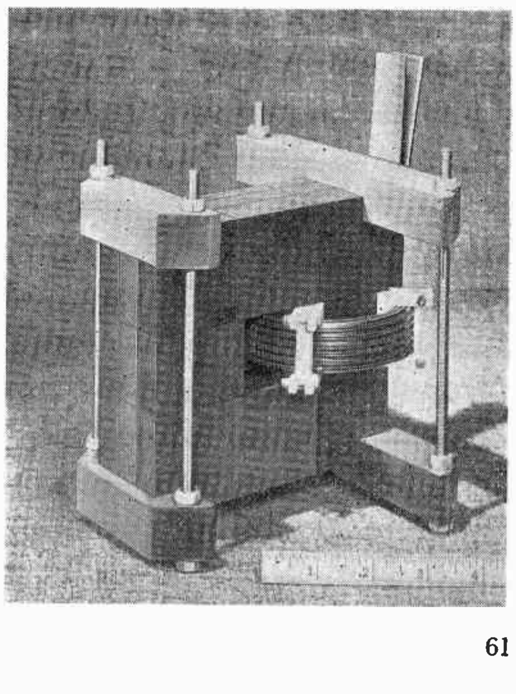
Finally, the magnetostrictive properties of some ferrites suit them to transducer applications, particularly in the frequency range of a few tens to a few hundreds of kc/s, in which metallic and crystal transducers are not very practicable.

The use of ferrites as core materials is limited to frequencies below about 100 Mc/s by the phenomenon of domain resonance. A piece of ferrite may be considered to consist of a number of magnetic regions or domains, each magnetized to saturation in a preferred direction to which the domain is bound by a restoring couple. The sudden application of an external magnetic field causes a resonance effect at a frequency proportional to the strength of the restoring couple. If an alternating field at this resonant frequency is applied, heavy core losses result. Some new materials have recently been announced by the Philips' Laboratories which promise to raise the upper frequency limit by about five times. These have no preferred direction of domain magnetization, only a preferred plane, and are therefore dubbed *Ferroxplana*. The permeabilities of Ferroxplana reported so far are not large (about 10) but are, nevertheless, useful, and are maintained well into the v.h.f. region.

REFERENCES

[1] C. J. Quartly, A. L. Cain, and R. W. Clarke, "A Matrix Store for Data Rate Conversion". I.E.E. Convention on Ferrites.
[2] W. Six, and R. A. Koolhof, "Some Applications of Square-Loop Ferrite Cores in Telecommunication Switching Circuits". I.E.E. Convention on Ferrites.
[3] W. Renwick, "A Magnetic Core Matrix Store with Direct Selection using a Magnetic-Core Switch Matrix". I.E.E. Convention on Ferrites.
[4] D. S. Ridler, and R. Grimmond, "The Magnetic Cell; A New Circuit Element". I.E.E. Convention on Ferrites.
[5] E. P. G. Wright, "The Application of Square-Loop Ferrite Materials in Data Processing Systems". I.E.E. Convention on Ferrites.
[6] P. J. B. Clarricoats, A. G. Hayes, and A. F. Harvey, "A Survey of the Theory and Applications of Ferrites at Microwave Frequencies". I.E.E. Convention on Ferrites.
[7] A. G. Fox, "Notes on Microwave Ferromagnetics Research". I.E.E. Convention on Ferrites.

Fig. 17. *5-kW wide-band transformer using nickel-zinc ferrite core. The transformer matches* 600 *ohms to* 70 *ohms in the range* 4–80 *Mc/s*
(Photo by courtesy of Standard Telephones & Cables Ltd.)



Solution of Algebraic Equations: Real Roots

The increasing use of mathematics in electronics and radio is often viewed with some disfavour by the engineer. Much of his difficulty with mathematics arises out of the fact that he and the mathematician speak different languages and have different habits of thought. The average mathematical textbook can be all but unintelligible to the engineer.

Recognizing the fact that mathematics is necessary to the engineer and that he normally tends to dislike it, it is felt that short articles on certain aspects could be helpful to him. Such articles will, therefore, appear from time to time in Electronic & Radio Engineer. *In this one, a method of finding the real roots of an equation is explained. The average engineer does not have to do this every day but, when it becomes necessary, he often finds it hard to track down a suitable method in the textbooks and to apply it.*

The method described here is so presented that it need not be 'learnt'. The engineer can apply it by following the step-by-step procedure almost as a 'drill'. A further article will extend the method to cover complex roots.

In circuit analysis, it is quite often necessary to find the roots of equations which are of degree higher than 2. Second-degree equations can, of course, always be solved by formula, but those of higher degree are usually considered to present great difficulty. In fact, however, it is possible to find the roots of equations of any degree with no more mathematical knowledge than the ability to perform algebraic long division!

The process can be tedious, it is true, especially if a high degree and high order of accuracy are required, for this entails working to a good many places of decimals. A calculating machine is a very great help. However, the ability to obtain a solution can often be very valuable and well worth the labour involved.

The method is one which can deal with complex as well as real roots and is thus especially useful in electrical work, where complex roots occur quite frequently. A typical case arises when it is required to compute the transient response of a circuit. Whatever method is used, Heaviside or Laplace transforms or ordinary differential equations, at some stage it is necessary to find the roots of an equation and some or all of these roots are very commonly complex.

The method is applicable only when the equation has numerical coefficients. Such an equation occurs in practice when it is desired to compute the performance of a circuit for given values of components, or sometimes, for given relations between the values of components.

If the equation is associated with a passive network or stable system, it will be free from roots with positive real parts. If it is of odd degree, it must have at least one real root. The remaining roots of an odd-degree equation, and all the roots of one of even degree, can be real or complex or some real and some complex. The complex roots always occur in conjugate pairs.

Because of this, a cubic, for example, must have one real root and either two further real roots or one pair of complex conjugate roots. A quartic can have two pairs of complex roots, one pair of complex roots and two real roots, or four real roots.

As already stated, the method of solution involves nothing more difficult than algebraic long division. It is based upon a method originally due to Shih-Nge Lin and it is most successful if we first look for the smallest root of our given equation; that is, the real root or complex conjugate root pair of least modulus. It can, however, easily be adapted for finding the root or root pair of greatest modulus. Having obtained the extreme roots they can be divided out of the given equation to reduce its degree and the process applied afresh to the new equation to find further roots.

Determination of a Real Root

The process will be explained in the first instance by considering a cubic equation having only real roots. Let this equation be

$$f(x) = x^3 + 18x^2 + 78{\cdot}75x + 81 = 0 \quad .. \quad (1)$$

In reality, this equation has three real negative roots whose exact values are $-1{\cdot}5$, $-4{\cdot}5$ and -12; we know this because we have constructed the equation to have these roots! We shall not make use of this knowledge in solving the equation, however, but merely reserve it to check our solution.

The first step is to obtain approximate values for the roots. By trying some extreme values, we find

$$f(0) = 81;\ f(-2) = -12{\cdot}5;\ f(-10) = 93{\cdot}5;$$
$$f(-\infty) = -\infty \quad .. \quad .. \quad .. \quad (2)$$

and from this we can see that there must be one real root between 0 and -2, for $f(x)$ changes sign between these values. By taking further values and plotting a *rough* graph (Fig. 1) we can easily discover that there are, in fact, three real roots, that the one between 0 and -2 is the smallest numerically and that the other two lie between -2 and $-12{\cdot}5$. We may also estimate from this rough graph that the value of this smallest root is about $-1{\cdot}7$. We take this value as a starting point and use it to obtain a more accurate value.

The first step is to divide $f(x)$ in (1) by $x(x + 1{\cdot}7)$;

incidentally, this same divisor would be used whatever the degree of $f(x)$. Performing the division, the quotient is $x + 16 \cdot 3$ with the remainder $51 \cdot 04x + 81$, which we express as $51 \cdot 04(x + 1 \cdot 587)$.

The process is now repeated, but using $x(x + 1 \cdot 587)$ as the divisor of $f(x)$. The quotient is now $x + 16 \cdot 413$ with remainder $52 \cdot 70x + 81 = 52 \cdot 70(x + 1 \cdot 537)$.

In this, quite simple, way we have obtained three successive approximations to the required root. They are, first, the value $-1 \cdot 7$ which we obtained from a rough graphical solution; secondly, $-1 \cdot 587$ as a result of the first division; and thirdly, $-1 \cdot 537$ as a result of the second division.

We can now use these to obtain a closer approximation. This is given by the quantity

$$P = \frac{p_1^2 - p_0 p_2}{2p_1 - p_0 - p_2} = p_0 + \frac{\delta_1^2}{2\delta_1 - \delta_2} \quad .. \quad (3)$$

where

p_0 = the original approximation (here $-1 \cdot 7$)

p_1 = the number arising out of the first division (here $-1 \cdot 587$)

p_2 = the number arising out of the second division (here $-1 \cdot 537$)

$\delta_1 = p_1 - p_0$ (here $0 \cdot 113$)

$\delta_2 = p_2 - p_0$ (here $0 \cdot 050$)

Inserting values in (3) we find $P = -1 \cdot 497$ and, since in this case we know that the exact value of the root is $-1 \cdot 5$, we see that the process has actually given us quite a close approximation to it.

For numerical work it is preferable to use the form of (3) involving δ_1 and δ_2. The validity of (3) depends upon the fact that if p_0, p_1 and p_2 are all sufficiently close to the true root (say, p) then the quantities $(p_0 - p)$, $(p_1 - p)$, $(p_2 - p)$ are theoretically expected to form a geometric progression. In numerical working, the original quantity p_0 can be rounded off to any convenient number of decimal places, but p_1 and p_2 should be calculated to as many decimal places as are required for the true root.

Having obtained the value $-1 \cdot 497$ for the root, if we do not consider this to be accurate enough we can repeat the whole process using this value for the initial value p_0. Doing this, we find $p_1 = -1 \cdot 49875$ and $p_2 = -1 \cdot 49948$. The use of equation (3) then gives $P = -1 \cdot 50000$.

In this way, we have found the smallest root of the equation, and by dividing by $x + 1 \cdot 5$ we can obtain a new equation of one degree lower. Since our equation is a cubic, the new one is a quadratic and can be at once solved by formula for the remaining two roots. If it had been of higher degree, however, the new one would have been at least a cubic and we should then have to tackle this in the same way as equation (1).

If, for any reason, we are primarily interested in the largest root of equation (1) instead of the smallest, we rewrite the equation in a different 'reciprocal' form before starting to find the root. The drill is to replace x by $1/y$ and multiply the resulting expression by y^3 (y^n in the general case of an equation of degree n). The root-finding process is then actually applied to

$$y^3 f(1/y) = 81y^3 + 78 \cdot 75y^2 + 18y + 1 \quad .. \quad (4)$$

We can if we like divide through by the coefficient (81) of the highest power of y.

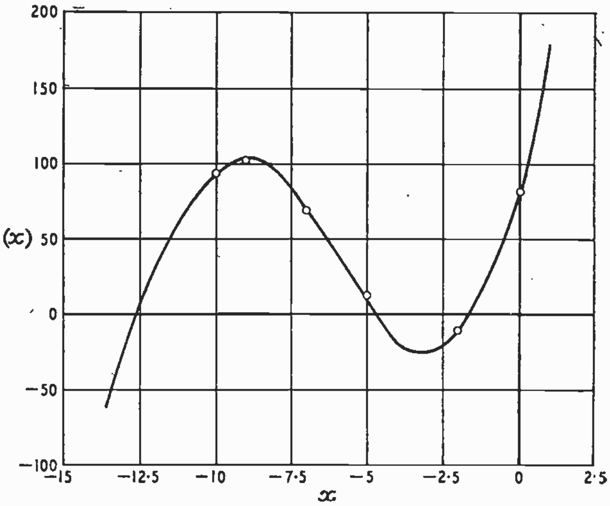


Fig. 1. *Rough plot of equation* (1) *made in order to determine the approximate value of the roots*

The process described is now applied to find the smallest root of (4) and this is, of course, the reciprocal of the largest root of (1).

The procedure for finding the smallest and largest roots of any equation having negative real roots has now been explained.

A cubic equation can always be solved by the procedure given here, and so can any equation having not more than one pair of complex conjugate roots and all its real roots distinct. It may be necessary to use the 'reciprocal' equation, derived as (4) was derived from (1), rather than the original equation, but with either the original or the 'reciprocal' equation or both we can obtain real roots in succession and divide by the corresponding linear factors until the degree of the residual equation is reduced to 2, so that the complex conjugate pair can be obtained from formula.

For an equation having some complex conjugate root pairs and some real roots, the process described will not work for the original equation if we seek the numerically smallest real root and there is a complex conjugate root pair of much smaller modulus, or if we use the 'reciprocal' equation and seek the numerically largest real root when there is a complex conjugate root pair having much larger modulus.

When two or more pairs of complex conjugate roots are present, whether there are also real roots or not, something more is needed, but we must defer that to a later article.

INTERNATIONAL SYMPOSIUM

An international symposium on "Physical Problems of Colour Television", organized by the International Union of Pure and Applied Physics and sponsored by UNESCO will be held in Paris 2nd–6th July, 1957.

Sessions will be devoted to the following subjects:

- Properties and behaviour of the human eye in colour television.
- Image analysis and reconstitution (pick-up tubes and colour kinescopes.
- Assessment and measurement of picture quality.
- Coding procedures for transmission of colour signals.

Additional information is obtainable from the Secretary, Colloque International sur les Problèmes de la Télévision en Couleurs, Conservatoire National des Arts et Métiers, 292 rue Saint-Martin, Paris 3e, France.

Dilemmas In Transmission-Line Theory

By R. A. Chipman*

SUMMARY. *The customary approximate formulae for the characteristics of transmission lines are shown to lead to an error of 100% in the calculation of the resistive component of the impedance of an electrically-short section of line terminated in a short-circuit. Terminations of a line with a non-reflective load and with a load equal to the conjugate of Z_0 are compared. It is shown that, in some cases, the conjugate load may receive more power than the non-reflective load. Simple, but exact, expressions are derived for the propagation constant and the ratio of reactance to resistance of a line.*

The theory of high-frequency transmission lines, derived from the 'telegraph equations', has become standard equipment for radio engineers in recent years. It is presented with only minor variations in a great many text-books, and the validity of certain expressions has come to be taken for granted. While it is quite true that the commonly-accepted approximations involve percentage errors in r.f. line calculations that are generally negligible, an example that follows will show that this is not always so. Another example will show that the approximations conceal a very interesting problem. Finally, some easily derived exact relationships among the line characteristics will be found, which are no more complicated than the approximate ones usually employed.

1. The Input Impedance of an Electrically Short Stub-Line with Short-Circuit Termination.

The propagation constant $\gamma = \alpha + j\beta$ of a uniform transmission line is *defined* from

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)\ (G + j\omega C)} \quad .. \quad (1)$$

where ω is the angular frequency and R, L, G and C are the usual distributed electrical constants of the line.

At 'high' frequencies, *defined* by $\omega L/R \gg 1$ and $\omega C/G \gg 1$, the standard procedure is to re-write equation (1) in the form

$$\alpha + j\beta = j\omega\sqrt{LC}\left(1 + \frac{R}{j\omega L}\right)^{1/2}\cdot\left(1 + \frac{G}{j\omega C}\right)^{1/2} \quad (2)$$

and to expand the two brackets by the binomial theorem as far as the terms in $\left(\frac{R}{j\omega L}\right)^2$ and $\left(\frac{G}{j\omega C}\right)^2$, finally separating the real and imaginary terms to obtain

$$\alpha = \left(\frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}}\right)\left\{1 + \tfrac{1}{2}\left(\frac{R}{2\omega L} - \frac{G}{2\omega C}\right)^2\right\} \quad ..(3)$$

$$\beta = \omega\sqrt{LC}\left\{1 + \tfrac{1}{2}\left(\frac{R}{2\omega L} - \frac{G}{2\omega C}\right)^2\right\} \quad .. \quad .. (4)$$

At radio frequencies, for any reasonable line construction, the right-hand bracket in equations (3) and (4) differs negligibly from unity, leading to

$$\alpha_{h.f.} = \frac{R}{2}\sqrt{\frac{C}{L}} + \frac{G}{2}\sqrt{\frac{L}{C}} \quad .. \quad .. \quad .. (5)$$

$$\beta_{h.f.} = \omega\sqrt{LC} \quad .. \quad .. \quad .. \quad .. \quad .. (6)$$

The characteristic impedance $Z_0 = R_0 + jX_0$ is defined by the equation

$$Z_0 = R_0 + jX_0 = \sqrt{\frac{(R + j\omega L)}{(G + j\omega C)}} \quad .. \quad .. (7)$$

and the same binomial theorem process leads to

$$R_0 = \sqrt{\frac{L}{C}}\cdot\left\{1 + \tfrac{1}{2}\left(\frac{R}{2\omega L} - \frac{G}{2\omega C}\right)\left(\frac{R}{2\omega L} + 2\frac{G}{2\omega C}\right)\right\} \quad (8)$$

$$X_0 = -\sqrt{\frac{L}{C}}\cdot\left(\frac{R}{2\omega L} - \frac{G}{2\omega C}\right)\times \left\{1 + \tfrac{1}{2}\left[\left(\frac{R}{2\omega L}\right)^2 + 2\left(\frac{R}{2\omega L}\right)\left(\frac{G}{2\omega C}\right) + 5\left(\frac{G}{2\omega C}\right)^2\right]\right\} \quad (9)$$

The corresponding high-frequency approximations are, therefore,

$$R_0\ (h.f.) = \sqrt{\frac{L}{C}} \quad .. \quad .. \quad .. \quad .. (10)$$

$$X_0\ (h.f.) = 0 \quad .. \quad .. \quad .. \quad .. \quad .. (11)$$

$$Z_0\ (h.f.) = \sqrt{\frac{L}{C}} + j0 \quad .. \quad .. \quad .. (12)$$

The input impedance Z_{inp} of a length l of transmission line terminated in an impedance Z_T is given, without approximation, by

$$Z_{inp} = Z_0\left\{\frac{\frac{Z_T}{Z_0} + \tanh(\alpha + j\beta)\,l}{1 + \frac{Z_T}{Z_0}\tanh(\alpha + j\beta)\,l}\right\} \quad .. \quad .. (13)$$

For short-circuit termination $Z_T = 0$, and

$$Z_{inp_{(s.c.)}} = Z_0 \tanh(\alpha + j\beta)\,l \quad .. \quad .. (14)$$

Consider a short stub-line, as shown in Fig. 1, which is a small fraction of a wavelength long ($\beta l \ll 1$), has low total attenuation ($\alpha l \ll 1$), and whose losses are due only to series resistance ($G = 0$). In equation (14), $\tanh(\alpha + j\beta)l = (\alpha + j\beta)l$ with high accuracy when

* Associate Professor of Electrical Engineering, McGill University, Montreal, Canada

$\alpha l \ll 1$ and $\beta l \ll 1$. For this short line therefore

$$Z_{inp_{(s.c.)}} = Z_0\,(\alpha l + j\beta l) \qquad \ldots \quad \ldots \quad \ldots (15)$$

Substituting in equation (15) for α, β and Z_0 from equations (5), (6) and (12) respectively gives

$$Z_{inp_{(s.c.)}} = \sqrt{\frac{L}{C}}\left\{\frac{R}{2}\sqrt{\frac{C}{L}}\,l + j\omega\sqrt{LC}\,l\right\}$$

$$= \frac{R\,l}{2} + j\omega L\cdot l \qquad \ldots \quad \ldots (16)$$

However, it is obvious just from inspection of Fig. 1 that the input impedance of this electrically-short line with no leakage losses is

$$Z_{inp_{(s.c.)}} = Rl + j\omega Ll \qquad \ldots \quad \ldots \quad \ldots (17)$$

The transmission-line equations have therefore given a resistance component which is in error by a factor of 2. Why ?

The answer lies in the least accurate of the approximations for the h.f. line ; i.e., equation (9). If instead of assuming $X_0 = 0$, the first term of equation (9) is retained (subject in the present case to $G = 0$), then

$$X_0 = -\sqrt{\frac{L}{C}}\cdot\frac{R}{2\omega L} \qquad \ldots \quad \ldots \quad \ldots \quad \ldots (18)$$

$$Z_0 = \sqrt{\frac{L}{C}}\left(1 - j\frac{R}{2\omega L}\right) \qquad \ldots \quad \ldots \quad \ldots (19)$$

Substituting (5), (6) and (19) into (15) gives

$$Z_{inp_{(s.c.)}} = \sqrt{\frac{L}{C}}\left(1 - j\frac{R}{2\omega L}\right)\left(\frac{R}{2}\sqrt{\frac{C}{L}}\,l + j\omega\sqrt{LC}\,l\right) \qquad (20)$$

$$= \frac{R\,l}{2} + \frac{R\,l}{2} + j\omega L\,l\left\{1 - \left(\frac{R}{2\omega L}\right)^2\right\} \quad \ldots (21)$$

and dropping the $\left(\frac{R}{2\omega L}\right)^2$ term leads to the correct result of equation (17).

Thus the complex component of the characteristic impedance, however small it may be, contributes 50% of the calculated resistive component of the input impedance for this electrically-short line.

2. The 'Proper' Termination of a Transmission Line

Somewhere in the history of transmission-line theory the phrase 'proper termination' was defined to mean termination of a line in its characteristic impedance; i.e., non-reflectively. To see that the word 'proper' does not necessarily mean 'optimum' in all significant respects, consider the circuit of Fig. 2. Here a transmission-line of any length and attenuation is supplied by a generator of voltage V_G whose impedance (to simplify the following analysis) is equal to Z_0, the characteristic impedance of the line.

At the terminals of the load Z_T, according to Thévenin's theorem, the generator's voltage V_G, its impedance Z ($=Z_0$), and the length l of transmission-line, can all be replaced by an equivalent generator, whose voltage V_T is the open-circuit voltage at the transmission-line terminals, and whose impedance is the impedance seen looking into the line from the load terminals when V_G is replaced by a short-circuit. Clearly this impedance is Z_0, so the transmission-line circuit becomes that of Fig. 3.

If Z_0 is purely real, then the condition for maximum power to the load is $Z_T = Z_0$, or $R_T = R_0$. But Z_0 for actual lines has a finite reactive component, however small, (unless $R/2\omega L = G/2\omega C$, the condition for Heaviside's 'distortionless' line).

Thus the question arises in the general case, does the load receive maximum power for $Z_T = Z_0$, which certainly results in no reflection of power from the load back into the line, or for $Z_T = Z_0^*$, where Z_0^* ($= R_0 - jX_0$) is the conjugate impedance of Z_0 ? If more power reaches the load in this latter case, where does this extra power come from ? Is it due to increased output from the source, or decreased losses in the line, or both ?

Very few text-books even mention this problem and none of them solves it. For r.f. lines the matter is of little practical importance, since the percentage difference between the received powers in the two cases is minute. For voice-frequency telephone lines, where X_0/R_0 can approach unity as a maximum value, the distinction could be more significant.

However, it is mainly as a theoretical dilemma that the problem is worth considering, to ensure that Thévenin's theorem is not violated, and to see how it is possible for the load to receive more power when its impedance is Z_0^* even though this termination results in reflected waves on the line.

An expression for the voltage at any distance s, measured from the *load* end of the line, for the transmission-line circuit of Fig. 2, is

$$V(s) = V_G\cdot\frac{Z_0}{Z_G + Z_0}\cdot\frac{e^{-(\alpha+j\beta)l}}{1 - k_G k_T\,e^{-2(\alpha+j\beta)l}} \times \left\{e^{(\alpha+j\beta)s} + k_T\,e^{-(\alpha+j\beta)s}\right\} \quad \ldots \quad \ldots (22)$$

where $k_T = \left|k_T\right| e^{j\phi T} = \dfrac{Z_T - Z_0}{Z_T + Z_0}$ is the reflection coefficient at the load

and $\quad k_G = \dfrac{Z_G - Z_0}{Z_G + Z_0}$ is the reflection coefficient at the generator.

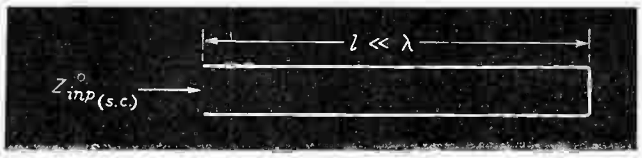
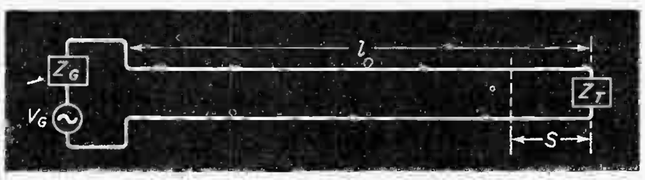


Fig. 1. *Short stub-line with short-circuit termination*

Fig. 2. *Line terminated in finite load*



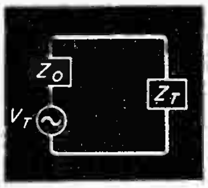


Fig. 3. *Equivalent circuit of terminated line*

The expression for the current distribution corresponding to equation (22) is

$$I(s) = \frac{V_G}{Z_G + Z_0}\,\frac{e^{-(\alpha+j\beta)l}}{1 - k_G\,k_T\,e^{-2(\alpha+j\beta)l}} \times \left\{e^{(\alpha+j\beta)s} - k_T\,e^{-(\alpha+j\beta)s}\right\} \quad \ldots \quad \ldots \quad (23)$$

The following analysis is unnecessarily complicated if a general value for Z_G is retained, so let $Z_G = Z_0$, which makes $k_G = 0$.

The equivalent Thévenin source voltage V_T of Fig. 3 is obtained from equation (22) through the fact that it is the voltage at $s = 0$, when $Z_T = \infty$, or $k_T = +1 + j0$. Using also $k_G = 0$, the result is $V_T = V_G\,e^{-(\alpha+j\beta)l}$ .. (24)
The power received by a load of impedance Z_0 is

$$P_T\,(Z_T = Z_0) = \left|\frac{V_T}{2\,Z_0}\right|^2 \cdot R_0 = \left|\frac{V_G}{2\,Z_0}\right|^2 e^{-2\alpha l} \cdot R_0 \quad (25)$$

and the power received by a load whose impedance is Z_0^*, the conjugate of Z_0, is

$$P_T\,(Z_T = Z_0^*) = \left|\frac{V_T}{2\,R_0}\right|^2 \cdot R_0$$

$$= \left|\frac{V_G}{2\,Z_0}\right|^2 e^{-2\alpha l} \cdot R_0 \cdot \left\{1 + \left(\frac{X_0}{R_0}\right)^2\right\} \quad \ldots \quad (26)$$

Subtracting (25) from (26) gives

$$P_T\,(Z_T = Z_0^*) - P_T\,(Z_T = Z_0)$$

$$= \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot e^{-2\alpha l} \cdot R_0 \cdot \left(\frac{X_0}{R_0}\right)^2 \quad \ldots \quad \ldots \quad (27)$$

as the *increase* of power received by the load on changing from the non-reflective termination to the conjugate termination. The *fractional* increase is given by the term $(X_0/R_0)^2$.

To find the source of this increase of power, it is necessary to calculate the power supplied by the generator to the line, and the losses in the line, in each case. While this can be done readily enough for a line with both R and G finite, the results are clearer if either $R = 0$ or $G = 0$. The calculations will therefore be made for $G = 0$ which results, as shown in Section 3 below, in

$$\frac{X_0}{R_0} = -\frac{\alpha}{\beta} \quad \ldots \quad \ldots \quad \ldots \quad (28)$$

It is useful to re-write equation (26) incorporating (28), as

$$P_T\,(Z_T = Z_0^*) = \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot e^{-2\alpha l} \cdot R_0 \cdot \left\{1 + \left(\frac{\alpha}{\beta}\right)^2\right\} \quad (29)$$

The power supplied to the line by the generator when the line is terminated in Z_0 is

$$P_{IN}\,(Z_T = Z_0) = \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot R_0 \quad \ldots \quad \ldots \quad \ldots \quad (30)$$

When the line is terminated in Z_0^*, the corresponding equation is

$$P_{IN}\,(Z_T = Z_0^*) = \left|\frac{V_G}{Z_0 + Z_{inp}}\right|^2 \cdot R_{inp} \quad \ldots \quad \ldots \quad (31)$$

where $Z_{inp} = R_{inp} + jX_{inp}$ is the input impedance of the length l of line terminated in Z_T.

After considerable manipulation, but without introducing any approximations, equation (31) can be brought to the form

$$P_{IN}\,(Z_T = Z_0^*) = \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot R_0 \times$$

$$\left\{1 - \left(\frac{\alpha}{\beta}\right)^2 e^{-4\alpha l} - 2\left(\frac{\alpha}{\beta}\right)^2 \cdot e^{-2\alpha l}\,\sin\,(2\beta l - \phi_T)\right\} \quad (32)$$

in which ϕ_T is the phase angle of the reflection coefficient k_T as defined above. This derivation also makes use of the actual value of k_T for the conjugate termination, which is

$$k_T = \frac{(R_0 - jX_0) - (R_0 + jX_0)}{(R_0 - jX_0) + (R_0 + jX_0)} = -j\frac{X_0}{R_0} = j\frac{\alpha}{\beta} \quad (33)$$

Since for a line of any length l, $\sin(2\beta l - \phi_T)$ may lie arbitrarily between $+1$ and -1, and since the $e^{-4\alpha l}$ factor of the second term must be less than the $e^{-2\alpha l}$ factor of the third term, changing the terminal impedance of a line from its characteristic impedance to the conjugate of this value *may either increase or decrease the power input to the line*, depending on the line length.

The power loss P_R in the resistance of the line conductors is obtained from

$$P_R = \int_0^l \left|I(s)\right|^2 \cdot R \cdot dl \quad \ldots \quad \ldots \quad \ldots \quad (34)$$

using equation (23) for $I(s)$.
This calculation also involves a good deal of manipulation, but leads to the results

$$P_R\,(Z_T = Z_0) = \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot R_0 \cdot (1 - e^{-2\alpha l}) \quad \ldots (35)$$

$$P_R\,(Z_T = Z_0^*) = \left|\frac{V_G}{2\,Z_0}\right|^2 \cdot R_0 \cdot \left\{(1 - e^{-2\alpha l}) - \left(\frac{\alpha}{\beta}\right)^2 e^{-2\alpha l} - \left(\frac{\alpha}{\beta}\right)^2 e^{-4\alpha l} - 2\left(\frac{\alpha}{\beta}\right)^2 e^{-2\alpha l}\sin\,(2\beta\,l - \phi_T)\right\} \quad \ldots (36)$$

For the case of non-reflective termination it is obvious immediately that
input power to line (30) = line loss (35) + power in load (25).

For the conjugate termination, inspection of equations (36), (32), and (29) reveals the following:

1. The terms corresponding to the non-reflective termination are present in each case; additional terms therefore represent differences from the non-reflecting case;

2. Terminating the line in Z_0^* changes the power input to the line from the source by

$$\left|\frac{V_G}{2\,Z_0}\right|^2 \cdot R_0 \times \left\{-\left(\frac{\alpha}{\beta}\right)^2 e^{-4\alpha l} - 2\left(\frac{\alpha}{\beta}\right)^2 e^{-2\alpha l}\sin\,(2\beta l - \phi_T)\right\}$$

and the power loss in the conductors changes by an identical amount; this change in power input to the line therefore does not change the power received by the load;

3. Independently of item 2, the power loss in the conductors is *reduced* by a term

$$\left|\frac{V_G}{2 Z_0}\right|^2 \cdot R_0 \cdot \left(\frac{\alpha}{\beta}\right)^2 e^{-2\alpha l}$$

and *the power received by the load is increased by the same amount.*

Item 3 is therefore the answer to the original question. Changing the line termination from the non-reflective value to the conjugate increases the power delivered to the load, and this power increase comes from a reduction in line loss.

This result contradicts a statement found in some text-books, including some that recognize the characteristic impedance to be complex in the general case, that conductor losses are minimized by a non-reflective termination.

Because of the arbitrary term involving sin $(2\beta l - \phi_T)$, no useful statement can in fact be made about minimizing line losses as such. However, since the *fractional* increase in power at the load on changing the terminal impedance from Z_0 to Z_0^* is $\left(\frac{\alpha}{\beta}\right)^2$, while the *fractional* increase in power input to the line cannot exceed $2\left(\frac{\alpha}{\beta}\right)^2 e^{-2\alpha l}$ (the maximum value occurs when $\sin(2\beta l - \phi_T) = -1$), it is approximately true when a line has a total attenuation of at least a few nepers (say 30 dB or more) that the *efficiency* of the line as an element of the total circuit is maximized by $Z_T = Z_0^*$.

3. Some Useful Relations among the Line Constants

It was shown in Section 1 how the defining equations (1) and (7) for α, β, R_0 and X_0 may be expanded to obtain high-frequency approximations. It seems not to be generally known that some similiar, and for many purposes more useful, expressions may be obtained directly from (1) and (7) without approximation.

The product of (1) and (7) gives

$$(\alpha + j\beta)(R_0 + jX_0) = R + j\omega L \quad \ldots \quad (37)$$

Separating the real terms,

$$\alpha R_0 - \beta X_0 = R \quad \ldots \quad (38)$$

Similarly the quotient (1)/(7) leads to

$$\frac{\alpha R_0 + \beta X_0}{R_0^2 + X_0^2} = G \quad \ldots \quad (39)$$

Substituting for βX_0 from (39) into (38), and using $|Z_0|^2 = R_0^2 + X_0^2$ gives

$$\alpha = \frac{1}{2 R_0}\left(R + G\frac{|Z_0|^2}{2}\right) \quad \ldots \quad (40)$$

If the approximation of equation (12), $Z_0 = R_0 = \sqrt{L/C}$ is introduced into equation (40), the high-frequency equation (5) is obtained.

There seems to be little point in emphasizing a separate form of high-frequency equation when an expression as simple as equation (40) is valid at all frequencies.

A similar expression may be found for β in the form

$$\beta = \frac{1}{2 R_0}\left(\omega L + \omega C|Z_0|^2\right) \quad \ldots \quad (41)$$

which has perhaps no obvious virtues.

If equations (38) and (39) are solved for X_0/R_0, the result is

$$\frac{X_0}{R_0} = \frac{\alpha}{\beta}\left(\frac{G|Z_0|^2 - R}{G|Z_0|^2 + R}\right) \quad \ldots \quad (42)$$

which involves no approximations. It shows that X_0/R_0 must lie between the extremes of $+\frac{\alpha}{\beta}$ (if the losses are all due to G) and $-\frac{\alpha}{\beta}$ (if the losses are all due to R). The case $R = G|Z_0|^2$, for which $X_0 = 0$, is the distortionless line whose losses are equally divided between R and G.

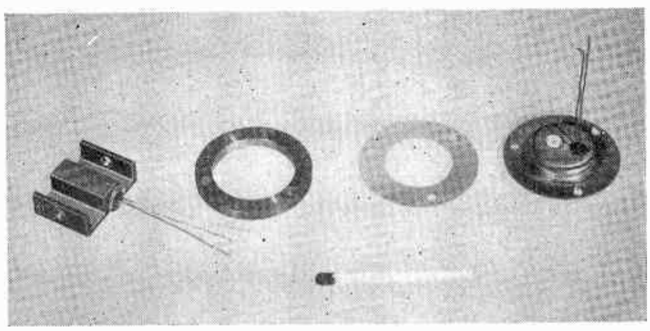
Since $\frac{\alpha}{\beta} = \frac{\textit{attenuation in nepers per wavelength,}}{2\pi}$ it is invariably a very small quantity for useful r.f. lines.

New Transistors

A DEMONSTRATION of the applications of junction transistors in audio amplifiers and radio receivers was given recently by the General Electric Company. A number of new types of germanium junction transistor are in production or pilot production by G.E.C., and also some silicon junction rectifiers. A feature of the transistors is a type of construction in which the base of the electrode is connected to the metal case; this ensures rigidity and provides a means of conducting away heat produced by internal power dissipation. All the new transistors are p-n-p alloyed-junction types, with current-gain cut-off frequencies up to 1·5 Mc/s and permissible collector dissipations up to about 5 watts at 45° C.

Type GET4 is a low-power transistor (collector dissipation 50 mW at 45° C) for audio and low radio-frequency applications. The current-gain cut-off frequency is 1/5 Mc/s, the collector capacitance is 40 pF at 12 volts, and the extrinsic base resistance is 60 ohms. The earthed-emitter current gain is 50. As a small-signal audio amplifier, the GET4 has a typical power gain of 40 dB or 33 dB in a cascaded amplifier. In class B audio output stages, a push-pull pair will deliver 200 mW. In neutralized tuned amplifiers, power gains of 24 dB at 315 kc/s (common emitter) and 20 dB at 465 kc/s (common base) are typical.

Type GET5 is similar, but is designed to have a low thermal resistance. If a suitable cooling fin is used, the collector dissipation rating at 45° is 400 mW and, at audio frequencies, a push-pull pair in class B will deliver 2 watts.



G.E.C. transistors Types GET5 and EW57. A mounting ring and mica insulator for the latter are also shown

Type GET6 is a low-noise transistor, the noise figure of 6 dB at 1,000 c/s being appreciably lower than usual. It is therefore particularly suitable for low-level audio applications. The remaining new transistors, types EW57/1, 2 and 3 are medium power devices for supplies of 6, 12 and 24 volts respectively. In class B audio output stages, push-pull pairs will deliver 10–20 watts.

Multiple Resonance Frequencies

EMPIRICAL FORMULA FOR SINGLE-LAYER COILS

By W. W. Fain, M.A., Ph.D., M.I.R.E.*

The results of measurements on several coils have been analysed to find a relationship between the frequencies of multiple resonances and the physical dimensions of the coils. This approach is purely empirical and, although based on only a small amount of data, the results appear significant and show definite correlation with the variables chosen.

Table 1 includes the physical dimensions, the frequencies at which the resonances occur and other quantities described below. Thus f_1, f_3, f_5, etc., are the frequencies of the impedance maxima, and f_2, f_4, f_6, etc. are the frequencies of the impedance minima. The inductance was calculated from the absolute value of the impedance $|Z|$, measured at 10 Mc/s.

TABLE 1

Coil Number	I	II	III	IV	V	VI	VII
Z at 10 Mc/s ..	1115	1060	1030	1110	1140	1135	1095
L, inductance ..	16·7	15·8	15·2	16·1	15·8	15·2	14·6
a, mean diameter of coil (cm) ..	1·9	1·59	2·54	2·54	5·08	6·35	6·35
b, coil length (cm)	3·66	7·19	7·62	2·77	5·84	6·04	8·89
Number of turns	46	48	48	35	23	19	21
d, diameter of wire (cm) ..	·0508	·0508	·0795	·0508	·127	·160	·191
D, pitch ..	·0795	·0795	·159	·0795	·254	·317	·424
f_1 (Mc/s) ..	43..	41	36	34	27	24	23
f_2 ,, ..	76·5	79	65·2	72	58	54	51
f_3 ,, ..	82·5	87	72	75	62	57	54
f_4 ,, ..	114	119	99·5	110	90	80	79
f_5 ,, ..	120	125	107	119	96	90	82
f_6 ,, ..	152	157	132	155	128	120	110
f_7 ,, ..	157	162	137	—	131	124	112
f_8 ,, ..	188	190	163	—	160	152	135
f_9 ,, ..	—	—	168	—	165	158	142
f_{10} ,, ..	—	—	194	—	—	186	—
C_s (pF) ..	·82	·95	1·28	1·36	2·19	2·78	3·26

TABLE 2

Coil	I	II	III	IV	V	VI	VII	av.
f_2/f_1	1·78	1·93	1·81	2·12	2·15	2·20	2·22	
f_3/f_1	1·91	2·12	2·00	2·21	2·30	2·33	2·35	
f_4/f_1	2·65	2·90	2·76	3·23	3·33	3·26	3·43	
f_5/f_1	2·79	3·05	2·99	3·50	3·55	3·67	3·56	
f_6/f_1	3·55	3·82	3·69	—	4·74	4·90	4·78	
f_7/f_1	3·65	3·95	3·80	—	4·85	5·06	4·87	
f_8/f_1	4·38	4·63	4·53	—	5·92	6·20	5·87	
f_9/f_1	—	—	4·67	—	6·11	6·45	6·17	
f_{10}/f_1	—	—	5·40	—	—	7·59	7·30	
K_2	1·64	1·77	1·60	1·89	1·79	1·74	1·68	1·73
K_3	1·77	1·96	1·79	1·98	1·94	1·87	1·81	1·88
K_4	2·38	2·58	2·34	2·78	2·60	2·34	2·35	2·48
K_5	2·52	2·73	2·57	3·05	2·82	2·75	2·48	2·70
K_6	3·14	3·35	3·05	—	3·65	3·52	3·16	3·31
K_7	3·24	3·48	3·16	—	3·76	3·68	3·25	3·43
K_8	3·84	4·00	3·68	—	4·46	4·36	3·71	4·01

$$L = \frac{|Z|}{\omega_0} \left| \frac{\dfrac{\omega^2}{\omega_0^2} - 1}{\dfrac{\omega}{\omega_0}} \right| \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where ω is the frequency at which Z was measured and ω_0 is $2\pi f_1$. The distributed capacitance, C_s, is

$$C_s = \frac{1}{4\pi^2 f_1^2 L} \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

It can be seen from Table 1 that the resonant frequencies (f_1, f_2, f_3, etc.) generally decrease with increased C_s. Table 2 includes the ratios of f_n/f_1, where $n = 2, 3$, etc. The curves of f_n/f_1 versus C_s are all reasonably linear, all of the points falling within $\pm$ 10% of a straight line.

Fig. 1 includes curves of f_2/f_1 and f_4/f_1 versus C_s Furthermore, it was found that the curves of f_4/f_1 and f_5/f_1 versus C_s have slopes of approximately twice the slopes of f_2/f_1 and f_3/f_1. Similarly, f_6/f_1 and f_7/f_1 have slopes of three times the slopes of f_2/f_1 and f_3/f_1, and so forth. That is, f_n/f_1 can be represented by

$$\frac{f_n}{f_1} = m\beta C_s + K_n \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where $m = 1$ when $n = 2$ and 3, $m = 2$ when $n = 3$ and 4, etc. It was found that a value of $\beta = 0{\cdot}166$ fits the data fairly well. K_n was calculated from the values of f_n/f_1, m, β, and C_s. The average values obtained are $K_2 = 1{\cdot}73$, $K_3 = 1{\cdot}88$, $K_4 = 2{\cdot}48$, $K_5 = 2{\cdot}70$, $K_6 = 3{\cdot}31$, $K_7 = 3{\cdot}43$, and $K_8 = 4{\cdot}01$. Table 3 includes a comparison of the experimental values of f_n/f_1 to the values of f_n/f_1 calculated from Equ. (3) and the average value of K. It is interesting to see that the average deviation from the empirical formula is only 4·5%. As more data become available, it should be possible to obtain more accurate values of the constants and to test more variables; thereby checking the validity of this formula.

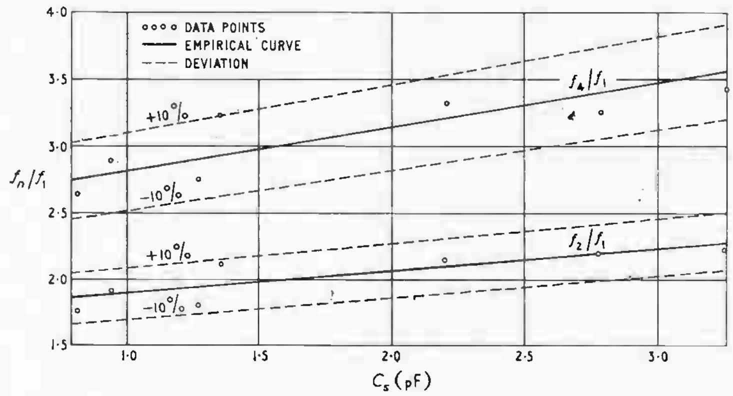
Several authors[1] have proposed formulae relating C_s to the physical dimensions of the single-layer solenoid. In the older theories, C_s was considered highly dependent on d/D, where d is the diameter of the wire and D is the winding pitch of the coil. However, Medhurst obtained an empirical relationship from measurements of more than 30 coils. This relationship is

$$C_s = aH \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

where a is the diameter of the coil in centimetres and H is a quantity dependent on b/a, where b is the length of the coil. According to Medhurst, C_s is not a function of d/D. This assumption is further supported by the theoretical work of Mostafa and Gohar[2], who derived

* Formerly with Electro-Mechanics Co., Austin, Texas, now with Systems Development Group, Chance Vought Aircraft, Dallas, Texas.

Fig. 1. *Relation between coil capacitance and the frequency ratios of multiple resonance*



an expression in agreement with Medhurst's experimental results. Medhurst includes tables for H, and an empirical formula which he says will calculate H within a few percent. The empirical formula for H is

$$H = 0 \cdot 1126\frac{b}{a} + 0 \cdot 08 + 0 \cdot 27\sqrt{\frac{a}{b}} \quad .. \quad (5)$$

In Table 4 the value of C_s calculated from the measurements is compared to that of Medhurst and that taken from a nomogram[3]. The value of C_s taken from the latter publication depends on d/D. It is seen that Medhurst's expression is a better approximation to the experimental results. In summary, the frequencies of multiple resonance appear to be related to the distributed capacitance associated with the coil and C_s is, according to Medhurst, a function of the diameter and length of the coil. Therefore, it is possible to predict from the physical dimensions of a single-layer solenoid, the frequency of the multiple resonances by use of equations (3) and (4).

Acknowledgments

The author wishes to thank Dr. S. L. Brown and Mr. Paul Varlashkin who made the measurements on the coils and to thank Dr. F. J. Morris of the Electro-Mechanics Co. and the U.S. Air Force [Contract AF 33 (600) 27091] for supporting this work.

REFERENCES

[1] See list of references in Medhurst's article. R. G. Medhurst, "H.F. Resistance and Self Capacitauce of Single-Layer Solenoids", *Wireless Engineer*, Feb. 1947, pp. 35-43, and March 1947, pp. 80-92.

[2] Mostafa, A. E. and Gohar, M. K., "Determination of Voltage, Current, and Magnetic Field Distributions Together with the Self-Capacitance, Inductance and H.F. Resistance of Single-Layer Coils", *Proc. Inst. Radio Engrs.*, April 1953, pp. 537-547.

[3] "Design Techniques for Interference-Free Operation of Airborne Electronic Equipment", Prepared by Frederick Research Corporation under Contract, AF 33 (038) 23341, 1952, pp. 3-26.

TABLE 3

Coil	I	II	III	IV	V	VI	VII	Av.	Max.
f_2/f_1 ..									
exp.	1·78	1·93	1·81	2·12	2·15	2·20	2·22		
calc.	1·87	1·89	1·94	1·95	2·09	2·18	2·26		
% dev.	+5·1	−2·1	+7·2	−8·0	−2·8	−0·9	+1·8	+4·7 −3·5	+7·2 −8·0
f_3/f_1									
exp.	1·91	2·12	2·00	2·21	2·30	2·33	2·35		
calc.	2·02	2·04	2·10	2·12	2·26	2·34	2·42		
% dev.	+5·8	−3·8	+5·0	−4·1	−1·7	+0·4	+3·0	+3·6 −3·2	+5·8 −4·1
f_4/f_1									
exp.	2·65	2·90	2·76	3·23	3·33	3·26	3·43		
calc.	2·76	2·80	2·92	2·94	3·23	3·42	3·57		
% dev.	+4·2	−3·5	+5·8	−9·0	−3·0	+4·9	+4·1	+4·8 −5·2	+5·8 −9·0
f_5/f_1									
exp.	2·79	3·05	2·99	3·50	3·55	3·67	3·56		
calc.	2·98	3·03	3·13	3·15	3·45	3·63	3·78		
% dev.	+6·8	−0·7	+4·7	−10·0	−2·8	−1·1	+6·2	+5·9 −3·7	+6·8 −10·0
f_6/f_1									
exp.	3·55	3·82	3·69		4·74	4·90	4·78		
calc.	3·72	3·78	3·94	3·98	4·42	4·69	4·92		
% dev.	+4·8	−1·1	+6·8		−6·8	−4·3	+2·9	+3·6 −4·1	+6·8 −6·8
f_7/f_1									
exp.	3·65	3·95	3·80		4·85	5·06	4·87		
calc.	3·84	3·91	4·07	4·11	4·56	4·82	5·06		
% dev.	+5·2	−1·0	+7·1		−6·0	−4·7	+3·9	+5·4 −3·9	+7·1 −4·7
f_8/f_1									
exp.	4·38	4·63	4·53		5·92	6·20	5·87		
calc.	4·55	4·64	4·86	4·92	5·47	5·86	6·17		
% dev.	+3·9	+0·2	+7·3		−7·6	−5·5	+5·1	+4·1 −6·6	+7·3 −7·6

TABLE 4

Coil	I	II	III	IV	V	VI	VII	Average Deviation
C_{s1} (experiment) ..	0·82	0·95	1·28	1·36	2·19	2·78	3·26	
C_{s2} (Medhurst) ..	0·93	1·14	1·46	1·17	2·34	2·92	2·96	
$\frac{C_{s2} - C_{s1}}{C_{s1}} \times 100\%$	+13·4	+20·0	+14·1	−14·1	+6·9	+5·0	−9·2	+11·9% −11·7%
C_{s3} (Design Tech)	1·7	1·3	1·7	2·2	3·3	4·1	4·0	
$\frac{C_{s3} - C_{s1}}{C_{s1}} \times 100\%$	+107	+36·8	+32·8	+61·8	+50·7	+47·5	+22·7	+51·3%

Network Matching Problems

By John Deignan

SUMMARY. *A simple graphical method of solving problems involving impedances in parallel is described, and worked examples given to illustrate its application to typical problems.*

The design of a matching network, as for example between transmitter and feeder, or between feeder and aerial can often be speedily and easily achieved by means of graphical methods.

This avoids messing about with complex numbers and the inherent risk of error in such operations, as well as yielding the solution or alternative solutions in clearly visual and easily followed forms.

In most problems of this nature, the solution can be attempted by considering impedances two at a time, combining the resultant with a third and so on, working one's way from a specified impedance at the input terminals to another specified impedance at the output terminals of the network. Now, those pairs of impedances are either series or parallel arrangements and the problem reduces to finding the resultant impedance of either of those arrangements, employing graphical means only. In the former case, it is quite simple ; a pair of perpendicular axes are chosen on graph or drawing-paper along which resistance and reactance values respectively are laid off according to a suitable scale of ohms per unit length. The pair of given impedances can then be represented by a pair of points, or, if one prefers, a pair of vectors joining those points to the origin and the resultant of their combination in series found by the familiar Parallelogram Law. But what if the pair is in parallel ? How can one find the vector of the resultant of this parallel arrangement by the most direct and simple geometrical construction ? The procedure is explained by reference to Fig. 1.

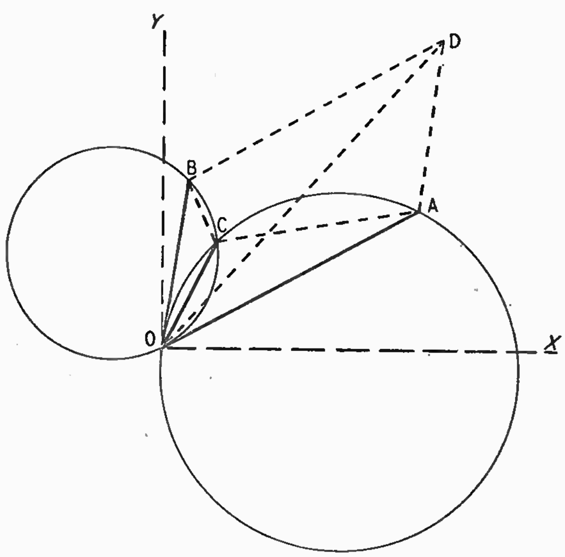


Fig. 1. *The value of two impedancies OA and OB in parallel is given by OC. The dash lines show the construction used for the proof of the method, which is given in the Appendix*

Let OX, OY be the axes and OA and OB be the vectors corresponding to two arbitrarily given impedances. Draw a circle OCA, tangent at O to OB and passing through A—an elementary problem of school geometry. Similarly, draw a circle OCB, tangent at O to OA and passing through B. Then the common chord OC of those two circles represents in magnitude and angle the impedance which is the equivalent of the two given impedances placed in parallel.*

This construction will be proven in the Appendix. Meanwhile, a few simple examples of the practical use of those methods will be considered.

Example 1

Find the equivalent series impedance of a pure resistance of 228 ohms in parallel with a purely inductive reactance of 110 ohms.

Take a sheet of graph paper and lay off according to as generous a scale as possible, resistive and reactive ohms along the OX and OY axes respectively. See Fig. 2. If the available graph paper is not large enough to give the result within the accuracy required, then take instead a drawing-board and a sufficiently large sheet of drawing-paper, set out a pair of perpendicular axes, along the horizontal axis mark off the length OA to represent 228 ohms and along the positive vertical axis, the length OB to represent 110 ohms, choosing a better scale of ohms per unit length. Simply draw two circles of diameters OA and OB respectively and their common chord OC represents the required impedance, the value of which can be written down in terms of its resistance and reactance components by noting the values of the projections of OC along the two axes.

* The above construction appears to fail when the angles of the given impedances are equal or differ by 180°. But the problem is now trivial, being equivalent to calculating a pair of pure resistances in parallel, for which a nomogram for the purpose or another simple geometrical construction can be used and anyway it amounts only to simple arithmetic.

To make the given construction cover the trivial case, put in parallel another pair of impedances, of equal and opposite sign to each other, differing in angle from either of the given pair of impedances. Thus form a new pair of impedances, on which the construction can now be repeated for the final result.

Example 2

Find an L-type network, having a capacitance in the shunt arm, to match a resistance of 200 ohms to 75 ohms.

See Fig. 3. Plenty of room should be left on the paper for representing reactances of negative sign, for a capacitive reactance has to be in the solution. Sketch a block schematic of the network as in the inset to Fig. 3. It is then clear that a negative reactance, of value as yet unknown, is to be put in parallel with a pure resistance of 200 ohms. The equivalent impedance of this combination must, however, turn out to be a resistance of 75 ohms in series with a reactance the value of which does not matter, for it can be cancelled out by an equal and opposite reactance which will constitute the series arm of the network.

As in the previous problem, layoff OA to represent 200 ohms. Something will be put in parallel with it, but it must be a pure reactance of some value or other so, as before, a circle of diameter OA should be constructed. But the second circle cannot be found exactly as before. However, it is known that it must be tangent at O to the horizontal axis and cuts the other circle at a point C, such that the projection of C is 75 ohms (point D). There are two such points C one below and one above the horizontal axis. Take the point below, then the second circle can be drawn. Note the intercept OB on the negative Y axis, it is —155 ohms, and is the required value of capacitive reactance for the shunt arm. The required value of impedance for the series arm is clearly that value which will cancel the capacitive reactance represented by DC in Fig. 3, namely, an inductive reactance of 97 ohms approx.

Given the frequency at which this network is required to operate it is a simple matter to find the corresponding *LC* values.

If the alternative point C had been taken, the complementary network having an inductance in the shunt arm would have been obtained and would also match 200 ohms to 75 ohms. It is seen that it is only a matter

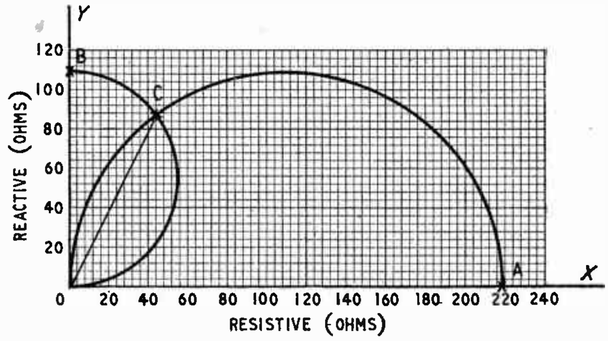


Fig. 2. *The equivalent series impedance of* 228 Ω || *j*110 Ω *is given by OC* = 43 Ω ± *j*89 Ω (*approx.*)

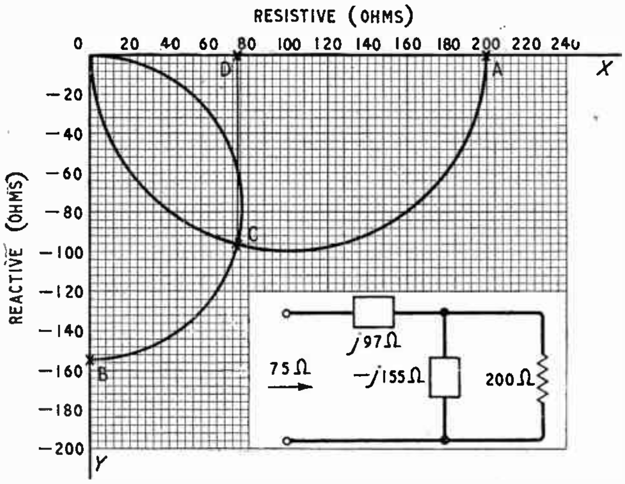
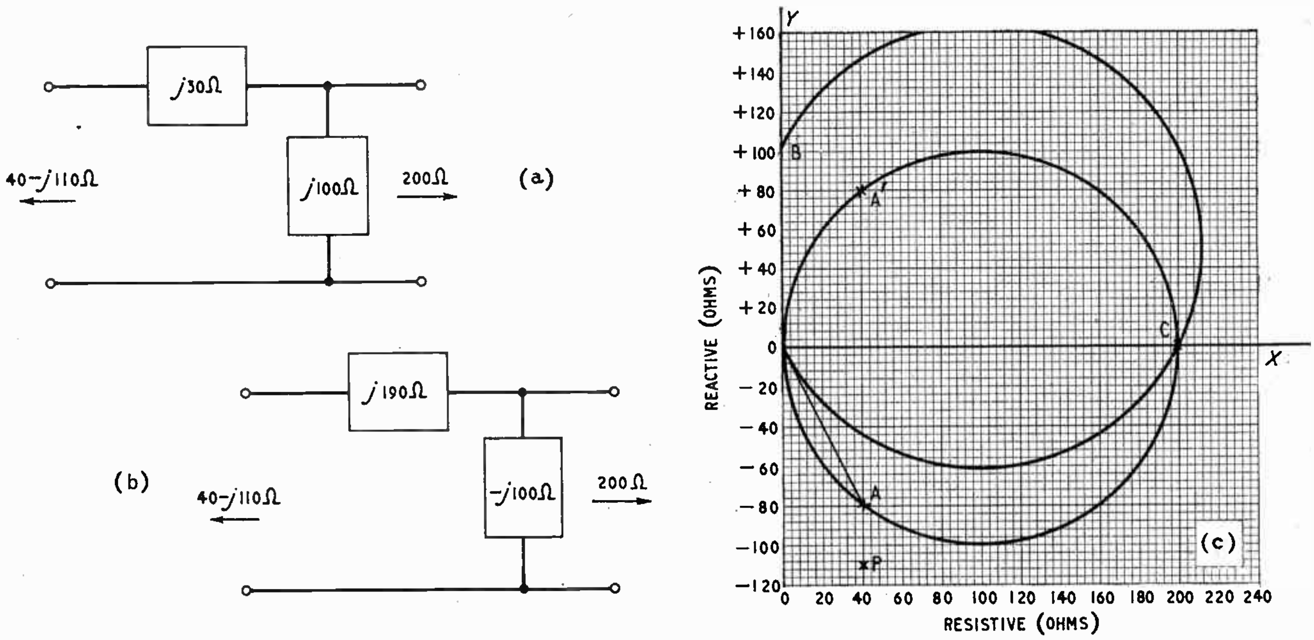


Fig. 3. *Finding an L-type network, having a capacitive shunt arm, to match a resistance of* 200 Ω *to* 75 Ω

Fig. 4. *Alternative forms of network* (*a*) *and* (*b*) *for matching* 40 Ω−*j*110 Ω *to* 200 Ω. *The constructions are shown at* (*c*)



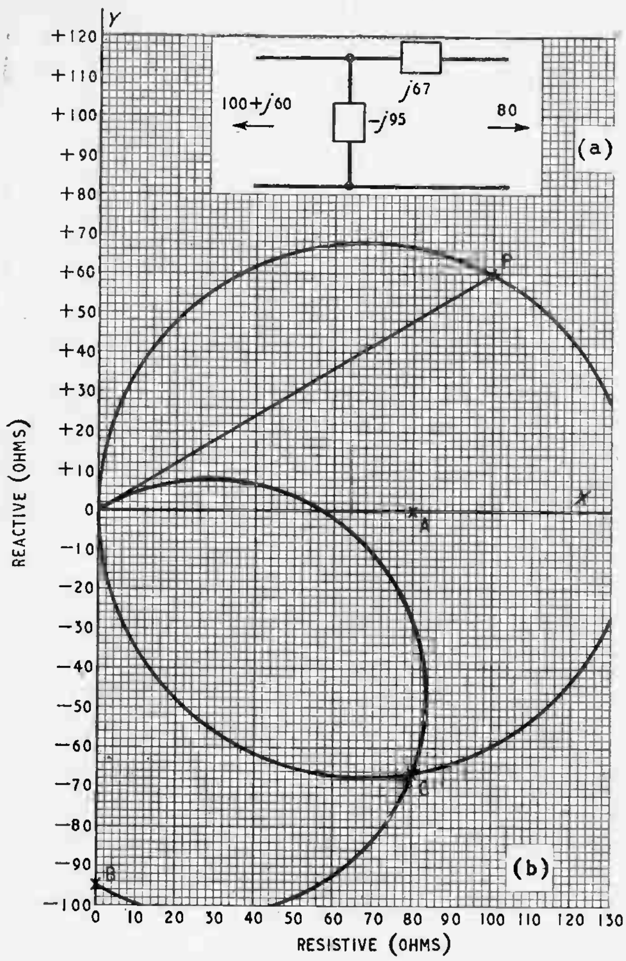


Fig. 5. *Transformation of* $100\,\Omega + j60\,\Omega$ *to* $80\,\Omega$ *(a) and the graphical construction (b)*

of an interchange of the signs in the reactances previously found and of course new values of LC. The capacitor will now be in the series arm. The previous solution would be better from the viewpoint of the suppression of harmonics.

Example 3

Find an L-type network to match a 200-ohm feeder-line to an aerial having an input impedance of $40 - j\,110$.

Arrange graph or drawing paper as in Fig. 4, with ample room for plotting reactances of both positive and negative signs. The aerial input impedance is represented by the point P, the co-ordinates of which are (40, − 110).

The feeder-line impedance is represented by the point C, the co-ordinates of which are (200, 0). Draw a circle with diameter OC. Suppose a purely inductive reactance were put in series with the aerial input of such value as to change the input impedance to the value represented by the point A, where A lies on the circle of diameter OC and has co-ordinates (40, − 80). This added reactance of $j30$ ohms represented by PA constitutes the series arm of a suitable L network, provided that a pure reactance can now be found such that when it is placed in shunt with the modified aerial impedance represented by the vector OA, the resultant impedance turns out to be a pure resistance of 200 ohms represented by OC. Such a reactance can, in fact, now be easily found. It is only necessary to draw a circle tangent at O to OA and passing through C. The point B where this circle intercepts the reactance axis gives the value of shunt reactance required, which is seen to be an inductive reactance amounting to 100 ohms. The complete network can now be shown as in Fig. 4 (a) and consists of two inductances the values L of which can readily be found for any given frequency f using the familiar formula: $2\pi fL = X$ where X is the absolute value of the reactance.

An alternative solution is got by considering the series reactance necessary to change the input impedance from the value given by the point P to that given by A′, where A′ is the other intersection of the ordinate through P with the circle of diameter OC. The series reactance needed is seen to be an inductive 190 ohms, and a shunt reactance of 100 ohms, capacitive, in this case. The value C of the shunt capacitor required can readily be found for any given operating frequency f from the familiar formula.

$$\frac{1}{2\,\pi f\,C} = X$$

where X is the absolute value of the reactance.

The network is shown in Fig. 4 (b).

Example 4

Find an L-type network, a capacitor forming its shunt arm, to match an aerial of impedance $100 + j60$ to an unbalanced feeder of 80 ohms.

Since, in this case, the resistive component of the aerial impedance is higher than that of the feeder, the solution is not exactly similar to that of the previous example.

A capacitive reactance can be found, such that if placed in shunt with the aerial input, the resultant impedance has a resistive component of 80 ohms. The reactive component of this impedance can then be cancelled by an inductive reactance, which forms the series arm of the network required.

The procedure is indicated in Fig. 5 (a) and (b); P represents the aerial impedance and A the feeder impedance. A circle is drawn through P and tangent at O to the vertical axis. Mark the point C on this circle which represents an impedance having a resistive component of 80 ohms and a reactive component which is negative in value. Draw a circle through C and tangent at O to OP. Its intercept on the vertical axis is OB. Then, OB represents a capacitive reactance of 95 ohms and is the value of the shunt arm, while CA represents an inductive reactance of 67 ohms which forms the series arm of the required network.

Acknowledgment

The writer is indebted to a friend and former colleague, Mr. H. Faust, for an introduction to the method described above.

APPENDIX

Proof of Construction for Finding Resultant of Two Impedances in Parallel.

In Fig. 1, through B draw BD ‖ OA, and through A draw AD ‖ OB meeting BD in D. Join CB, CA, OD.

We have to prove that if OA represents the impedance Z_1, and OB represents the impedance Z_2, then OC represents the resultant of these connected in parallel, which is $\dfrac{Z_1 Z_2}{Z_1 + Z_2}$ and has modulus

$\frac{OA.OB}{OD}$ and argument $\angle XOA + \angle XOB\ \angle XOD$, in the notation of Fig. 1.

In the triangles OCB, ACO, we have

$$\angle COB = \angle CAO \text{ ('alternate segment')}$$
$$\angle CBO = \angle COA \text{ ('alternate segment')}$$

because OA and OB are tangents.

Hence the triangles OCB, ACO are equiangular and therefore their corresponding sides are proportional.

$$\therefore \frac{OB}{AO} = \frac{BC}{OC}$$

But AO = BD (opposite sides of parallelogram OADB)

$$\therefore \frac{OB}{BD} = \frac{BC}{OC}$$

which can be re-arranged in the form

$$\frac{OB}{BC} = \frac{BD}{CO}$$

Further, the triangles OBD, BCO have $\angle OBD = \angle BCO$. They are, therefore, similar and so

$$\frac{OB}{BC} = \frac{BD}{CO} = \frac{DO}{OB},\ \angle BOD = \angle CBO, \text{ and } \angle ODB = \angle COB.$$

$$\text{Hence } OC = \frac{BD.OB}{OD} = \frac{OA.OB}{OD}$$

and therefore OC has the correct modulus.

$$\begin{aligned} \text{Also,}\quad & \angle XOA + \angle XOB - \angle XOD \\ & = \angle XOA + \angle BOD \\ & = \angle XOA + \angle CBO \\ & \qquad \text{(already seen from } \Delta\text{s OBD, BCO)} \\ & = \angle XOA + \angle COA \text{ ('alternate segment')} \\ & = \angle XOC \end{aligned}$$

so that OC also has the correct argument.

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.

Standard-Frequency Transmissions—Droitwich 200 kc/s

SIR,—I would confirm the point made by Dr. Essen in his letter in the December *Wireless Engineer*, namely that the continued publication of the Droitwich carrier measurements would serve no very useful purpose.

The figures which have been published indicate that the carrier has been stable to within 10^{-7} which is adequate for a great volume of industrial calibration.

If an assurance could be obtained from the B.B.C. that this would continue (confirmed perhaps by a recurrent note in the *Radio Times*), many industrial users would probably be satisfied.

It would probably have been useful if the B.B.C. could have been persuaded years ago to equip Droitwich with a drive which was stable to 10^{-8} or better, for the benefit of laboratories requiring higher precisions. The situation in respect of such more refined work, however, has changed somewhat.

Not only are there now available local frequency standards with an operational stability of 10^{-8}, but there will shortly be Quartz Servo Standards of reasonable cost which will have hour-to-hour and day-to-day erratics of no more than 10^{-10}.

With proper precautions it seems possible to make comparisons between the N.P.L. and local standards in this country via the 60-kc/s MSF carrier with comparison errors no greater than about 10^{-9}. Comparisons between separate laboratories to an accuracy of 10^{-10} is "another kettle of fish" and outside the scope of this letter.

Research Division, NORMAN LEA
Marconi's Wireless Telegraph Co. Ltd.,
Great Baddow, Essex.
19th December 1956.

Free Oscillations in Simple Distributed Circuits

SIR,—I am indebted to Mr. J. W. Head and Mr. W. Proctor Wilson for their letter (p.37, January) identifying the functions in my paper in the December issue of your journal. The fact that Laguerre functions arise in the study of waveforms in quite simple circuits illustrates their fundamental importance.

Atomic Energy Research Establishment, A. B. HILLAN
Aldermaston, Berks.
24th December 1956.

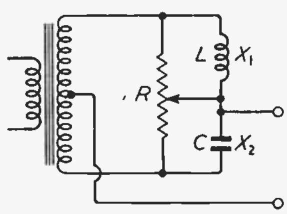


Fig. 1

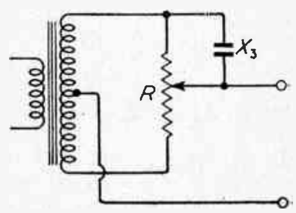


Fig. 2

Phase-Adjusting Circuits

SIR,—Following the article by Griffiths and Mole, on phase-adjusting circuits, in the January issue, I would like to raise two points of criticism concerning the practical circuit.

First, there is some uncertainty about the ends of the phase-shift. and, secondly, the use of a variable capacitor is not always convenient.

There are two circuits which I think might be included in a work of reference, the second of which does not fulfil the constant-amplitude conditions. The transformers of both are centre-tapped and the ends of the phase-shift are clearly defined.

In Fig. 1, $X_1 = X_2 = R/4$, after compensation has been made for losses in X_1. The adjustment of phase can be claimed to be linear.

For 50-c/s operation, the following values have been used: $L = 50$ H, $C = 0{\cdot}2\ \mu$F and $R = 50$ kΩ.

In Fig. 2, there is a very simple arrangement giving 180° phase-shift. However, there is some loss of amplitude. When using a linear potentiometer, the 90° phase shift can be arranged to be half-way on the rotation. Thus, X_3 has a reactance of $2R/3$ ohms. Decreasing X_3 results in a compression of the degree scale at one end of the angular movement. It is then convenient to use a 'logarithmic' potentiometer and have the 90° phase-shift at centre rotation. If the 'low' of the potentiometer is increased still further, the loss of amplitude becomes negligible.

The first circuit is offered as a complete solution for low frequencies, with the second as a convenient alternative.

Sidcup, Kent. J. CAMPBELL
7th January 1957.

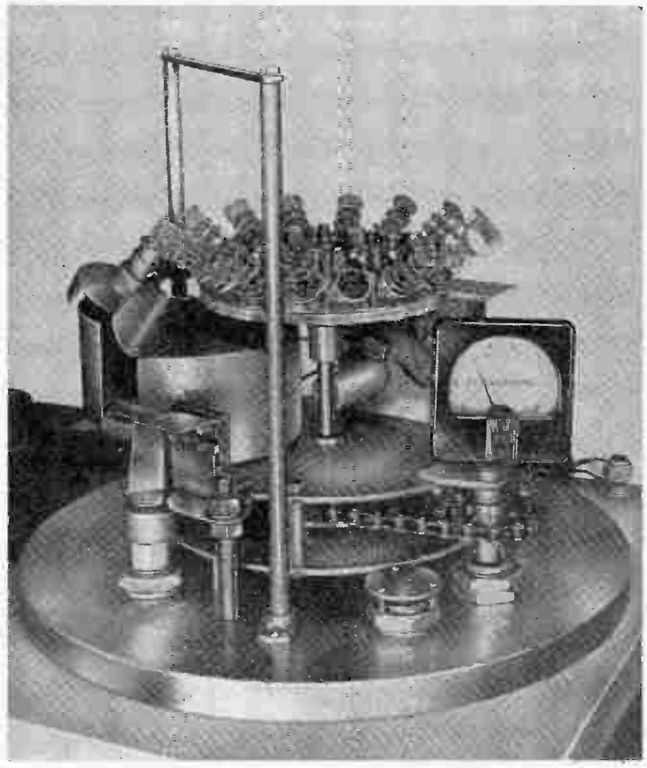
Fine Adjustment of Quartz-Crystal Frequencies

THE resonant frequency of a quartz crystal is influenced to some extent by the thin films of gold or silver which are deposited on opposite faces to provide electrical connections. Fine frequency adjustment can be effected by measuring the resonant frequency of a crystal during vacuum deposition of the electrodes, and stopping the deposition process when the correct frequency is reached.

In order that its frequency may be measured, a crystal must be made to oscillate. If this is done by connecting it through long leads to a valve oscillator circuit, fine frequency adjustment is rendered very difficult by the stray capacitance across the crystal introduced by the leads. A solution to the problem is to mount the oscillator valve and associated components inside the vacuum deposition apparatus. The photograph shows such an equipment, developed by Automatic Telephone & Electric Co. Ltd. in conjunction with W. Edwards & Co., and believed to be the first multiple adjusting unit of its kind. The crystals are mounted on a turret and, as each one is brought to the frequency-adjusting position, it is automatically connected to the oscillator valve through short leads. There is sufficient stray radiation to be picked up by an external receiver for operating frequency-measuring equipment. By this means, it is possible to adjust the crystal frequency to within a few parts in a million. Crystals for use up to 45 Mc/s have been produced.

The oscillator valve and circuit components are themselves contained in an evacuated glass envelope.

Close-up view of frequency-adjusting equipment



New Books

Principles of Color Television

By THE HAZELTINE LABORATORIES STAFF. Edited by Knox McIlwain and Charles E. Dean. Pp. 595 + xvi. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 104s.

This American book has 18 chapters, 3 appendixes and both author and subject indexes. The first four chapters cover light and photometry, colour perception, colour space and colour triangles, and colorimetry. The next three deal with colour in a television system, the required information content and the characteristics of the eye. These seven chapters occupy 119 pages and are thus a smaller proportion of the book than would at first appear. They form the necessary introduction, and a very good one, to colour television by explaining the necessary basic concepts.

Chapter 8 deals with the choice of the colour components and their interleaving in the composite signal, while Chapter 9 covers the production of this signal. Chapters 10, 11 and 12 deal respectively with synchronization, with non-linear amplitude relations and gamma correction, and with the F.C.C. standards. Chapters on transmitters, receivers, three- and one-gun decoders, and measuring apparatus, follow.

The treatment is very detailed but it is by no means highly mathematical. It should be understandable by an engineer who is familiar with ordinary television practice but, unless he is also well up in colour, he is likely to find himself spending more time on the first 119 pages than on all the rest of the book. This is as it should be, for he is likely to be more at home with the circuitry than with the rest. It is a most commendable feature of the book that it does include so good an introduction to colour, for it will save the engineer much reading elsewhere. Where more detailed information is required, a good bibliography helps the reader to find his further reading.

W.T.C.

Vacuum-Tube Circuits and Transistors

By LAWRENCE BAKER ARGUIMBAU, with transistor contributions by Richard Brooks Adler. Pp. 646. John Wiley & Sons Inc. Available in the U.K. from Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 82s.

A new version of L. B. Arguimbau's "Vacuum-Tube Circuits": two chapters have been added on transistors, a complete chapter is now devoted to noise, and there are some minor additions to the original chapters. "The present book is explanatory rather than descriptive.... We should not be content with knowing the generally accepted methods of building amplifiers but should be able to analyse them, understanding the precise and detailed reasons for their operation".

Elements of Pulse Circuits

By F. J. M. FARLEY. Pp. 143. Methuen's Monographs in Physical Subjects. Methuen & Co. Ltd., 36 Essex Street, London, W.C.2. Price 8s. 6d.

This monograph is a largely non-mathematical treatment of pulse circuits, with chapters on Basic Concepts, Fundamental Valve Circuits, Square Wave Generators, Trigger Circuits, Time Bases, Pulse Amplifiers, and Applications.

Pulse and Digital Circuits

By Jacob Millman and Herbert Taub. Pp. 687. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 94s.

The aim of this book is to provide a source of information on circuits using non-sinusoidal waveforms such as are encountered in radar, television, and computers. It does not treat these subjects in a specialized way, but rather gives a comprehensive survey of circuits classified under such chapter headings as: Wave Shaping, Pulse Amplifiers, Time-Base Generators, Delay Lines, and Counting. The physical operation of circuits is discussed prior to mathematical analysis. Over 400 homework problems are included.

Electronic Analog Computers. Second Edition.

By Granino A. Korn and Theresa M. Korn. Pp. 452. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 56s. 6d.

D.C. analogue computers are dealt with, largely from the users' point of view. In addition to information on setting up and problem preparation, there are chapters on linear computing elements, d.c. amplifiers, multipliers and function generators, auxiliary circuits, and the design of complete installations. "No mathematics beyond that taught in an elementary course on differential equations is required".

Radio and Electronic Components, Vol. III—Fixed Capacitors

By G. W. A. Dummer, M.B.E., M.I.E.E. Pp. 260. Sir Isaac Pitman & Sons Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 45s.

In addition to general information on capacitors, and a chapter on each of the principal types, there are chapters on measurement of capacitance, faults which may occur in fixed capacitors, and future developments in fixed-capacitor design. The book contains an 18-page bibliography and a 79-page chart of representative types of capacitor.

Electricité

By G. Bruhat, revised by G. Goudet. Pp. 900. Masson et Cie, 120 Boulevard Saint-Germain, Paris 6e, France. Price 5,100 francs.

Intended for use as a textbook for those undertaking a course in physics, the book contains chapters on Mathematics, Electrostatics, Direct Current, Magnetism, Induction, Electrical Measurement, Steady-State Alternating Current Circuits, Power Generators, General Electromagnetic Theory, and Electronics.

Proceedings of the 1956 Electronic Components Symposium

Published by Engineering Publishers, G.P.O. Box 1151, New York 1, U.S.A. Pp. 240, with 293 illustrations. Price: cloth $8.25, paper $5.00.

Of the 43 papers reprinted in this collection, there are 6 in each of the following categories: General, Progress with Materials, Theory and Operating Principles, Instruments and Measurements, Electron Tubes and Solid State Devices and 13 on Passive Components.

Electronic Computers

Edited by T. E. Ivall. Pp. 175, with 40 diagrams and 28 pages of art plates. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 25s.

The aim of the book is "to give a reasonably broad picture of electronic computing to those who are at present on the fringe and may be thinking of taking it up, or to those who are just interested in the subject and do not wish to get too deeply involved".

Vacuum Deposition of Thin Films

By L. Holland. Pp. 541+25 plates. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 70s.

A summary of technical procedures used in the preparation of solid thin films by vacuum evaporation and cathodic sputtering. One chapter is devoted to the preparation of thin films for electrical purposes.

Annual Report of the British Standards Institution 1955-6

Pp. 260. British Standards Institution, British Standards House, 2 Park Street, London, W.1. Price 5s.

B.B.C. Handbook 1957

Pp. 288. British Broadcasting Corporation, Broadcasting House, London, W.1. Price 5s.

NEW YEAR HONOURS

In the New Year's Honour List, awards have been made to a number of those who have been responsible for the trans-Atlantic cable. They include J. N. Dean, chairman of the Telegraph Construction and Maintenance Company (Knighthood); R. J. Halsey, an assistant engineer-in-chief at the G.P.O. (C.M.G.); A. H. Roche, telecommunication engineer in charge of Submarine Cable System Development and Production Division, Standard Telephones & Cables (O.B.E.); E. F. Neve, foreman, submerged repeater manufacturing shop, Standard Telephones & Cables (B.E.M.); and E. V. T. Perrins, technical officer, Post Office Research Station (B.E.M.).

Sir Stanley Angwin, who recently retired from the chairmanship of the Commonwealth Telecommunication Board, and E. M. Jones, director, the Government Communications Headquarters, Foreign Office, are appointed K.C.M.G.

Sir John Cockcroft, director of the Atomic Energy Research Establishment, Harwell, is appointed to the Order of Merit.

Three members of the G.E.C. Research Laboratories staff received awards: O. W. Humphreys, director, is appointed C.B.E.; E. G. James, head of the crystal valve development, O.B.E.; and W. C. Cropper, group leader in charge of a special project for the Admiralty, M.B.E.

Among those appointed M.B.E. are Miss B. K. Chaplin, executive officer at the D.S.I.R. Radio Research Station; W. H. Hopkins, works manager, E.M.I. Factories; and W. W. Syrett, export manager of Ecko's Radio Division.

L. A. G. Hooke, managing director of Amalgamated Wireless (Australasia) received a knighthood for "services to the radio industry in Australia".

NOISE

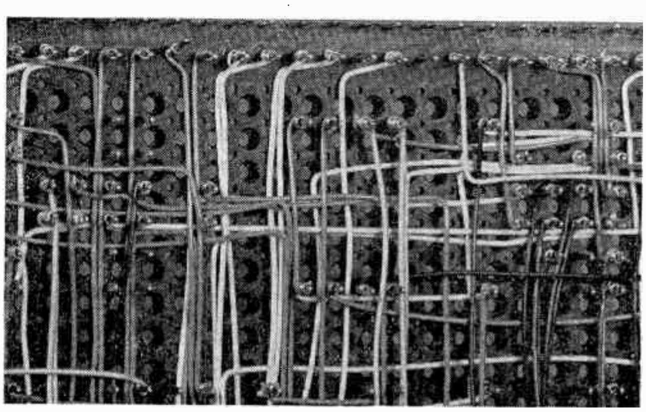
A course on noise, with emphasis on the mechanism of noise generation and including lectures on advanced measurement technique and industrial noise control, is to be held at Southampton University on 1st–6th April. It is intended chiefly for those in the aeronautical industry and no preliminary knowledge of acoustics is needed. The fee for the course is £21 including residence, and further details can be obtained from D. M. A. Mercer, Physics Department, The University, Southampton. Application must be made prior to 1st March.

Woven Wiring

A new kind of automatic wiring system is being developed by Bell Telephones. Based on solderless wrapped connections with an expected life in excess of 40 years, the new system draws on techniques developed in the textile industry for attaching threads and for preparing punched tapes for controlling embroidery machines. It is expected to be an economic method for wiring medium-sized units of area one to four square feet. Smaller units can most economically employ printed circuits, while large areas will continue to be wired by hand.

The illustration is a close-up of a machine-woven telephone trunk circuit. The area shown is roughly 5 inches across, and it will be seen that the density of connections is higher than can readily be achieved by hand-soldering, while individual connection points are still accessible.

R. F. Mallina, *I.R.E. Transactions on Production Techniques*, September 1956, pp. 12–22.



THE ELECTRICAL RESEARCH ASSOCIATION

H. G. Taylor, D.Sc.(Eng.), D.I.C., M.I.E.E., F.Inst.P., has been appointed Director of the Electrical Research Association with effect from 1st April in succession to the late Dr. S. Whitehead. For the last nine years he has been Director of Research of the British Welding Research Association.

R. D. BANGAY

Raymond Dorrington Bangay, Foreign Manager of Marconi's Wireless Telegraph Company Ltd., retired at the end of December after more than 54 years' service with the Company.

RADIO INTERFERENCE REDUCTION

A conference on the problems associated with interference suppression is being organized by the Armour Research Foundation of Illinois. It will be held on 26th and 27th February in Chicago.

MEETINGS

I.E.E.

12th February. "The Ultimate Performance of the Single-Trace High-Speed Oscillograph" and "The Design and Performance of a New Single Transient Oscillograph with Very High Writing Speed", M. E. Haine, M.Sc., and M. W. Jervis, M.Sc.Tech.

13th February. "Nuclear Energy in the Service of Man", Faraday Lecture, T. E. Allibone, D.Sc., Ph.D., at the Central Hall, Westminster, London, S.W.1, at 6 o'clock. Admission by ticket only.

20th February. "The Stereosonic Recording and Reproducing System (A Two-Channel System for Domestic Tape Records)", H. A. M. Clark, G. F. Dutton, Ph.D., and P. B. Vanderlyn. To be held at Northampton Polytechnic, St. John Street, London, E.C.1.

26th February. "The Analysis of Waveforms". Discussion to be opened by A. Cooper and D. A. Drew.

4th March. "Electronics in Administration—a Survey", D. C. Espley, O.B.E., D.Eng.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30, *except where otherwise stated.*

Brit.I.R.E.

27th February. "Some Applications of Nucleonics in Medicine", E. W. Pulsford, B.Sc., and N. Veall, B.Sc., to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Television Society

8th February. "Scatter Propagation and its Application to Television", J. A. Saxton, D.Sc., Ph.D.

21st February. "The Design of Oscilloscopes for Television Laboratory Work", O. H. Davie. These meetings will be held at 7 o'clock at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

Society of Instrument Technology

14th February. "A Servo Speed-Control for a Camera Crane", K. G. Crack. Control Section Annual General Meeting at 6 o'clock.

26th February. "The Determination of Parameters of a Controller by Simple Frequency Measurements", J. H. Westcott, B.Sc., Ph.D at 7 o'clock.

These meetings will be held at Manson House, Portland Place, London, W.1.

Radar Association

13th February. "Automation-Computer Controlled Machine Tools for Small Quantity Production", D. T. N. Williamson, to commence at 7.30 at the Anatomy Theatre, University College, Gower Street, London, W.C.1.

B.S.R.A.

15th February. "Some Recent Developments in Amplifiers", F. Langford-Smith, B.Sc., B.E., to be held at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, at 7.15.

The British Kinematograph Society

6th February. "Ilford Negative Materials for Cinema and Television and a New Developing Agent", G. S. Moore, M.Sc. and A. J. Axford, Ph.D., M.Sc., at 7.30.

14th February. "Photo-Electronic Aids to Photography", Professor J. D. McGee, O.B.E., at 7.15.

Both these meetings will be held at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.

EXHIBITIONS

March 4–8. Television Society, Royal Hotel, Woburn Place, London, W.C.1.

March 25–28. Physical Society, Royal Horticultural Society's Halls, London, S.W.1.

March 25–29. Third International Instrument Show, Caxton Hall, Westminster, London, S.W.1.

April 8–11. Radio & Electronic Component Manufacturers' Federation, Grosvenor House and Park Lane House, Park Lane, London, W.1.

April 9–13. The Electrical Engineers' Exhibition (A.S.E.E.), Earls Court, London, S.W.5.

April 12–15. (*including Sunday 14th*) London Audio Fair, Waldorf Hotel, Aldwych, London, W.C.2. Exhibition Office, 42 Manchester Street, London, W.1.

May 6–17. British Industries Fair, Castle Bromwich, Birmingham.

May 7–17. Instruments, Electronics and Automation Show, Olympia, London, W.14.

May 22–June 1. Scottish Radio Show (R.I.C.), Kelvin Hall, Glasgow.

July 10–20. Institution of Electronics Exhibition, College of Science and Technology, Manchester.

July 10–20. British Plastics Exhibition, Grand Hall, Olympia, London, W.14.

Aug. 28–Sept. 7. National Radio Show, Earls Court, London, S.W.5.

Aug. 29–Sept. 12. Engineering, Marine and Welding Exhibition, Olympia, London, W.14.

Sept. 3–9. Farnborough Air Show (S.B.A.C.), Farnborough, Hants.

Sept. 20–22. British Sound Recording Association, Waldorf Hotel, Aldwych, London, W.C.2.

Oct. 23–26. Radio Hobbies Exhibition (R.S.G.B.), Seymour Hall, London, W.1.

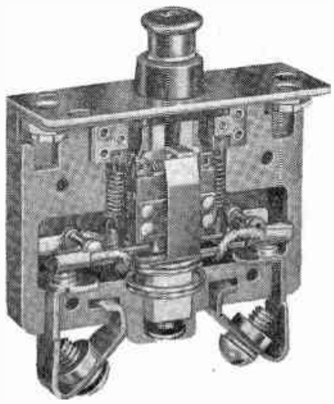
STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)
Values for December 1956

Date 1956 December	MSF 60 kc/s Frequency deviation from nominal:* parts in 10^9
1	−2
2	−2
3	−1
4	−1
5	−1
6	−1
7	−1
8	−1
9	−1
10	−1
11	0
12	0
13	0
14	0
15	0
16	+1
17	+1
18	+1
19	+1
20	+1
21	+1
22	+1
23	+1
24	+1
25	+1
26	+1
27	+2
28	+2
29	+2
30	+2
31	+2

* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator.*

New Products

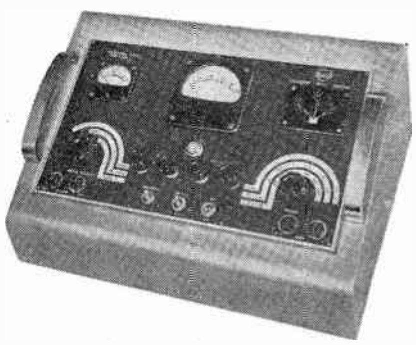


Circuit Breakers for use in Aircraft

Circuit breakers rated at 5–50 A and capable of withstanding overloads of 6,000 A are now being manufactured. The devices incorporate a thermal release which operates independently of the mechanical switch latches, even if the operating button is held in the 'on' position. The circuit breakers comply with British and American military and aircraft specifications.
The Plessey Company Ltd., Aircraft and Automotive Group, Ilford, Essex.

Simple Transistor Tester

For use where complete and detailed information about the parameters of junction transistors is not needed, but only an indication of their general characteristics and condition, a new and simplified transistor tester has been introduced. Three of

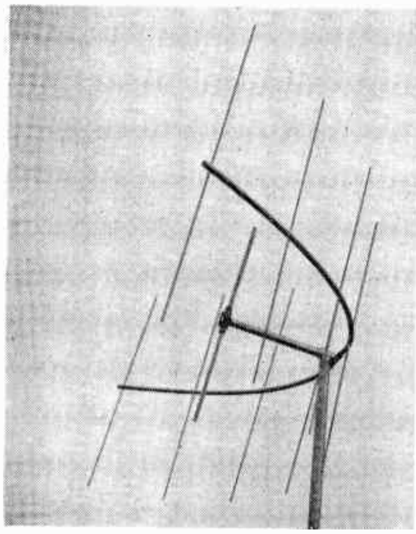


the more important junction-transistor parameters can be measured: base–collector short-circuit current gain, direct collector current for zero base current, and collector turnover voltage. All measurements are presented as direct meter readings.

Current gain is measured at d.c., advantage being taken of the approximately linear relationship between collector current and base current, which permits finite changes of current to be used to measure this parameter with an accuracy high enough for all practical purposes. Measurement is thus reduced to observing the collector current produced by a convenient known base current, and transcribing it into a direct meter reading of base–collector current gain. The standing current is backed-off in the collector-current meter.

Since the direct collector current is sensibly independent of collector voltage, direct measurement of this parameter is made. A controllable collector supply voltage (0–20 V) is provided.

The transistor tester measures the collector–emitter turnover voltage for zero base current. A relatively high voltage is applied to the collector via a resistance, and the turnover voltage is read directly from the meter. Facilities are incorporated to vary the feed resistance and collector supply voltage to give three ranges of collector dissipation: 2·5, 25 and 250 mW.
Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.

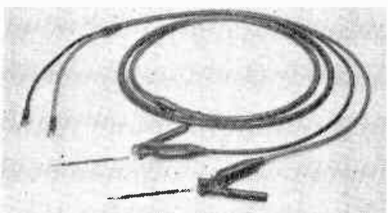


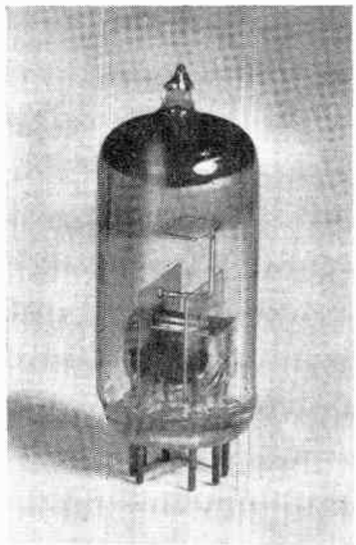
Band III Receiving Aerial

This aerial array has a dipole with an approach to a parabolic reflector which is constructed from eight rod elements. The makers claim a gain of 14 dB relative to that of a single dipole, a front-to-back ratio of 36 dB, and an acceptance angle of 22°.
Meadow-Dale Manufacturing Co. Ltd., The Dale, Willenhall, Staffs.

Fused Meter Leads

Well-insulated test leads embodying strong stainless-steel crocodile clips and 5-A fuses are available from Ferranti. Test prods are also provided; these can be inserted in the clips as required.
Ferranti Ltd., Hollinwood, Lancs.

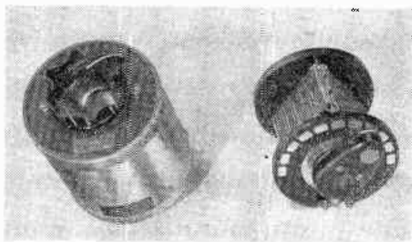




New G.E.C. Valves

The ACT.100, ACT.101 and ACT.102 are forced-air-cooled triodes with anode dissipations of 5, 10 and 20 kW respectively. Water-cooled versions of the 10- and 20-kW types are also available. The valves, which employ thoriated-tungsten filaments, are of robust construction. They are primarily intended for use in industrial r.f. heating equipment.

The A.2521 (above) is a high-slope (12 mA/V) low-noise triode, suitable for use as an r.f. amplifier at 500–1,000 Mc/s. When the valve is operated as an earthed-grid amplifier at 100 Mc/s, power gains of 6 dB at 80-Mc/s bandwidth and 16 dB at 4-Mc/s bandwidth are available. Noise factor is 12 dB at 900 Mc/s and 9 dB at 500 Mc/s.
General Electric Co. Ltd., Magnet House, Kingsway, London, W.C.1.



Decade Resistance Units

Improved non-reactive resistance units are arranged for panel mounting and occupy the minimum of mounting space. Screening is provided by an aluminium can which completely encloses each unit. New and improved switches are incorporated which ensure extremely low and constant contact resistance and abolish the need for lubrication of the contact surfaces.

Resistance ranges are from 1 Ω (in steps of 0·1 Ω) to 1 MΩ (in steps of 100 kΩ). D.C. accuracy is ±0·1% ±0·0005 Ω for values above 1 Ω, and 0·5% ±0·0005 Ω for 0·1-Ω steps.
Muirhead & Co. Ltd., Beckenham, Kent.

Microwave Dielectric Test Set

With this instrument, direct readings can be made of permittivity and loss tangent for small samples of dielectric materials at fixed spot frequencies; three different models are available to cover the frequency range 6,000 Mc/s to 17,000 Mc/s. Provision is made for measurements at temperatures up to 450° C.

The equipment is designed for use by chemists having little knowledge of microwave techniques.

Energy enters the 3-dB coupler (Fig. 1) from the klystron in arm 1. The properties of this coupler are such that the energy divides equally between arms 2 and 3, none emerging from arm 4. Arms 2 and 3 are terminated respectively in a shorting plate and adjustable short-circuiting plunger. The plunger is adjusted to give a path difference of 180° between arms 2 and 3.

The reflected energy in arms 2 and 3 travels back to the coupler and is absorbed by the attenuator in arm 1. Insertion of a dielectric sample in arm 2 causes a

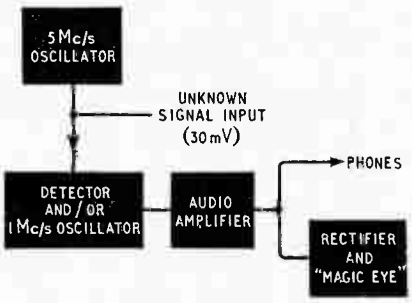
change in electrical length and some of this reflected energy passes to arm 4 which is terminated in a detector unit whose output current is indicated on the panel meter. By noting the shift of the plunger necessary to restore the meter reading to a minimum, the electrical length of the sample is obtained. This enables the permittivity to be calculated.

A measure of loss tangent for the sample can be obtained from the difference in amplitude of the reflected waves due to the loss in the sample.

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

Crystal Calibrator

The block diagram illustrates the essentials of the Advance Components Crystal Calibrator Type 74, for the frequency range 1–250 Mc/s. The frequency accuracy is



better than 2 parts in 10,000, ±15 c/s, using visual indication.

Although primarily intended for calibrating signal sources, the equipment may also be used for receiver calibration.

Advance Components Ltd., Roebuck Road, Hainault, Ilford, Essex.

Mains-Operated Relays

Relay Type M1R is for operation on voltages up to 440 a.c. or 110 d.c., or 10–12 or 22–24 d.c.

Individual contacts (rated to pass 6 A at 230 V a.c.) can be replaced without disturbing other contacts. The standard arrangement of contacts is double-pole change-over. Energizing-coil consumption is 1–2·5 W (d.c.) or 2–4 VA (a.c.).

Electrical Remote Control Co. Ltd., South Road, Templefields, Harlow New Town, Essex.

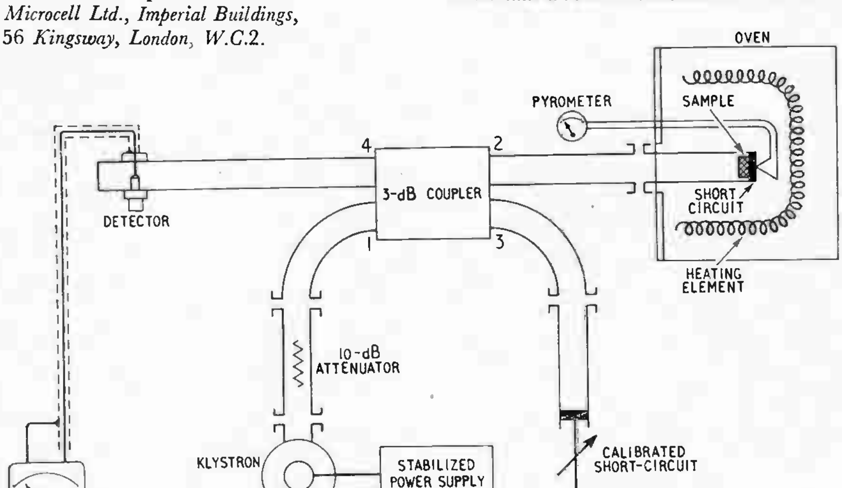
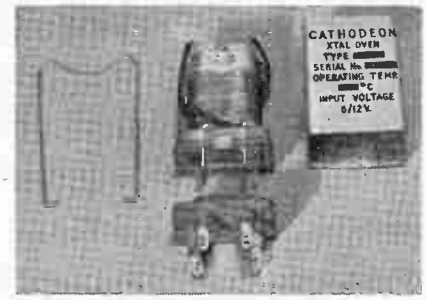


Fig. 1.

Miniature Crystal Oven

Designed for an accurate temperature control of Cathodeon Type 2M (Ministry style D) crystal units, the Cathodeon crystal oven can be used for temperature control when the ambient temperature is in the range −20° C to +70° C. The heater operates from 6·3-V or 12·6-V supplies and consumes 0·73 A at 6·3 V. Over the range 75° C to 80° C, the temperature differential is ± 2° C.



The crystal holder fits tightly inside a plated-copper inner shell, round the outside of which the insulated heater is wound. A pre-set bi-metallic contact, mounted on the outside of the inner shell and making a good thermal contact with it, is in series with the heater coil. An aluminium outer case is provided and the base and socket are of low-loss material.

The time taken from switching on to reach 85° C is less than five minutes. The photograph shows the construction of the heater, the outer can, socket, and spring clip. The overall dimensions are $1\frac{1}{4}$ in. × $\frac{13}{16}$ in. × $2\frac{5}{8}$ in.

Cathodeon Crystals Ltd., Linton, Cambridge.

Universal Spectrum Analyser

This instrument covers the S, X and L bands. It is designed for use with pulsed signals (0·2 to 2·5 μsec) at repetition frequencies of 200 to 2,000 c/s. Sweep-repetition rates are 2, 5, 10 and 24 per second, the amplitude/frequency curve of the

input signal being displayed on a 5-in. cathode-ray tube with a long-persistence screen. A built-in wavemeter operates in the TE_{011} mode and has a Q factor of 15,000. Absolute frequency measurements can be made to accuracies of ±4 Mc/s or ±1·5 Mc/s according to the band, and relative measurements to ±250 kc/s or ±150 kc/s. The frequency sweeps are 10–40 Mc/s (Xband) and 3–20 Mc/s (S band).

Winston Electronics Ltd., Shepperton, Middx.

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 journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses. Copies of articles or journals referred to are not available from Electronic & Radio Engineer. *Application must be made to the individual publisher concerned.*

ACOUSTICS AND AUDIO FREQUENCIES

534.2+[538.566 : 535.4 316

First Correction to the Geometric-Optics Scattering Cross-Section from Cylinders and Spheres.—Rubinow & Wu. (See 414.)

534.2 317

Propagation of [sound] **Waves in a Medium with Random Inhomogeneities of the Refractive Index.**—V. A. Krasil'nikov & A.M. Obukhov. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 107–112.) A review including 21 references to Russian work.

534.2 318

Focusing of Sound Waves by Inhomogeneous Media.—L. M. Brekhovskikh. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 124–132.) The cases considered include (*a*) focusing by reflection of a spherical wave at the boundary of an inhomogeneous medium, and (*b*) waveguide propagation. The region of the caustic is considered in detail.

534.2 319

Waveguide Propagation of Sound in Inhomogeneous Media.—Yu. L. Gazaryan. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 133–136.) The field is calculated of a point source in a horizontally stratified medium, the sound velocity in which varies with height in a specified manner. A similar velocity distribution law has been discussed previously by Epstein (*Proc. nat. Acad. Sci., Wash.*, 15th Oct. 1930, Vol. 16, No. 10, pp. 627–637; 1931 Abstracts, p. 31) for e.m. waves.

534.2 320

Correlation Properties of a Wave in a Medium with Random Inhomogeneities.—L. A. Chernov. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 211–216.) The coefficients of the longitudinal space autocorrelation of the amplitude and phase are calculated; it is shown that the longitudinal correlation spreads over a longer distance than does the transverse correlation. The coefficients of the time autocorrelation of amplitude and phase fluctuations are also determined. Some experimental results in hydroacoustics are discussed. For related earlier work, see 3233 of 1955.

534.21 321

Experiments on Acoustic Relaxation Processes using Electrical Models.—K. Walther. (*Acustica*, 1956, Vol. 6, No. 2, pp. 245–251. In German.)

534.232 322

Excitation of a Quartz Radiator Simultaneously at Several Frequencies.—G. D. Mikhailov, N. V. Tikhonova & I. M. Yadrova. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, p. 231.) A preliminary note on the excitation of vibrations in a quartz disk at two frequencies not harmonically related. The two exciting oscillators were connected respectively between the common electrode covering one face of the disk and the semicircular electrodes covering the other face.

534.232-14-8 323

Dielectric Heating of Quartz Oscillating in Several Organic Liquids.—S. Parthasarathy & V. Narasimhan. (*Z. Phys.*, 15th June 1956, Vol. 145, No. 4, pp. 508–510. In English.) Measurements were made on crystals driven at 8·7 Mc/s and at 2·84 Mc/s; the results indicate that the dielectric heating is greater in liquids of lower sound-absorption coefficient.

534.232-14-8 324

The Output of a Quartz Transducer Oscillating in its Fundamental and Higher Harmonics.—S. Parthasarathy & V. Narasimhan. (*Z. Phys.*, 15th June 1956, Vol. 145, No. 4, pp. 511–514. In English.) Measurements were made on a crystal oscillating in various liquids; the observed output is much smaller than predicted by theory.

534.24 325

Use of Layers Preventing the Production of Transverse Waves in the Reflection of a Longitudinal Wave at the Boundary of a Solid Body.—M. A. Isakovich. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 150–153.)

534.26 326

Scattering and Radiation of Waves by Statistically Inhomogeneous and Statistically Oscillating Surfaces.—M. A. Isakovich. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 146–149.) Extension of previous work (2969 of 1953); see also 2541 of 1953 (Eckart).

534.26 **327**
Scattering of Sound Waves by Sinusoidal and Sawtooth Surfaces.—A. N. Leporski. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 177–181.) An experimental investigation is reported. The results are compared with Lysanov's theory (see 328 below).

534.26 **328**
An Approximate Solution of the Problem of Scattering of Sound Waves at an Irregular Surface.—Yu. P. Lysanov. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 182–187.) The calculation is based on the solution of an approximate integral equation for the normal component of the velocity potential at the scattering surface.

534.3 : 534.78 **329**
Some Results of an Analysis of a Singer's Voice.—S. N. Rzhevkin. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 205–210.) The frequency characteristics of a trained bass voice and an untrained baritone voice are presented graphically and discussed.

534.6-8 **330**
Differential Method of Measuring the Absorption of Ultrasonic Waves in Liquids.—I. G. Mikhailov & G. N. Feofanov. (*Akust. Zh.*, April–June 1956, Vol. 2, No. 2, pp. 194–198.)

534.61 **331**
Absolute Method for Sound Intensity Measurement.—D. R. Pardue & A. L. Hedrich. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 631–632.) The method described is based on measurement of the temperature variations associated with the sound wave, using a thermometer with a very fast response.

534.7 **332**
The Unity of Speech and Hearing.—H. Mol. (*PTT-Bedrijf*, July 1956, Vol. 7, No. 2, pp. 69–75.) The interdependence of the two functions in communication by language and the shortcomings of purely objective measurements are stressed.

534.845 **333**
The Absorption of Sound in Air at Audio Frequencies.—E. J. Evans & E. N. Bazley. (*Acustica*, 1956, Vol. 6, No. 2, pp. 238–245.) Measurements have been made in a large reverberation chamber with very small surface absorption, at frequencies from 1 kc/s to 12·5 kc/s, for values of relative humidity from about 5% to 85% and a temperature of 20°C. The values obtained for the absorption due to the air are in close agreement with values given by relaxation theory. A general expression is derived for the attenuation of sound in air as a function of frequency, humidity and temperature.

621.395.61.089.6 : 534.612 **334**
The Thermophone, an Aerodynamic Pistonphone.—P. Riéty. (*Acustica*, 1956, Vol. 6, No. 2, pp. 251–258. In French.) Rigorous theory presented previously (657 of 1956) is supplemented by a discussion based on the physical processes, i.e. energy transformations, in the thermophone. The operation of the device is compared with that of the pistonphone. A formula derived for the acoustic pressure inside the thermophone is identical with that obtained previously. The device is of interest for calibrating microphones, though not so accurate as the reciprocity method.

AERIALS AND TRANSMISSION LINES

621.372 **335**
The Launching of a Plane Surface Wave.—G. J. Rich. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 787–788.) Discussion on 1548 of 1955.

621.372.2 **336**
Theory of Helical Line Surrounded by a Cylindrical Semiconducting Envelope.—E. G. Solov'ev & L. V. Belous. (*Radiotekhnika, Moscow*, April 1956, Vol. 11, No. 4, pp. 31–35.) The propagation of e.m. waves along a helix inside a quartz tube coated with a semiconducting layer is discussed. An equation is derived indicating the dependence of the attenuation on the thickness d of the semiconducting layer, the conductivity σ, retardation and frequency. Curves show the calculated and observed dependence of the attenuation on $\sigma.d$.

621.372.2 : 621.372.8 **337**
Surface Electromagnetic Waves on a Comb Structure.—L. A. Vainshtein. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 385–397.) Theory is developed based on the functional equations used in the rigorous theory of radiation from the open end of a waveguide. An exact characteristic equation of the surface waves is derived, as well as a simplified approximate form; a method is proposed for estimating the accuracy of the latter equation. Curves show the dispersion properties of periodic comb structures.

621.372.2+621.372.8] : 621.385.029.6 **338**
Electron Waves in Retarding Systems.—L. A. Vainshtein. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 126–140 & 141–148.) The linear theory of electron waves in retarding systems is discussed in relation to the excitation of waveguides. The characteristic wave equation is derived and its solutions are studied. The physical meaning of the quantities appearing in the equation is established. The following particular retarding systems are considered: (*a*) waveguide filled with a dielectric, (*b*) transmission line of 'comb' type and (*c*) helical line. The results obtained are compared with those published in the literature.

621.372.21 **339**
Free Oscillations in Simple Distributed Circuits.—A. B. Hillan. (*Wireless Engr*, Dec. 1956, Vol. 33, No. 12, pp. 279–290.) Analysis is presented for a representative distributed circuit in the form of a finite length of uniform transmission line, (*a*) with a pure inductance at one end and an open-circuit at the other, or (*b*) with a pure capacitance at one end and a short-circuit at the other. Distinction is drawn between the cases where the energy is initially stored in the lumped-circuit element and where it is stored in the line. The method is useful for determining the effect of measuring circuits and cables on line waveforms.

621.372.8 **340**
A Low-Attenuation Waveguide Free from Phase and Attenuation Distortion.—H. G. Unger. (*Arch. elekt. Übertragung*, June 1956, Vol. 10, No. 6, pp. 253–260.) For the H_{01} mode in a circular metal waveguide with a suitably dimensioned coaxial inner tube of low-loss dielectric, the attenuation/frequency curve exhibits a minimum and the group-velocity/frequency curve exhibits an extreme value at the same frequency, at which propagation is hence free from distortion. For wide-band applications, the diameter and wall thickness of the dielectric tube must be small.

621.372.8 **341**
Influence of a Semiconducting Film on the Attenuation of Radio Waves in Waveguides with Circular Cross-Section.—V. V. Malin. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 34–37.) The attenuation of H_{0m}, E_{0m} and E_{nm} waves in a cylindrical waveguide whose inner surface is coated with a material having a complex permittivity is calculated. The formulae derived are valid for $\epsilon'' \ll \epsilon'$ and $\epsilon'' \gg \epsilon'$ as well as for $\epsilon'' \approx \epsilon'$. Graphs show that the maximum attenuation for all modes except the H_{0m} occurs at $\epsilon'' \approx \epsilon'$; it is assumed that the film is thick compared with the surface film of the metal.

621.372.8 **342**
Scattering by a Semi-infinite Resistive Strip of Dominant-Mode Propagation in an Infinite Rectangular Waveguide.—V. M. Papadopoulos. (*Proc. Camb. phil. Soc.*, July 1956, Vol. 52, Part 3, pp. 553–563.) A calculation is made, using Laplace transforms, of the scattering produced by a strip arranged parallel to the electric field in the mid-plane of the waveguide. Formulae are derived for the amplitude of the scattered waves, and numerical results are given for various values of the surface resistivity of the strip.

621.372.8 : 621.318.134 : 538.221 **343**
Relations between the Structure of Ferrites and Conditions for their Resonance in Waveguides. Unidirectional Guides.—Suchet. (See 512.)

621.396.67+[621.372.8 : 538.63]+ **344**
621.396.11+[538.566 : 535.42/.43
Symposium on Electromagnetic Wave Theory.—(See 415.)

621.396.674.3 : 621.396.93 **345**
The Use of a Horizontal Dipole as a Direction-Finding Aerial.—G. Millington. (*Marconi Rev.*, 3rd Quarter 1956, Vol. 19, No. 122, pp. 97–118.) The problem is considered in relation to the type of wave radiated by the transmitter, neglecting site and instrumental errors. Conditions are analysed for both small and large angles of elevation at the receiver: examples show that errors may be very large in the latter

case. A comparison is made between the vertical-frame and horizontal-dipole aerials for u.s.w. d.f.; the nature and order of bearing errors are similar for the two types.

621.396.677 **346**

Ground Aerials.—J. Grosskopf. (*Nachrichtentech. Z.*, June 1956, Vol. 9, No. 6, pp. 241–244.) Simple analysis indicates that the performance of ground aerials can be predicted both qualitatively and quantitatively from accepted theory; freedom from noise is no greater than for other types of aerial. Measurements on several different systems support this view.

621.396.677 **347**

Investigations of Ground Aerials (Long-Wave Directional Receiving Installations).—W. Kronjäger & K. Vogt. (*Nachrichtentech. Z.*, June 1956, Vol. 9, No. 6, pp. 245–249.) Symmetrical aerials were used in the measurements reported, on account of their relative insensitivity to local noise. The results indicate that these aerials have similar receiving properties to a frame aerial with vertical axis of rotation. At a communication station with sufficient ground space for a crossed ground aerial, such an aerial is, on account of its simplicity, preferable to an equivalent crossed-frame system.

621.396.677 **348**

An Experimental Design Study of some S- and X-Band Helical Aerial Systems.—G. C. Jones. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 764–771.) The general characteristics of helical aerials are summarized, and measurements of radiation patterns are reported for single and multiple types. Methods such as end loading and tapering are discussed for increasing beam width and bandwidth. Satisfactory techniques have been developed for sealing the helices inside foamed insulating materials to improve their rigidity. Wide-band aerials giving linearly polarized radiation can be produced using rectangular helices.

621.396.677 : 523.16 **349**

Radio Astronomy and the Jodrell Bank Telescope.—(See 421.)

621.396.677.3 **350**

Note on the Fourier Coefficients for Tchebycheff Patterns.—H. E. Salzer. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 286–288.) A formula derived for the feeding coefficients for optimum beam patterns for aerials is equivalent to a set of formulae given by Duhamel (2225 of 1953) but is more convenient for computation.

621.396.677.3 **351**

The Determination of the True Side-Lobe Level of Long Broadside Arrays from Radiation-Pattern Measurements made in the Fresnel Region.—R. H. T. Bates & J. Elliott. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 307–312.)

621.396.677.3 **352**

Influence of a Parasitic Aerial in a Rectangular Array.—G. Boudouris. (*J. Brit. Instn Radio Engrs*, Oct. 1956, Vol. 16, No. 10, pp. 571–584.) "A rectangular aerial array has a parasitic element placed at its centre. All the aerials making up the array are symmetrical half-wave dipoles parallel to one another and not displaced in the sense of their axes, and the system radiates in free space. The aerials are assumed to be thin and in the form of wires. Radiation diagrams and the gain of the network are considered from the double standpoint of the influence of the parasitic element and of the geometric configuration of the rectangle. The formulae produced are developed in the form of graphs. Some comments relative to the case of earthed dipoles are given." See also 554 of 1950.

621.396.677.3 : 621.372.6 **353**

N-Terminal Networks.—Bloch. (See 383.)

621.396.677.31 **354**

Optimal Linear Arrays of Aerials, Radiating Perpendicular to the Axis.—V. L. Pokrovski. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1956, Vol. 109, No. 4, pp. 769–770. In Russian.) The problem considered previously by Dolph (2487 of 1946) is solved for arbitrary radiator spacing. The calculation is carried out for arrays with symmetry about a mid-point, but the calculated optimum current distribution applies to all linear arrays.

621.396.677.71 **355**

Radiation Patterns of Circumferential Slots on Moderately Large Conducting Cylinders.—J. R. Wait & J. Kates. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 289–296.) "Computed patterns are presented for thin half-wave circumferential slots on circular conducting cylinders of infinite length. The cases considered are for single and diametrically opposed slots on cylinders whose circumferences vary from 3 to 21 wavelengths."

621.396.677.8 **356**

Wide-Angle Scanning Performance of Mirror Aerials.—J. F. Ramsay & J. A. C. Jackson. (*Marconi Rev.*, 3rd Quarter 1956, Vol. 19, No. 122, pp. 119–140.) Design details are discussed of a coma-corrected zoned paraboloidal mirror and a spherical mirror aerial, the latter based on the work of Ashmead & Pippard (1342 of 1947). Results of performance tests on both types using offset feed agree closely. A comparison of mirror and lens aerials shows that mirrors are preferable for line scanning, a lens being more advantageous where a large volume of scan is required. Scanning charts show possible 'pin-cushion' and 'barrel' distortion; a generalized, approximate chart has been developed for indicating the scanning performance of both mirrors and lenses.

621.396.677.83 **357**

The Insertion Equivalent of Passive Reflectors [in microwave links].—C. Micheletta. (*Alta Frequenza*, June/Aug. 1956, Vol. 25, Nos. 3/4, pp. 275–304.) An expression is derived which relates the field strength received at an aerial via a deviating reflector to that received at the same aerial without the reflector, over a path of the same total length. By applying the formula to reflectors of various shapes the validity of the usual approximations is assessed. Numerical examples are given for paths with one or two reflectors. The minimum distance to which the formula is applicable is found by comparison with the method of Jakes (1243 of 1953).

621.396.677.85 **358**

A Study of the Field Distribution at an Axial Focus of a Square Microwave Lens.—P. A. Matthews & A. L. Cullen. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 449–456.) Discussion indicates that the principal component of the electric field vector can be evaluated with sufficient accuracy from the scalar theory. Measurements of the transverse component of the electric field, made by a pertubation method using a spinning dipole, give results in good agreement with theory. The 180° phase shift associated with passage of a wave through the focal plane is considered; the related change in wavelength near the focus is verified experimentally.

AUTOMATIC COMPUTERS

681.142 **359**

Transistor/Magnetic Analogue Multiplier.—G. L. Keister. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 160–163.) A four-quadrant voltage multiplier using magnetic cores and junction-transistor switches is described, giving an output linear within $\pm 3\%$. Multiplication is performed by averaging a square wave of which the amplitude is proportional to one input voltage and the phase to the other.

681.142 : 621.318.134 **360**

Design of the Components of a Fast-Acting Store using Ferrite Ring Cores.—H. Gillert. (*Nachrichtentech. Z.*, June 1956, Vol. 9, No. 6, pp. 250–252.) The requirements for transmission between line selector and lines and between column selector and columns in matrix storage devices are investigated; design data for the selector-core windings are hence derived. Some details are given of the storage unit in the Darmstadt computer DERA.

681.142 : 621.383 **361**

Photoelectric Analogue Function Generator.—R. A. Sinker. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 178–181.) Three-dimensional data stored as density variations on photographic film are read by means of a c.r. beam and photomultiplier. Satisfactory accuracy for function generation is obtained by providing a grey-scale standard deflection feedback loop and a servo feedback loop controlling light intensity.

CIRCUITS AND CIRCUIT ELEMENTS

621.318.424 : 621.3.011.3 **362**

On the Inductance of Iron-Cored Coils.—P. Hammond. (*Proc. Instn elect.*

Engrs, Part C, Sept. 1956, Vol. 103, No. 4, pp. 249–259.) "The magnetic field in the neighbourhood of coils threaded through holes in iron cylinders is calculated. The results are relevant to the estimation of the self-inductance of rotating machines and transformers and form the basis for an examination of the soundness of approximate formulae used in the design of such apparatus."

621.318.57 **363**

Precision Electronic Switching with Feedback Amplifiers.—C. M. Edwards. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1613–1620.) Circuits are described in which precise control of voltage or current levels is achieved by using a high-gain feedback amplifier to minimize differences and nonlinearities in the circuit elements. Applications in analogue computers, signal-comparing devices and communication systems are indicated.

621.319.45 **364**

Tantalum Capacitors use Solid Electrolyte.—D. A. McLean. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 176–177.)

621.372 **365**

Nyquist's Stability Criterion.—E. A. Freeman & J. F. Meredith. (*Wireless Engr*, Dec. 1956, Vol. 33, No. 12, pp. 290–294.) A proof based on Laplace-transform calculus is presented; the analysis is applicable to multi-loop as well as single-loop feedback systems.

621.372 : 534.213-8 **366**

On the Measurement of Attenuation in Ultrasonic Delay Lines.—M. Redwood & J. Lamb. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 773–780.) "A theoretical and experimental study has been made of the effects of coupling films on the propagation of compressional waves from a transducer to a solid medium. In practice it has been found that 'wringing' the transducer to the specimen with oil as a coupling medium produces a film of non-uniform thickness. Although the variations in thickness are of the order of a wavelength of light, these variations are important at ultrasonic frequencies in the region of 50 Mc/s and above. Conditions are described under which such films can lead to the propagation of a predominantly first-order mode in the specimen, resulting in an exponential decay of the amplitudes of successive reflections, with a consequent improved accuracy of attenuation measurement."

621.372.412 : 549.514.51 **367**

Frequency/Temperature/Angle Characteristics of AT-Type Resonators made of Natural and Synthetic Quartz.—R. Bechmann. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1600–1607.) Differences between the frequency/temperature characteristics and optimum orientation angles of natural and synthetic quartz resonators are discussed on the basis of detailed experimental and analytical studies. Synthetic quartz with deliberately modified properties can be produced by introducing other substances during the growing process. Measurements are reported on AT-type resonators cut from quartz grown in an alkaline solution containing germanium oxide; the third-order temperature coefficient is noticeably reduced.

621.372.412 : 621.372.54 **368**

The Use of Ethylene Diamine Tartrate for Piezoelectric Filter Elements.—J. Birch, A. G. Frith, A. C. L. Ferguson, R. H. A. Miles & J. F. Werner. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 420–427.) "Crystal resonators suitable for use in telephone system channel filters have been made from ethylene diamine tartrate (e.d.t.). Methods used in the fabrication and mounting of these units are described. The circuits used in the determination of the electrical parameters are given, and the results of a large number of measurements are outlined. Freedom from unwanted resonances over the desired frequency bands combined with the required characteristics has been achieved by suitably dimensioning the plates, and by applying electrodes to a part of the crystal surface only. Increased activity for crystals mounted in air can be obtained by the use of suitably placed reflectors."

621.372.45 **369**

A Negative Resistance for Direct and Alternating Current.—L. Waldmann & R. Bieri. (*Z. Naturf.*, Nov. 1955, Vol. 10a, No. 11, pp. 814–820.) The negative resistance is constituted by a symmetrical two-terminal valve circuit comprising in its simplest form a twin triode with separate anode resistances. By connecting further twin triodes in parallel and providing cathode resistances, a resistance of about $-3\,\mathrm{k}\Omega$ is obtained, constant to within $1{\cdot}5\permil$ at voltages up to ± 12 V. The stability limits of the arrangement are discussed. Applications in the field of measurements and analogue technique are indicated.

621.372.5 **370**

A Method of Analysing the Performance of Tandem-Connected Four-Terminal Networks.—P. W. Seymour. (*Proc. Instn Radio Engrs, Aust.*, July 1956, Vol. 17, No. 7, pp. 249–255; *J. Brit. Instn Radio Engrs*, Oct. 1956, Vol. 16, No. 10, pp. 555–562.) A graphical technique is presented.

621.372.5 **371**

Some Properties of the Transfer Function of Unbalanced *RC* Networks.—I. Cederbaum. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 400–406.)

621.372.5 **372**

A Transformation Diagram for Lossy Quadripoles.—F. Gemmel. (*Arch. elekt. Übertragung*, June 1956, Vol. 10, No. 6, pp. 265–267.) A graphical method is described which, using measured input and termination data, represents separately the transformation of the lossy and loss-free components. The input impedance corresponding to any required terminating impedance can thus be determined.

621.372.5 : 621.374.5 : 621-52 **373**

The Continous Delay-Line Synthesizer as a System Analogue.—J. H. Westcott. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 357–366.) The use of a tapped continuous delay line for simulating transfer functions of linear systems is described. The accuracy of the device is estimated with particular reference to servo systems.

621.372.5 : 621.374.5 : 621-52 **374**

Properties of a Feedback-System Analogue based on a Discontinuous-Delay-Line Synthesizer.—R. M. F. Houtappel. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 367–377.) A simple method is presented for determining the number of sections required for a discontinuous delay line to simulate with a given degree of accuracy the transfer function of a network considered as part of a feedback system.

621.372.5 : 621.375.2 **375**

Determination of Optimum Linear-Network Parameters based on Time Characteristics.—R. Kulikowski. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 2, pp. 323–346. English summary, pp. 345–346.) The method of analysis used is based on minimization of the deviation between the input and output functions considered in a particular function space. Several amplifier circuits are discussed in detail, with emphasis on pulse response.

621.372.5.029.3.018.783 **376**

Compensation Method of Reducing Nonlinear Distortion.—A. A. Gorbachev. (*Radiotekhnika, Moscow*, April 1956, Vol. 11, No. 4, pp. 67–74.) The principles of a method of compensating distortion by means of distortion voltages or currents fed in phase opposition are considered theoretically. A block diagram of the arrangement is given. Results of an experimental verification in an a.f. power amplifier are tabulated and indicate, in this particular case, a decrease of the coefficient of nonlinearity at the load from 13% to $1{\cdot}4$% at 400 c/s, with smaller improvements at higher and lower frequencies.

621.372.54 **377**

Filter Design by Synthesis.—G. De Lotto & M. Trinchieri. (*Alta Frequenza*, June/Aug. 1956, Vol. 25, Nos. 3/4, pp. 233–274.) The application of Darlington's method (*J. Math. Phys.*, Sept. 1939, Vol. 18, pp. 257–353) is detailed. By modifying the attenuation function used in the calculations, compensation for losses in the circuit, and hence a closer approach to the ideal response curve, can be achieved. A numerical example and useful tables are included.

621.372.54 **378**

Comparison between the Image-Parameter Method and the Modern Insertion-Loss Method of Filter Design.—V. Fetzer. (*Arch. elekt. Übertragung*, June 1956, Vol. 10, No. 6, pp. 225–240.) The two design methods are outlined; discussion shows that the insertion-loss method is superior, as it permits closer conformity to the required tolerances and a greater freedom in the selection of parameters. The larger amount of calculation necessary can, in special cases, be reduced by reference to a filter catalogue [351 of 1956 (Glowatzki)]. Further applications of the modern method are mentioned. 76 references.

621.372.54 : 621.315.212 **379**

V.H.F. Band-II Harmonic Filter.—B. M. Sosin. (*Marconi Rev.*, 3rd Quarter 1956, Vol. 19, No. 122, pp. 89–96.) The design and characteristics of a filter for use in transmitters are described. The filter is of the varying-impedance type [see e.g. 2338 of 1954 (Yin & Foley)] and forms part of a 3½-in. diameter 51·5-Ω coaxial feeder run.

621.372.57.029.6 **380**

The Equivalent Noise Quadripole Treated as a Wave Quadripole.—H. Bauer & H. Rothe. (*Arch. elekt. Übertragung*, June 1956, Vol. 10, No. 6, pp. 241–252.) Sources of noise voltage and current are interpreted as waves to make the equivalent network [2665 of 1956 (Rothe & Dahlke)] applicable to u.h.f. conditions. The relation between matrices based on wave parameters and impedance concepts is derived.

621.372.6 **381**

New Hybrid Devices for Combining and Distributing Electric Power at High Frequencies.—A. A. L'vovich. (*Radiotekhnika, Moscow*, April 1956, Vol. 11, No. 4, pp. 36–43.)

621.372.6 **382**

Analysis of Linear *n*-Port Networks.—I. Cederbaum. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 267–271.) Analysis is presented for the general case of the nonreciprocal *n*-port linear network; using a symbolic notation, a unique expression for all network functions is derived. Examples of the application of the method are given.

621.372.6 : 621.396.677.3 **383**

***N*-Terminal Networks.**—A. Bloch. (*Wireless Engr*, Dec. 1956, Vol. 33, No. 12, pp. 295–300.) Generalized two-terminal-network theorems are used to analyse the directive properties of aerial arrays.

621.373 : 621.316.729 **384**

Synchronization of Oscillators by Sloping [-edge] **Radio** [-frequency] **Pulses.**—E. S. Voronin & R. V. Khokhlov. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 79–87.) A theoretical analysis is presented.

621.373.2.029.6 **385**

Researches into Spark Generation of Microwaves.—M. H. N. Potok. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 781–787.) The wide frequency band generated by spark generators permits desired ranges to be selected by means of filters. Waveguide filters of post and iris type are suitable for this purpose. Measurements of wavelength and bandwidth are reported; a Boltzmann interferometer was used, with a c.r.o. and recording camera.

621.373.4 : 621.396.61 **386**

An Analysis of Pulse-Synchronized Oscillators.—G. Salmet. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1582–1594.) Problems in the design of high-precision variable-frequency oscillators, as required for communication transmitters, are discussed. The principles of operation of the impulse-governed oscillator [see e.g. 767 of 1951 (Hugenholtz)] are explained. Use of a modified form of the circuit, termed a 'phase follower', eliminates the tendency to instability as well as other undesirable characteristics of the I.G.O.

621.373.421 **387**

Theory of the Triode Valve Oscillator with Feedback.—V. A. Zore. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 181–192.) Continuation of a previous paper (2480 of 1949). A general design method is given taking into account the effect of grid current and of electron transit time. The condition of self-excitation and the dependence of the frequency generated on the anode voltage are investigated. A formula is derived for calculating the limiting wavelengths.

621.373.421 : 621.314.7 **388**

A Transistor RC Oscillator.—G. Francini. (*Alta Frequenza*, June/Aug. 1956, Vol. 25, Nos. 3/4, pp. 198–210.) The substitution of a transistor for a triode is investigated in the *RC* oscillator with twin-T feedback network described e.g. in 3198 of 1955 (Tucker). A single transistor without matching transformer is sufficient because of the low attenuation and high selectivity of the network even at very low frequencies where its impedance rises to about 1 MΩ.

621.373.421.14 : 621.372.413 **389**

Frequency Control in the 300-1 200-Mc/s Region.—D. W. Fraser & E. G. Holmes. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1531–1541.) Oscillators controlled by coaxial-cavity resonators are discussed. Frequency stability can be increased ten- to twenty-fold by connecting a small capacitor in series with the resonator. Using a Type-6AF4 valve with an anode voltage of 50–60 V, the variation of frequency with voltage is 0·3 c/s per Mc/s per volt in the 600-Mc/s region: this compares favourably with overtone-crystal oscillators in their upper frequency range. For frequencies between 700 Mc/s and 1 kMc/s a control system comprising two cavities arranged end to end is found satisfactory, with a pencil triode Type-5876; the series capacitor is constituted by an iris between the two cavities. A resonator tunable over a range of ± 15 Mc/s around 600 Mc/s is described. Variations with temperature are minimized by the design.

621.373.423 : 621.316.729 **390**

Mutual Synchronization of Reflex Klystrons.—R. V. Khokhlov. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 88–97.) The possibility of a continuous transition from control by one klystron to control by the other is shown by an analysis of the solutions of van der Pol's equations describing the synchronization process.

621.375.2 **391**

Negative-Impedance Amplifiers.—W. Nowicki. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 2, pp. 279–322. French summary, pp. 318–322.) An analysis is made of the performance of amplifiers in which negative impedance is introduced by positive feedback. Frequency distortion is greater than for other types of line amplifier; stability also is inferior. Such amplifiers are nevertheless useful in certain circumstances since they are very economical of copper.

621.375.221 **392**

Wide-Band Multistage Amplifiers with Gaussian Characteristics.—W. Golde. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 2, pp. 215–246. English summary, pp. 245–246.) Analysis is based on use of the Taylor approximation to the Gaussian function. Typical low-pass and band-pass circuits are examined. The response of such amplifiers to step signals is nearly monotonic, overshoots being $\ngtr 1\%$ for the number of stages commonly used. A comparison of asynchronous and synchronous types indicates that the former give better pulse response.

621.375.227 **393**

A Differential Amplifier of High Input Impedance for Suppression of [unbalanced] **Earth Voltages.**—A. P. Bolle & D. Capel. (*PTT-Bedrijf*, July 1956, Vol. 7, No. 2, pp. 58–63.) The circuit described covers a frequency band from 10 kc/s to 1 or 2 Mc/s. Consideration is given to the rejection factor [see also 362 of 1956 (Klein)], which varies with frequency and according to the adjustment of the balancing network.

621.375.23 **394**

Nonlinear-Amplifier Design for Pulse-Height Analysers.—G. W. Hutchinson. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 592–596.) "The ratio of maximum to minimum pulse sizes which can be simultaneously recorded by a kick sorter is limited by the curvature of the characteristic of its biased amplifier over a finite region of input potentials. The extent of this region can be reduced from a few volts to about 10 mV by including the nonlinear elements of the amplifier in its negative feedback loop. An amplifier is described which embodies this principle and also provides a discriminator and gate circuit."

621.375.4 : 621.314.7 **395**

Gain Chart for Transistor Amplifiers.—G. H. Myers. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 224, 226.)

621.375.4 : 621.314.7 **396**

Common-Emitter Transistor Video Amplifiers.—G. Bruun. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1561–1572.) Design theory applicable to alloy-junction transistors makes use of the hybrid-Π equivalent network. The bilateral nature of the transistor is taken into account by adding a 'Miller' capacitance term to the diffusion capacitance. Gain-bandwidth products and optimum load resistances are determined for cascaded stages. The production of maximally flat frequency response in a single stage by means of a capacitor shunting the feedback resistor or by means of inductances in the interstage couplings is discussed.

621.375.5 **397**

Resonant Dielectric Amplifier.—M. Vadnjal. (*Alta Frequenza*, June/Aug. 1956, Vol. 25, Nos. 3/4, pp. 211–232.) The solution of a second-order differential equation yields an expression for the amplification in terms of all the circuit parameters. Hence the optimum voltage and power amplification, the distortion, and the frequency response are easily determined [see also 2903 of 1954 (Penney et al.)]. Experimental results confirm the validity of this analysis.

GENERAL PHYSICS

537.312.62 **398**

Magnetic Energy and Electron Inertia in a Superconducting Sphere.—E. G. Cullwick. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 441–446.)

537.5 **399**

Polarization of the Continuous Spectrum in a Gas Discharge.—B. V. Paranjape. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 765–768.) Arguments based on the velocity distribution of the electrons are advanced to show that the continuous part of the spectrum of a gas discharge may be expected to be polarized.

537.5 **400**

Electronic Motion in Gases and the Method of Free Paths.—L. G. H. Huxley. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 769–771.) Discussion on statements made in a paper by Jancel & Kahan (*The Physics of the Ionosphere*, conference report, 1955, p. 365).

537.533 **401**

Electron Emission from Zinc Crystals subjected to Plastic Deformation.—J. Lohff. (*Z. Phys.*, 15th June 1956, Vol. 145, No. 4, pp. 504–507.)

537.533 : 537.534.8 : 537.525.8 **402**

Auger Ejection of Electrons from Barium Oxide by Inert Gas Ions and the Cathode Fall in Normal Glow Discharges.—Y. Takeishi. (*J. phys. Soc. Japan*, June 1956, Vol. 11, No. 6, pp. 676–689.) Calculated total yields and energy distribution for He, Ne, Ar, Kr and Xe positive ions are high compared with those observed by Hagstrum (681 of 1955) for emission from tungsten; the values for Ar^+ agree with those observed by Varney (2357 of 1954). Cathodic phenomena observed were in agreement with theory.

537.533 : 537.58 **403**

Thermionic Emission Constants of Iridium.—D. L. Goldwater & W. E. Danforth. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 871–872.) Measurements on ribbon specimens subjected to prolonged cleaning are reported; the values found for the constants A and ϕ are respectively 170 A/cm² per (deg C)² and 5·40 V. The spectral emissivity is 0·33 at $\lambda = 0{\cdot}65\,\mu$.

537.533 : 621.385.032.21 **404**

Field Emission and Field-Emission Cathodes.—Zernov & Elinson. (See 637.)

537.534 **405**

Mass-Spectrometer Investigations of the Field Emission of Positive Ions.—M. C. Inghram & R. Gomer. (*Z. Naturf.*, Nov. 1955, Vol. 10a, No. 11, pp. 863–872.) Preliminary experiments indicate that the combination of the field-emission source and the mass spectrometer is likely to be useful for investigating various phenomena such as adsorption processes, etc.

537.56 **406**

Theory of Plasma Resonance.—P. A. Wolff. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 845–850.) "Starting from the Boltzmann transport equation, a formula is derived for the rate of change of electron density in a gas plasma. With its aid a study is made of the oscillations of electron density (about the steady state value) in a discharge confined between parallel plates. The oscillations are described in terms of a set of normal modes characteristic of the plasma under study. An expression is obtained for the impedance of the discharge as a function of frequency: for the one case calculated in detail, this formula gives a resonance in power absorption at a frequency of 0·7 of the plasma resonance frequency corresponding to the central electron density."

537.56 **407**

Helmholtz Instability of a Plasma.—T. G. Northrop. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1150–1154.)

537.56 **408**

The Extraction of Ions from Plasmas and Plasma-Like Systems.—W. Fischer & W. Walcher. (*Z. Naturf.*, Nov. 1955, Vol. 10a, No. 11, pp. 857–863.) Report of an experimental and theoretical investigation of the extraction mechanism; conclusions are drawn regarding the limits of applicability of probe theory and of the term 'plasma'.

537.56 **409**

Recording Decay of Electron Density in Ionized Gases.—G. E. Deakins & C. M. Crain. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 606–608.) The electron density was measured and recorded photographically at times up to 500 μs after removal of a 24·5-Mc/s ionizing voltage, using a cavity-resonator refractometer operating at about 9·4 kMc/s. Observations indicate that for commercial neon 90% of the decay occurred within the first 250 μs.

537.56 : 538.56 : 538.6 **410**

The Boltzmann Equation and the One-Fluid Hydromagnetic Equations in the Absence of Particle Collisions.—G. F. Chew, M. L. Goldberger & F. E. Low. (*Proc. roy. Soc. A*, 10th July 1956, Vol. 236, No. 1204, pp. 112–118.) "Starting from the Boltzmann equation for a completely ionized dilute gas with no interparticle collision term but a strong Lorentz force, an attempt is made to obtain one-fluid hydromagnetic equations by expanding in the ion mass-to-charge ratio. It is shown that the electron degrees of freedom can be replaced by a macroscopic current, but true hydrodynamics still does not result unless some special circumstance suppresses the transport of pressure along magnetic lines of force. If the longitudinal transport of pressure is ignored, a set of self-contained one-fluid hydromagnetic equations can be found even though the pressure is not a scalar."

537.562 **411**

The Dependence of the Electronic Recombination Coefficient on Temperature and Pressure.—I. L. Aptekar' & B. L. Timan. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 343–347.) Electronic recombination in gases is examined on the basis of statistical relations. The variation of the recombination coefficient thus determined coincides with that determined experimentally for ionic recombination in air.

537.562 **412**

The Behaviour of Ion Columns in Pure Gases.—A. Müller. (*Z. Phys.*, 15th June 1956, Vol. 145, No. 4, pp. 469–485.) Measurements of recombination and diffusion in oxygen and in inert gases are reported.

538.3 **413**

Some Problems relating to the Application of Hertzian Vectors.—K. Bochenek. (*Archiwum Elektrotech.*, 1955, Vol. 4, No. 2, pp. 247–268. English summary, pp. 266–268.) Two theorems on e.m. fields are presented; in the first, the field is described by only one vector, electric or magnetic; in the second it is described by two vectors.

538.566 : 535.4]+534.2 **414**

First Correction to the Geometric-Optics Scattering Cross-Section from Cylinders and Spheres.—S. I. Rubinow & T. T. Wu. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1032–1039.) "The total scattering cross-section in the short-wavelength limit is considered in this paper. The problems treated include diffraction of a plane electromagnetic wave by a conducting cylinder (two possible polarizations) or a conducting sphere, acoustic scattering by a rigid sphere, and quantum-mechanical scattering by an impenetrable sphere."

538.566 : 535.42/.43]+621.396.11+621.396.67+[621.372.8 : 538.63 **415**

Symposium on Electromagnetic Wave Theory.—(*Trans. Inst. Radio Engrs*, July 1956, Vol. AP-4, No. 3, pp. 190–586.) Report of a conference held at the University of Michigan in June 1955, giving the text of 45 papers and abstracts of 54 others, together with some discussion; an author index is included. The main material is grouped under the headings (*a*) boundary-value problems of diffraction and scattering theory, (*b*) forward and multiple scattering, (*c*) antenna theory and microwave optics, and (*d*) propagation in doubly-refracting media.

538.569.4 : 535.33 **416**

Recording Magnetic-Resonance Spectrometer.—M. W. P. Strandberg, M. Tinkham, I. H. Solt, Jr, & C. F. Davis, Jr. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 596–605.) "Apparatus especially designed for studying electron paramagnetic resonance is described and discussed. A magnet of novel yokeless design is presented. Field stabilization and modulation procedure is considered. The microwave sample cavity is analysed to determine conditions for optimum operation. The klystron stabilization problem is examined. Appropriate lumped circuits for low-frequency operation are described. The signal amplication and presentation system is treated in detail."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 **417**

Flux Measurements of Discrete Radio Sources at Frequencies below 30 Mc/s.—H. W. Wells. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 541–545.) Measurements on Taurus A, Virgo A, Cygnus A and Cassiopeia A are reported; the amplitude ratios between pairs of these sources have different values at 26·75 and 18·5 Mc/s.

523.16 **418**

The Measurement of the Distance of Radio Sources by Interstellar Neutral Hydrogen Absorption. — D. R. W. Williams & R. D. Davies. (*Phil. Mag.*, July 1956, Vol. 1, No. 7, pp. 622–636.) Three different methods are discussed for determining the distances from the absorption spectra. The technique has been applied to the intense sources in Cassiopeia, Cygnus, Taurus and Sagittarius; some results are presented.

523.16 **419**

The Low-Frequency Spectrum of the Cygnus (19N4A) and Cassiopeia (23N5A) Radio Sources.—R. J. Lamden & A. C. B. Lovell. (*Phil. Mag.*, Aug. 1956, Vol. 1, No. 8, pp. 725–737.) Intensity measurements have been made at frequencies of 16·5, 19·0, 22·6 and 30·0 Mc/s, using the 218-ft-aperture transit radio telescope at Jodrell Bank. The intensity of both sources falls abruptly at frequencies below 22 Mc/s; this is probably due to absorption in an interstellar H II region of average density and extent.

523.16 : 551.510.535 **420**

Low-Angle Fluctuations of the Radio Star Cassiopeia as Observed at Ithaca, N.Y., and their Relation to the Incidence of Sporadic E.—B. Dueño. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 535–540.) Observations over the period September 1954–August 1955 are reported. Correlation between the radio-star fluctuations and the occurrence of E_s was good during midwinter and poor afterwards. The E_s layer would be expected to exert its greatest influence over the incoming radiation from Cassiopeia during midwinter, since the radiation then pierces through the ionosphere at a height of 400 km, about 1 500 km north of Ithaca; at this point the normal sun-controlled forms of ionization would be at a minimum.

523.16 : 621.396.677 **421**

Radio Astronomy and the Jodrell Bank Telescope.—A. C. B. Lovell. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 711–721.) Text of the 47th Kelvin lecture. The 250-ft-aperture steerable radio telescope is to be used for studying both galactic and extragalactic sources of r.f. radiation over a wide frequency range. It will also be used as a combined transmitter and receiver for studies of the moon, and possibly of the planets. Very faint meteors and various solar/terrestrial relationships of particular importance to the International Geophysical Year will also be investigated. 57 references.

523.16 : 621.396.822 : 523.75 **422**

Absorption of Cosmic Radio Noise at 22·2 Mc/s Following Solar Flare of February 23rd 1956.—S. E. Forbush & B. F. Burke. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 573–575.) Absorption effects noted in records obtained at an observatory near Washington are briefly discussed.

523.5 : 621.396.96 **423**

Diurnal Variations in Forward-Scattered Meteor Signals.—C. O. Hines. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 229–232.)

523.75 : 551.510.535 : 621.396.11.029.45 **424**

V.L.F. Phase Shifts associated with the Disturbance of February 23rd 1956.—Pierce. (See 557.)

550.3 **425**

A Method for Drawing the Great-Circle Path between Any Two Points on Earth.—J. H. Meek. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 445–448.)

550.38 : 551.594.6 **426**

Arc Lengths along the Lines of Force of a Magnetic Dipole.—S. Chapman & M. Sugiura. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 485–488). Formulae and tables for the arc length along the lines of force of a magnetic dipole are given with reference to the earth treated as a sphere. These tables may prove useful in connection with the study of radio whistlers and of the motion of charged particles along the lines of geomagnetic force.

550.380.8 + 550.37 **427**

Constructional Details of the Inductive Magnetic-Pulsation and Earth-Current Measuring Equipment at the Geomagnetic Observatory at Fürstenfeldbruck [W. Germany].—K. Burkhart. (*Geofis. pura appl.*, Jan.–April 1956, Vol. 33, No. 1, pp. 78–85. In German.)

550.380.8 : 621.317.444 **428**

High-Altitude Measurements of the Earth's Magnetic Field with a Proton Precession Magnetometer.—Cahill & Van Allen. (See 526.)

550.385 **429**

Mean Results of Geomagnetic Observations in Tromsø, Norway, for the Years 1930–50.—J. Frøshaug. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 435–444.) Summarized tables of results are presented; graphs show short-term and long-term variations.

550.385 : 550.37 **430**

The Origin of Earth Currents and Their Probable Influence on the Earth's Magnetic Field.—K. Burkhart. (*Geofis. pura appl.*, Jan.–April 1956, Vol. 33, No. 1, pp. 49–77. In German.) For short distances between measuring points a definite relation between earth currents and magnetic variations is generally confirmed. To explain discrepancies over longer distances, not only the subsoil resistance within the area of measurement but the total earth current circuit must be considered. Anomalies in Japan and North Germany are analysed in relation to the gradient of conductivity normal to the induced e.m.f. Observations agree satisfactorily with theory based on inductively coupled circuits.

551.5 **431**

Pulsed Searchlighting the Atmosphere.—S. S. Friedland, J. Katzenstein & M. R. Zatzick. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 415–434.) An optical reflection technique which has been used to measure the density profile of the upper atmosphere up to a height of 40 km uses a 50-Mlm light pulse of duration 20 μs from a lamp at the focus of a 60-in. mirror, with a photomultiplier at the focus of a similar mirror. The results are in agreement with those obtained by previous investigators and by theoretical methods.

551.5 **432**

Circulation in the Upper Atmosphere.—P. S. Pant. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 459–474.) A study covering the height range 20–100 km over the northern hemisphere. Summer and winter temperatures computed from the wind field, using rocket mean-pressure data and assuming that the wind field is geostrophic, agree with direct observations. Possible causes of observed seasonal temperature changes are discussed. 48 references.

551.51 **433**

Gravitational and Thermal Oscillations in the Earth's Upper Atmosphere.—M. L. White. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 489–499.) Analysis given previously [1404 of 1956 (Sen & White)], for the case where heat is introduced only at the base of the atmosphere, is extended to apply to cases where heat is introduced at any region. Expressions obtained for the velocity components and pressure variation at any height are identical with the corresponding equations for the purely gravitational case, except for a new interpretation of the wave function. Expressions are also obtained for the vertical and horizontal displacements and for the amplification over equilibrium tide at any level. Results of the analysis are compared with those obtained by other workers.

551.510.535 **434**

The Ionization of the E layer.—H. Pichler. (*Geofis. pura appl.*, Jan.–April 1956, Vol. 33, No. 1, pp. 146–152. In German.) The effect of geograghical location, season and solar activity on the relation between the critical frequency f_0E and the position of the sun is discussed. Comparison with observations shows that formulae previously derived, e.g., by Harnischmacher (1682 of 1950), are inadequate, probably owing to oversimplification, and that more extensive investigations are needed to clarify the correlation.

551.510.535 **435**

The World-Wide Height Distribution of the F_2 Layer.—R. Eyfrig, E. Harnischmacher & K. Rawer. (*Geofis. pura appl.*, Jan.–April 1956, Vol. 33, No. 1, pp. 153–162. In German.) An analysis is made of (M3000) F_2 maps covering America from high north magnetic latitudes to the magnetic equator, for years of sunspot minimum and maximum respectively. Generally a daily minimum occurs on the magnetic equator and a maximum at a geographical latitude of 40° N, the latter being less pronounced in summer than in winter. A sunrise maximum occurs irrespective of latitude. Increased solar activity is correlated with decreased M values and accentuation of the equatorial minimum.

551.510.535 **436**

Physical Properties of the Atmosphere from 90 to 300 km.—H. K. Kallmann, W. B. White & H. E. Newell, Jr. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 513–524.) A model atmosphere based on recent experimental and theoretical studies has the following features: molecular oxygen begins to dissociate at a height of about 90 km; at about 130 km about 30% of O_2 is still in the undissociated state; molecular nitrogen begins to dissociate at about 220 km; the concentrations of O_2 and N_2 decrease exponentially with increasing height; the temperature ceases to vary with height at about 360 km. This model gives lower temperatures and densities throughout the ionosphere than have been deduced previously.

551.510.535 **437**

Daytime Measurement of Positive and Negative Ion Composition to 131 km by Rocket-Borne Spectrometer.—C. Y. Johnson & J. P. Heppner. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, p. 575.) Negative ions of mass numbers 46, 32, 29, 22 and 16 were detected, but no positive ions. For night-time measurements, see 1409 of 1956.

551.510.535 **438**

Neutral Gas Composition of the Upper Atmosphere by a Rocket-Borne Mass Spectrometer.—E. B. Meadows & J. W. Townsend, Jr. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 576–577.) Measurements at heights up to 141·6 km are reported. In addition to the usual constituents of air, components with mass numbers 46 and 23 were detected in the neighbourhood of 85 km. See also 437 above.

551.510.535 **439**

Resonance Scattering by Atmospheric Sodium: Part 2—Nightglow Theory.—J. W. Chamberlain & B. J. Negaard. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 169–178.) Continuation of previous discussion [3728 of 1956 (Chamberlain)]. Three models of the nightglow layer are considered in which the primary excitation is concentrated at the bottom of the layer, evenly distributed through the layer, or concentrated at the top of the layer.

551.510.535 **440**

Resonance Scattering by Atmospheric Sodium: Part 3—Supplementary Considerations.—D. M. Hunten. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 179–183.) For the excitation mechanism assumed, the best model of the sodium layer is that in which the excitation is concentrated at the bottom. Part 2: 439 above.

551.510.535 : 523.75 **441**

Ionospheric Changes associated with the Solar Event of 23 February 1956.—C. M. Minnis, G. H. Bazzard & H. C. Bevan. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 233–234.) A discussion based on observations at Singapore, Inverness and Slough. A magnetic crochet and intense ionospheric absorption were observed characteristic of an important solar flare. Effects associated with the incidence of high-speed and low-speed particles and wave radiation are distinguished.

551.510.535 : 523.78 **442**

The Response of the Ionosphere to the Solar Eclipse of 30 June 1954 in Great Britain.—C. M. Minnis. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 201–209.) "Vertical-incidence measurements of virtual height and critical frequency were made at two points at which the maximum obscuration of the disk area was 93% and 74% respectively. The change with time in the intensity of the ionizing radiation during the eclipse was computed from the observed variation in f_0F_1; from this change a model has been constructed giving the brightness distribution of the ionizing radiation over the sun's disk. 92% of the radiation was emitted from a uniformly bright disk on which were superposed, near the E and W limbs, small areas having about twice the brightness of the disk and, near the poles, similar areas having about half this brightness. Accurate measurements of the shape and height of the F_2 layer are difficult owing to the proximity of f_0F_1 and f_0F_2, but an approximate analysis shows that no major changes in the height or thickness of the F_2 layer accompanied the considerable fall in f_0F_2 during the eclipse. It has not been possible to make any reliable estimates of α'_E or α'_{F1}."

551.510.535 : 621.396.11 **443**

The Calculation of the True Heights of Reflection of Radio Waves in the Ionosphere.—W. J. G. Beynon & J. O. Thomas. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 184–200.) The calculation of the true height from the variation of the virtual height of reflection with frequency is discussed for parabolic distributions of electron density. Existing theory is extended to include the case of reflections from contiguous parabolic sections or truncated parabolae, and an expression is derived for the variation of virtual height with frequency in terms of the layer parameters. Methods are indicated for calculating the true critical frequency of a truncated layer in terms of the observed cusp frequency and for deriving the layer parameters.

551.594.21 **444**

A Theory of Thundercloud Electricity.—C. T. R. Wilson. (*Proc. roy. Soc. A.*, 2nd Aug. 1956, Vol. 236, No. 1206, pp. 297–317.) Theory is developed in which the thundercloud is regarded as an influence machine, the ionization currents associated with it being the agents by which its e.m.f. is generated and maintained.

551.594.6 : 621.396.822 **445**

An Investigation of Atmospheric Radio Noise at Very Low Frequencies.—F. Horner & J. Harwood. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 743–751.) Investigating technique is described and typical results obtained in southern England are discussed. The noise in a band of width 300 c/s over the frequency range 10–35 kc/s is found to be intermediate in nature between fluctuation noise and discrete pulses, the ratio of the r.m.s. value of the envelope to the average value being about 5, compared with 1·1 for fluctuation noise. A detailed analysis of the noise is made in terms of the amplitude distribution of the peaks in the envelope and the amplitude probability distribution of the envelope itself. These distributions can be interrelated at the higher voltage levels, where the pulses have consistent shape determined by the receiver characteristics. The stronger pulses are randomly distributed in time while the weaker ones tend to occur in groups.

551.594.6 : 621.396.9 **446**

The Location of Thunderstorms by a Single-Station High-Frequency Ranging Technique.—C. Clarke & B. J. Byrne. (*J. atmos. terr. Phys.*, Oct. 1956, Vol. 9, No. 4, pp. 210–228.) Continuation of work reported by Horner (1065 of 1954); the influence of ionospheric conditions on the observations is investigated in greater detail. Outside the sunset and sunrise periods, the E- and F_1-layer conditions can be calculated sufficiently accurately from the zenithal angle of the sun; the F_2-layer conditions are derived from the predicted critical frequencies and m.u.f. factors. Range measurement appears to be impossible when propagation is controlled by the E_s layer. Observations made during the summer of 1954 are compared with thunderstorm positions given by a direction-finder network. The results indicate that the single-station technique can be expected to be satisfactory for locating thunderstorms at a distance of 500–2 000 km for about 70% of the time.

551.594.5 **447**

The Polar Aurora. [Book Review]—C. Størmer. Publishers: Clarendon Press, Oxford, and University Press, London, 1955, 403 pp., 55s. (*Nature, Lond.*, 6th Oct. 1956, Vol. 178, No. 4536, p. 713.) An authoritative study in the series of International Monographs on Radio. Chapters are included on auroral r.f. radiation and on radio echoes from aurora.

LOCATION AND AIDS TO NAVIGATION

621.396.93 : 621.396.674.3 **448**

The Use of a Horizontal Dipole as a Direction-Finding Aerial.—Millington. (See 345.)

621.396.93 : 621.396.677 **449**

Possible Errors of a Particular Wide-Aperture Direction Finder.—W. C. Bain. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 313–324.) "A study is made of the extent to which the high-frequency cyclical direction-finder devised by Earp & Godfrey [1059 of 1949] is subject to three common types of error. First, the result is presented of theoretical computations on the errors given by a practical fixed-aerial system in wave-interference conditions. The variance of these errors as the phase difference between the incident rays is varied is shown to be the same as that given by the ideal rotating-aerial version of this direction-finder; it is appreciably smaller than that of an Adcock for a system aperture of 4 λ, and, in general, much smaller for an aperture of 10 λ. Secondly, errors due to aerial interaction are considered for a system of 24 unipoles, 9 m high and 1·1 m in diameter, placed on a circle of 100 m diameter. It is concluded that the errors in indicated bearing are likely to be negligible, provided that the aerials not in use at any instant are terminated by a resistor equal to their nominal characteristic impedance. Finally, the polarization error is examined for such a system in which surface feeders are used, without an earth mat, on ground of moderate conductivity; it is found to be small, being greatest at the low-frequency end of the band, where the standard-wave error is about 1° at 3 Mc/s. With extended feeders the errors at low frequencies are reduced considerably."

621.396.93 : 621.396.677.6 **450**

H.F. Bearing Variations on an Adcock Direction Finder. — E. N. Bramley. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 350–356.) "Measurements on a number of transmitters at ranges from 1 000 to 5 000 km show that the variance of snap bearings within a period of half an hour is of the order of 10 deg^2. To reduce this variance by a factor of ten, time averaging over about 5 min is required when the bearings are taken at 10-sec intervals. Bearing changes from hour to hour and from day to day have a variance of about 1 deg^2 and thus set a limit to the error reduction obtainable by averaging over a half-hour period. The results are consistent with previously published estimates of bearing variances."

621.396.93 : 621.396.677.6 **451**

The Calibration of a 6-Mast Adcock Array.—K. Baur. (*Nachrichtentech. Z.*, July 1956, Vol. 9, No. 7, pp. 299–305.) A raised test transmitter in the vicinity of the array provides a beam of the desired oblique incidence but also causes a complex bearing error due to beam divergence. The real part of this error consists of the natural system error for plane-polarized waves, modified by a divergence error, and the imaginary part determines the blurring effect. A minimum divergence error, irrespective of ground conditions, is obtained for an angle of elevation of 40° and the error may be neglected where the transmitter distance exceeds 15*a*, where *a* is the distance between opposite masts.

621.396.96 **452**

Marine Radar Developments.—(*Wireless World*, Dec. 1956, Vol. 62, No. 12, pp. 585–586.) Two new developments in British commercial equipment are described. The 'true-motion' display is obtained by deriving a voltage which is used to shift the origin of the p.p.i. display in accordance with the ship's motion. The other development is the use of a slotted-waveguide aerial and printed circuits in a compact, reliable, low-cost equipment.

621.396.963.3 **453**

Radar Simulator for Laboratory Use.—H. J. Bickel & R. I. Bernstein. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 170–173.)

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 : 621.316.825 **454**

Investigation of the Use of Thermistors for the Measurement of Low Pressures.—M. Varicak. (*C. R. Acad. Sci.*, Paris, 24th Sept. 1956, Vol. 243, No. 13, pp. 893–895.) Theory indicates that the sensitivity of thermistor vacuum gauges is increased by making the wall temperature low and the thermistor surface area large. Observations of the time variation of the voltage across bead thermistors passing a current of 1 mA following a sudden change of pressure from 10^{-5} to 10^{-3} mm Hg at wall temperatures of 203° and 293°K confirm the theory. The time taken to attain thermal equilibrium is 5 min. On increasing the heat-dissipating surface by placing a piece of tinfoil in contact with the thermistor both the response time and the sensitivity are greatly improved. Pressures down to $10r^{-6}$ mm Hg can be measured.

535.37 : 539.154 **455**

The Effect of Nuclear Radiation on the Optical Properties of Inorganic Phosphors.—F. Bandow. (*Optik, Stuttgart*, 1956, Vol. 13, No. 6, pp. 259–263.) Effects produced by α rays are summarized.

535.37 : [546.472.21+546.47-31 **456**

Connection between the Catalytic Properties and the Luminescence of Zinc Oxide and Zinc Sulphide.—L. N. Shekhter, I. A. Myasnikov & S. Ya Pshezhetski. (*C. R. Acad. Sci. U.R.S.S.*, 21st Aug. 1956, Vol. 109, No. 6, pp. 1163–1166. In Russian.)

535.37 : 546.472.21 **457**

Electron Traps at Very Low Energy Levels in ZnS.—N. Riehl & H. Ortmann. (*Z. Naturf.*, Nov. 1955, Vol. 10a, No. 11, pp. 896–897.) Observations made at temperatures below that of liquid air are briefly reported. A very sharp peak in the glow curve is exhibited between 63° and 93°K.

537.226/.227 **458**

Ferroelectricity in the Langbeinite System.—F. Jona & R. Pepinsky. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, p. 1126.) Preliminary note on an investigation of $(NH_4)_2Cd_2(SO_4)_3$ crystals.

537.226/.227 **459**

Nonlinear Properties of Ferroelectrics at High Field Strengths.—A. L. Khodakov. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 51–60.) The dependence on field strength of the permittivity and the loss tangent of solid solutions involving $BaTiO_3$ was investigated experimentally. The strong effect of the firing conditions of the ceramic on its nonlinear properties was established; these properties appear at temperatures above the Curie point. Curves of the a.c. permittivity are plotted, as are also curves of the variation of the differential permittivity during one period, obtained by oscillograph. The maxima of the latter curves at saturation are almost independent of the value of the applied constant field, and occur at a definite instantaneous value of the alternating field.

537.226/.227 : 546.431.824-31 **460**

Dielectric Properties of Certain Solid Solutions containing Barium Titanate.—N. S. Novosil'tsev & A. L. Khodakov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 310-322.) A detailed report is presented, with numerous curves and tables, on an experimental investigation of the temperature variation of the permittivity, losses and conductivity of various solid solutions. The temperature range within which the tetragonal phase exists can be extended or reduced by the suitable choice of constituents.

537.226/.227 : 546.431.824-31 **461**

Effect of Pile Irradiation on the Dielectric Constant of Ceramic $BaTiO_3$.—F. T. Rogers, Jr. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1066–1067.) A peak in the dielectric-constant/temperature curve, usually associated with ferroelectricity, was greatly attenuated after irradiation and the dielectric constant assumed a much reduced value, nearly constant over the range 30°–140°C.

537.226/.227 : 547.476.3 **462**

On the Domain Structure of Rochelle Salt Crystal.—T. Nakamura. (*J. phys. Soc. Japan*, June 1956, Vol. 11, No. 6, pp. 624–632.) Slow crystallization at temperatures between two Curie points gave domains parallel to the *b*-axis; crystallization at temperatures above the upper Curie point gave domains parallel to the *c*-axis. Domain width remains unchanged with rising temperature until the pattern disappears at 24·25°C $\pm$0·2°. Domain formation appears to be governed by elastic rather than by electrostatic factors.

537.226/.228 : 546.431.824-31 **463**

The Preparation of Barium Titanate as a Ceramic Transducer Material.—A. L. Gray & J. M. Herbert. (*Acustica*, 1956, Vol. 6, No. 2, pp. 229–234.) "Modified barium titanate ceramics can be prepared with reduced temperature coefficients at room temperature. Values of coercive field and dielectric loss which permit the operation of transducers up to the onset of cavitation in liquids can be obtained. The mechanical and electrical properties of the modified ceramics change significantly with time but the drift can be minimized. Transducers of suitable shapes can be made by a variety of methods."

537.226/.228 : 546.431.824.831-31 **464**

Structural Transitions in Barium Titanate-Zirconate Transducer Materials.—R. C. Kell & N. J. Hellicar. (*Acustica*, 1956, Vol. 6, No. 2, pp. 235–238.) The properties of ceramic materials having compositions with Ti : Zr ratios between 100 : 0 and 70 : 30 are described. A material with a Ti : Zr ratio of 95 : 5 is most suitable for transducers ; this has an orthorhombic phase which is stable between 5° and 50° C, and the change in resonance frequency over this range is only 4%.

537.226/.228.2 **465**

Determination of the Electrostriction Constant Q_{11} of Barium Titanate Ceramic.—G. Schmidt. (*Z. Phys.*, 15th June 1956, Vol. 145, No. 4, pp. 534–542.) The constant was determined from measurements of the thickness variations and polarization of disks oscillating at low frequency, at temperatures between 20° and 150° C. Its value is about $0 \cdot 6 \times 10^{-12}$ c.g.s. units within the Curie region, and somewhat more at higher temperatures ; there is a pronounced minimum at the Curie point.

537.226/.228.1 **466**

The Effect of Impurities on the Permittivity and Piezoelectric Modulus of Rochelle Salt.—T. Kh. Chormonov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 323–326.) Rochelle-salt crystals were grown with impurities (aluminium alums, copper sulphate, and rubidium, lithium and strontium chlorides). Curves show the effects on the electrical properties.

537.311.31 : 538.221 **467**

Electrical Resistance of Ferromagnetic Metals.—T. Kasuya. (*Progr. theor. Phys.*, July 1956, Vol. 16, No. 1, pp. 58–63.) Theoretical and experimental results indicate that the anomalous resistivity associated with the ferromagnetic properties can be explained by the dependence of the exchange energy between the conduction electrons and those of the unfilled inner shell on the relative direction of the electron spins.

537.311.33 **468**

Intrinsic Electronic Conduction in Semiconductors.—K. W. Böer. (*Z. Naturf.*, Nov. 1955, Vol. 10a, No. 11, pp. 898–899.) Under conditions of true intrinsic conduction, the current-carrier concentration and mobility can be calculated from the measured conductivity. Results which have been obtained in this way for various semiconductors are smaller by some orders of magnitude than values obtained by Hall-effect and other measurements. A family of conductivity/temperature curves for CdS shows the existence of limit curves for high and low rates of heating. Considering the observations on the basis of lattice imperfections, it is concluded that only for very rapid heating will the measured conductivity agree with the values calculated purely from analysis of the electron system ; the type of conduction occurring is not in fact intrinsic but may be termed 'intrinsic impurity'.

537.311.33 **469**

Thermomagnetic and Galvanomagnetic Effects in Semiconductors taking Account of the Variation of the Carrier Concentration.—G. E. Pikus. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 22–35 & 36–50.) A mathematical discussion is presented in two parts. In the first part, the effects in semiconductors with current carriers of both types are considered for small variations of the concentration of electron-hole pairs i.e. in weak fields. The second part deals with the case of strong fields, when the concentration of the carrier pairs differs considerably from the equilibrium value. The effect of the concentration variations on the electron and exciton thermal conductivities is also discussed.

537.311.33 **470**

The Recombination of Electrons and Holes in the Presence of Traps of Various Types.—S. G. Kalashnikov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 241–250.) The stationary case, with a low concentration of nonequilibrium carriers, is considered. The degree of filling of traps of any type depends on the presence of other types, hence the probabilities of recombination caused by traps of various types are not in general additive. The case is considered where the concentration of centres of one type is high. Under certain conditions, the existence of such centres may greatly affect the lifetime of non-equilibrium carriers, although the centres themselves may not affect the recombination or the conductivity of the semiconductor.

537.311.33 **471**

The Effect of a Strong Field in Semiconductors.—Yu. K. Pozhela. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 277–280.) It was established by A. V. & A. F. Ioffe (*Zh. eksp. teor. Fiz.*, 1939, Vol. 9, No. 12, pp. 1428–1458) that if the field applied to a semiconductor exceeds a critical value, a sharp increase in the current is observed. This can only be explained by an increase in the number of current carriers. Various possible explanatory mechanisms are discussed ; the additional carriers may be produced by a transfer of electrons from the valence band to the conduction band. Observations of the drift of the additional carriers confirming the theory are reported in a separate paper (*ibid.*, pp. 281–283).

537.311.33 **472**

The Emission Capacity of an Abrupt *p-n* Junction and its Effect on the Conductivity of a Semiconductor.—K. B. Tolpygo. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 293–309.) An approximate solution is obtained of equations describing the forward flow of current at a semiconductor-junction barrier layer. It is assumed that both acceptor and donor levels are almost completely ionized and that the width of the region of variable impurity concentration is smaller than or of the order of the screening length. Estimates are made of (*a*) current distribution and concentrations of electrons and holes as functions of the total current and the properties of the junction, and (*b*) conditions necessary for the current to be carried by minority carriers.

537.311.33 : 537.312.8 **473**

D.C. Magnetoconductivity and Energy-Band Structure in Semiconductors.—R. M. Broudy & J. D. Venables. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 1129–1130.) An experimental method suitable for the direct evaluation of the components of the magnetoconductivity tensor is described.

537.311.33 : 546.23 **474**

The Electrical Conductivity of Hexagonal Selenium.—R. A. Hyman. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 743–747.) It is suggested that the crystal is formed on continuous chains of atoms which zig-zag so as to fill a volume large compared with the lattice spacing ; it is assumed that charge carriers (holes) move freely along these chains, but transitions between chains are difficult. The calculated dependence of conductivity on frequency and the rise of mobility with temperature are in agreement with actual values, but the magnitude of the resistivity is not yet explained. Bending of single crystals is also discussed briefly in a separate paper (*ibid.*, pp. 771–772).

537.311.33 : 546.24 : 538.63 **475**

Galvanomagnetic Properties and Hole Conductivity of Tellurium.—S. S. Shalyt. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1956, Vol. 109, No. 4, pp. 750–752. In Russian.) An experimental investigation at temperatures of 77·4°, 4·2°, and 1·3°K is reported ; results, which are presented graphically, indicate the presence of two groups of holes with different mobilities.

537.311.33 : 546.26-1 **476**

Cyclotron Resonance Effects in Graphite.—J. K. Galt, W. A. Yager & H. W. Dail, Jr. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1586–1587.) Report of effects observed in crystalline flakes of graphite at 77°, 4·2°, 1·3° and 1·1°K, at a frequency of 24 kMc/s. A tentative interpretation of the observations is given.

537.311.33 : [546.28+546.289 **477**

Theory of Cyclotron Resonance Absorption in Many-Valley Semiconductors.—L. Gold, W. M. Bullis & R. A. Campbell. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1250–1252.) Theory is presented which allows for energy dependence of scattering time in Ge and Si.

537.311.33 : 546.28 **478**

Application of the Orthogonalized-Plane-Wave Method to Silicon Crystal.—T. O. Woodruff. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1159–1166.)

537.311.33 : 546.28 **479**

Line Broadening of an Impurity Spectrum in Silicon.—D. Sampson & H. Margenau. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 879–885.) A simplification of the method of calculation presented by Lax & Burstein (1086 of 1956).

537.311.33 : 546.28 **480**

Nuclear Magnetic Resonance of Si^{29} in *n*- and *p*-Type Silicon.—R. G. Shulman & B. J. Wyluda. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 1127–1129.)

537.311.33 : 546.281.26 **481**

The Effect of Impurities on the Electrical Conductivity and Nonlinearity of Silicon Carbides.—L. I. Ivanov & V. I. Pruzhinina-Granovskaya. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 220–231.) A method is described for determining the nonlinearity and resistance of powder semiconductors, and the dependence of these two parameters on the granular composition of the powders and on the pressure is discussed. Experiments have shown that impurities greatly affect the properties of silicon carbides.

537.311.33 : 546.289 **482**

Visual Evidence of Inversion Layers on Semiconductor Materials.—P. Levesque. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1104–1105.) Observations on etched Ge specimens, made by a technique involving deposition of a $BaTiO_3$ layer, are briefly reported.

537.311.33 : 546.289 **483**

An Investigation of the Resistance Variation of Germanium in a Magnetic Field.—V. I. Stafeev & V. M. Tuckkevich. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 273–276.) The experimental curves for $\Delta\rho/\rho_0$ versus magnetic field for different temperatures show that the variation is nonlinear both for strong and weak fields, the power indices depending on temperature. At relatively low temperatures, of the order of 170° K, $\Delta\rho/\rho_0$ varies more slowly than the square of the mobility. These findings are at variance with existing theory. For all *p*-type specimens the temperature variation curve exhibits a maximum, as predicted by theory.

537.311.33 : 546.289 **484**

The Diffusion of Impurities in Germanium.—B. I. Boltaks. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 457–474.) A comprehensive review of the experimental data, divided into the following sections: (*a*) methods for measuring the diffusion coefficients in semiconductors; (*b*) diffusion and electrical activity of impurities in Ge; (*c*) temperature dependence of the diffusion coefficients of impurities in Ge, and (*d*) diffusion and solubility of impurities in Ge. A close connection between the diffusion and solubility of impurities and the electrical properties of Ge is indicated. The diffusion and solubility exhibit a number of important peculiarities which do not exist in metals and alloys. 48 references.

537.311.33 : 546.289 **485**

Field-Induced Conductivity Changes in Ge.—H. C. Montgomery & W. L. Brown. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 865–870.) Measurements were made on filament specimens with fields of strength up to 10^5 V/cm normal to the surface. From observations of the minimum in the conductance curve, information can be derived on surface states as a function of surface potential. Data obtained using various gaseous ambients are compared with the contact-potential observations of Brattain & Bardeen (1698 of 1953). Measurements at temperatures down to 170° K give information about properties of 'fast' surface states. Phase-shift loops observed at frequencies around 1 kc/s are interpreted in terms of minority-carrier lifetime.

537.311.33 : 546.289 **486**

Acceptors Quenched into Germanium.—S. Mayburg. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 1130–1131.) Discrepancies between results obtained previously by the author (148 of 1955) and other workers [1765 of 1956 (Hopkins & Clarke) and 2793 of 1956 (Logan)] are explained by taking note of dislocation effects.

537.311.33 : 546.289 **487**

Use of Infrared Absorption in Germanium to determine Carrier Distributions for Injection and Extraction.—N. J. Harrick. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1173–1181.) Continuing the work reported previously (2109 of 1956), measurements of infrared absorption have been used to determine longitudinal distributions of free carriers for the cases of field-opposed and field-aided injection and extraction.

537.311.33 : 546.289 **488**

Elastogalvanomagnetic Effect and Intervalley Scattering in *n*-Type Germanium.—R. W. Keyes. (*Phys. Rev.*, 1st Sept. 1956, Vol. 103, No. 5, pp. 1240–1245.) "Starting from a multivalley model of a cubic semiconductor, a calculation of the effect of elastic strain on certain galvanomagnetic effects is carried out. It is found that the effects are sensitive to the strength of the intervalley scattering. An experiment on Ge to which the calculation is applicable is described. It is concluded from a comparison of the theory and the experiment that the coupling constant which characterizes the coupling of the electrons to the intervalley phonons in the model of Herring [2642 of 1955] is considerably smaller than the coupling constant to the acoustic phonons."

537.311.33 : 546.289 **489**

Carrier Accumulation in Germanium.—J. B. Arthur, A. F. Gibson & J. B. Gunn. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 697–704.) An account is given of experiments on junctions between lightly and heavily doped regions of crystals of the same conductivity type; these are designated L-H junctions. They can be made largely impermeable to minority carriers but permeable to majority carriers, and high concentrations of minority carriers can be accumulated at such junctions.

537.311.33 : 546.289 **490**

Current Gain at L-H Junctions in Germanium.—J. B. Arthur, A. F. Gibson & J. B. Gunn. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 705–711.) The relatively low permeability to minority carriers of junctions between lightly and heavily doped crystals of the same type (see 489 above) can be considered as a reduction of the minority-carrier mobility, and gives rise to enhanced current gain in certain structures, for example filamentary transistors. Experiments confirming the existence of the effect and indicating its magnitude are described.

537.311.33 : 546.289 : 535.215 : 538.639 **491**

The Transverse Photomagnetic Effect in *n*- and *p*-Type Germanium.—I. K. Kikoin & Yu. A. Bykovski. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1956, Vol. 109, No. 4, pp. 735–736. In Russian.) The effect investigated is the following: if a semiconductor in a magnetic field H, with components H_x and H_y in the x and y directions, is illuminated by light in the direction of the y axis, then in addition to the e.m.f. proportional to H along the z axis an e.m.f. is produced in the x direction proportional to H_xH_y. The e.m.f. E is plotted against H for *p*-type Ge at temperatures of +20°, −20°, and −100°C, and against temperature for *p*- and *n*-type Ge at $H = 20\,000$ oersted.

537.311.33 : 546.482.21 **492**

Redistribution of the Electron Density in Cadmium Sulphide Crystals associated with Changes in its Electrical Conductivity.—Yu. N. Shuvalov. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1956, Vol. 109, No. 4, pp. 753–756. In Russian.) Results of an X-ray investigation of hexagonal crystals are reported.

537.311.33 : 546.682.19 **493**

The Electrical Properties of InAs.—D. N. Nasledov & A. Yu. Khalilov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 251–254.) An investigation was made over the temperature range 1·3°–673°K and in magnetic fields up to 33 000 oersted. The main results are as follows: (*a*) conductivity is practically independent of temperature from 1·3°K to room temperature; above this temperature it rapidly increases; (*b*) the concentration of carriers at room temperature is about $10^{17}/cm^3$; (*c*) in a magnetic field of 20 000 oersted, resistance increases fourfold at 400°C; (*d*) mobility increases greatly at high temperatures and reaches 120 000 cm/s per V/cm.

537.311.33 : 546.682.86 **494**

Electrical Properties of InSb.—D. N. Nasledov & A. Yu. Khalilov. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 6–14.) Specimens with *n*- and *p*-type conductivity were investigated over a range of temperatures from 1·3° to 673°K. Curves show the variation of conductivity with temperature and the effect of a magnetic field of strength 20 000 oersted. The Hall effect was also investigated for various compositions, using magnetic field intensities up to 33 000 oersted. A theoretical interpretation of the results is given.

537.311.33 : 546.682.86 **495**

Indirect Transitions in Indium Antimonide.—R. F. Potter. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 861–862.)

"An interpretation of published infrared absorption data for InSb is made. It is proposed that the absorption beyond the main optical edge is due to indirect transitions involving both optical mode and low-energy acoustical mode phonons."

537.311.33 : 546.817.221 **496**

Calculation of the Cohesive Energy of Zincblende.—S. Asano & Y. Tomishima. (*J. phys. Soc. Japan*, June 1956, Vol. 11, No. 6, pp. 644–653.)

537.311.33 : 546.817.221 : 539.234 **497**

Surface Structure of Thin Layer of PbS obtained by Evaporation in Vacuum.—R. Ya. Berlaga, M. I. Rudenok & L. P. Strakhov. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 3–5.)

537.311.33 : 621.396.822 **498**

Shot Noise in Semiconductors.—L. Ya. Pervova. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 98–105.) An expression is derived for the spectral density of shot noise in an arbitrary length of semiconductor taking into account the true lifetimes, τ, of electrons in the conduction zone (instead of the average lifetime) and the length L of the semiconductor. For $\lambda \ll L$, where λ is the free path of the electron, the noise spectral density is proportional to $1/\omega$ in the range $\omega\tau \approx 1$ to $\omega\tau \approx 10^3$; for $\omega\tau < 1$, the noise intensity is independent of frequency, for $\omega\tau > 10^3$ the noise varies as $1/\omega^2$. For $\lambda > L$ the spectral density remains nearly constant up to $\omega\tau \approx \lambda/L$, and is proportional to $1/\omega^2$ for $\omega\tau > \lambda/L$.

538.22 **499**

The Magnetic Properties of $FeSe_x$ with NiAs Structure.—T. Hirone & S. Chiba. (*J. phys. Soc. Japan*, June 1956, Vol. 11, No. 6, pp. 666–670.) In the range 48·8%–53·1% Se, at room temperature, the compound is made up of two phases, α and β; the α phase has PbO structure and is weakly paramagnetic or antiferromagnetic, while the β phase has NiAs structure and is ferrimagnetic.

538.221 **500**

A Symposium on Magnetism—London, September 1955.—A. C. Lynch & J. Watkins. (*Brit. J. appl. Phys.*, July 1956, Vol. 7, No. 7, pp. 236–242.) Summaries are presented of papers and discussion on theoretical studies and applications, particularly of ferrites, and including the use of neutron diffraction techniques.

538.221 **501**

Curvature of the Bloch Wall as an Elementary Process in Reversible Variations of Magnetization (Initial Permeability and ΔE-Effect).—M. Kersten. (*Z. angew. Phys.*, July 1956, Vol. 8, No. 7, pp. 313–322.) The observed temperature variations of initial permeability and ΔE-effect can be explained if cylindrical rather than cushion-type or spherical walls are assumed.

538.221 **502**

The Magnetic Properties of Chromium-Tellurium-Selenium System.—I. Tsubokawa. (*J. phys. Soc., Japan*, June 1956, Vol. 11, No. 6, pp. 662–665.) Properties of compounds having the formula $Cr(Te_{1-x}\,Se_x)$ are discussed. They are ferromagnetic in the range $0 < x < 0{\cdot}8$; outside this range they are paramagnetic or antiferromagnetic.

538.221 **503**

Effect of Magnetic Field Strength during Condensation on the Coercivity and Form of Vapour-Deposited Iron.—A. J. Griest, J. F. Libsch & G. P. Conard. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1022–1024.) The size, shape and coercivity of Fe particles deposited from vapour on to a Cu surface were all influenced by the temperature of condensation and the strength of the applied magnetic field. The coercivity increased with the field strength, but the amount of the increase decreased as the condensation temperature was raised. The observed coercivity values of 30–120 oersted were related to strain in the deposited material.

538.221 : 621.318.122 **504**

Magnetic After-Effect in Ni_3Mn Alloy.—T. Taoka. (*J. phys. Soc. Japan*, May 1956, Vol. 11, No. 5, pp. 537–547.) Continuation of work described previously [2042 of 1955 (Taoka & Ohtsuka)]. Experimental results are reported in detail. An electron-microscope study confirms that alloys showing marked after-effect consist of numerous single-domain particles of prolate ellipsoidal form embedded in a matrix.

538.221 : 621.318.122 **505**

Study of Magnetic Annealing on Ni_3Fe Single Crystal.—S. Chikazumi. (*J. phys. Soc. Japan*, May 1956, Vol. 11, No. 5, pp. 551–558.)

538.221 : 621.318.124 **506**

Investigations on Barium Ferrite Magnets.—K. J. Sixtus, K. J. Kronenberg & R. K. Tenzer. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1051–1057.) Report of an experimental investigation of the relation between sintering temperature, particle size and coercive force in BaO : $6Fe_2O_3$. With particles of linear dimensions $> 10^{-3}$ cm, domain-wall movements are observed on application of a magnetic field; for dimensions $< 5 \times 10^{-4}$ cm the observations indicate reversals of magnetization by the rotation process. With particles of intermediate size, both processes occur.

538.221 : 621.318.13 **507**

Some Properties of the Coercive Force in Soft Magnetic Materials.—D. S. Rodbell & C. P. Bean. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 886–895.) A discussion in terms of domain-wall movements indicates that the coercive force is composed of two terms, one characteristic of the bulk material and the other arising from the pinning of domain walls at the surfaces. The observed increase in coercive force with decrease in thickness of sheet specimens is thus explained. See also 1126 of 1956.

538.221 : 621.318.13.014.4 **508**

The Eddy-Current Anomaly in Electrical Sheet Steel.—H. Aspden. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 272–278.) "A theory which accounts for the well-known discrepancy between predicted eddy-current losses in electrical sheet steels and the experimentally observed values is presented. The anomaly is shown to be due partly to the magnetic inhomogeneity arising from ferromagnetic domain structure and partly to a time-lag effect caused by the finite speed of domain boundary movements. A new experimental approach to the study of the eddy-current anomaly is described. This involves the use of a method of measuring the anomaly factor as it applies instantaneously at a point in a magnetization cycle."

538.221 : 621.318.13.014.4 **509**

Magnetic Time-Lag Effects in Solid Steel Cores.—H. Aspden. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 279–285.) The discrepancy between theoretical and actual eddy-current effects in thick steel cores is found to be attributable to time-lag in the magnetization process, the magnitude of which decreases with increasing frequency, its value being about 10^{-5} s at 10 kc/s.

538.221 : 621.318.134 **510**

Cation Distributions in Ferrospinels. Theoretical.—H. B. Callen, S. E. Harrison & C. J. Kriessman. (*Phys. Rev.*, 15th Aug. 1956, Vol. 103, No. 4, pp. 851–856.) The thermodynamic relation between the ion distribution and the nonthermal part of the internal energy function is developed. The results are used in a separate paper [*ibid.*, pp. 857–860 (Kriessman & Harrison)] to interpret observations on Mg-Mn ferrites.

538.221 : 621.318.134 **511**

On the Uniaxial Anisotropy Induced by Magnetic Annealing in Ferrites.—S. Taniguchi & M. Yamamoto. (*J. phys. Soc. Japan*, May 1956, Vol. 11, No. 5, pp. 604–605.)

538.221 : 621.318.134 : 621.372.8 **512**

Relations between the Structures of Ferrites and Conditions for their Resonance in Waveguides. Unidirectional Guides.—J. Suchet. (*Onde élect.*, June 1956, Vol. 36, No. 351, pp. 508–519.) An examination is made of the influence on the behaviour of ferrites of their composition and method of preparation, and the unidirectional propagation characteristics of waveguides enclosing Ni-Zn and Ni-Al ferrites are calculated.

548.0 **513**

Observations of Dislocation Glide and Climb in Lithium Fluoride Crystals.—J. J. Gilman & W. G. Johnston. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1018–1022.)

621.315.61+621.318.1+621.315.3 **514**

Materials for Electronics.—J. Markus & D. A. Findlay. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 185–216.) A survey of U.S. products, including insulating and magnetic materials, wires and solders.

621.315.612.6 **515**

Thermal Expansion of Binary Alkali Silicate Glasses.—H. F. Shermer. (*J. Res. nat. Bur. Stand.*, Aug. 1956, Vol. 57, No. 2, pp. 97–101.)

621.315.616 : [537.531.9+539.166.9 **516**

Radiation - Induced Conductivity in Polyethylene and Teflon.—R. A. Meyer, F. L. Bouquet & R. S. Alger. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1012–1018.) Conductivity changes induced by bombardment with X rays and gamma rays have been studied as a function of time, temperature, specimen geometry, exposure rate, and applied electric field. Observed photocurrents were directly proportional to exposure rate and field. The conductivity increased by a factor of about 10^3 during irradiation and the photocurrent was nearly independent of temperature over the range 78°–273°K.

MATHEMATICS

517 **517**

Incomplete Bessel and Struve Functions.—W. H. Steel & J. Y. Ward. (*Proc. Camb. phil. Soc.*, July 1956, Vol. 52, Part 3, pp. 431–441.) "Some properties are given of the incomplete Bessel and Struve functions defined by a Poisson-type integral. These functions are tabulated for the orders 0 and 1."

517 : 518.2 **518**

Laguerre Functions : Tables and Properties.—J. W. Head & W. P. Wilson (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 428–440.) "The first 21 Laguerre functions have been tabulated to four decimal places (or two significant figures when this is more accurate) for values of the argument 0(0·1)1(0·2)3(0·5)6(1) 14(2)40(5)100. The practical applications of these functions are briefly considered. The zeros of these Laguerre functions are also tabulated to 5 places, the last of which is not reliable except in the case of the smallest zero for orders above 6. Differentiation and integration of Laguerre functions, orthonormal properties and addition formulae are briefly discussed. Finite or infinite series of Laguerre functions whose sums are well-known functions such as products of polynomials and circular or exponential functions, step and delta functions, Bessel and Kelvin functions, and gamma and error functions are stated."

512.9 **519**

Champs de Vecteurs et de Tenseurs. [Book Review]—E. Bauer. Publishers: Masson, Paris, 204 pp., 2200 fr. (*Phil. Mag.*, July 1956, Vol. 1, No. 7, p. 691.) A straightforward account of vectors, tensors and electromagnetism, in a form ready for application to engineering problems.

517 **520**

Numerical Analysis. [Book Review]—Z. Kopal. Publishers: Chapman and Hall, London, 1955, 556 pp., 63s. (*Brit. J. appl. Phys.*, July 1956, Vol. 7, No. 7, pp. 269–270.) A comprehensive handbook; emphasis is on the application of numerical techniques to problems of infinitesimal calculus in a single variable.

MEASUREMENTS AND TEST GEAR

621.314.7.001.4 (083.74) **521**

I.R.E. Standards on Solid-State Devices : Methods of Testing Transistors, 1956. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1542–1561.) Standard 56 I.R.E. 28. S2.

621.317.3.029.6 : 621.372.5 **522**

Microwave Measurements with a Lossy Variable Termination.—H. M. Altschuler & A. A. Oliner. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 392–399.) The problem is treated by considering the lossy termination as the combination of a purely lossy quadripole ('reflection-coefficient transformer') with a loss-free termination. The measurement data can then be analysed as for the familiar case of an actual loss-free termination.

621.317.32 : 537.525.8 **523**

'Glo-Ball' Development.—J. F. Steinhaus. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 575-580.) The 'glo-ball' is a thin-walled partially evacuated glass sphere containing helium, used for investigating electric field distributions in resonant cavities; spheres with diameters ranging between ¼ in. and 1 in. have been used in studying linear accelerators. The indication of the field strength is given by ionization of the gas in the device. Technique for producing 'glo-balls' with stable and relatively low ionization thresholds is discussed.

621.317.382 : 621.317.784 :538.632 :537.311.33 **524**

The Application of the Hall Effect in a Semiconductor to the Measurement of Power in an Electromagnetic Field, and the Design of Semiconductor Wattmeters for Power-Frequency and Audio-Frequency Applications.—H. E. M. Barlow. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, p. 710.) Discussion on 1735 and 1744 of 1955.

621.317.431 **525**

Magnetic-Switch *B/H* Loop Tracer.—W. Geyger. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 167–169.) Magnetic switching of Si-diode chopper circuits enables dynamic hysteresis loops to be traced at frequencies up to 20 kc/s.

621.317.444 : 550.380.8 **526**

High-Altitude Measurements of the Earth's Magnetic Field with a Proton Precession Magnetometer.—L. J. Cahill, Jr, & J. A. Van Allen. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 547–558.) An instrument of the Packard-Varian type (*Phys. Rev.*, 15th Feb. 1954, Vol. 93, No. 4, p. 941) has been used for measurements at heights up to 100 000 ft. The equipment, including magnetic head, amplifier and telemetering transmitter, is carried by a plastic balloon. The results indicate that the field strength decreases with increasing height, and that there are large variations with geographical position. An instrument that can be carried to a height of 150 km by rocket has been constructed.

621.317.7 : 621.373.4 **527**

Phase Generator for Tropospheric Research.—R. W. Hubbard & M. C. Thompson, Jr. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 220–223.) A laboratory-standard instrument based on earlier work [*Rev. sci. Instrum.*, June 1955, Vol. 26, No. 6, pp. 617–618 (Thompson)] gives pulsed or sinusoidal signals with phase displacements up to 360° in steps of 2°.

621.317.7.082.64 : 621.316.86 **528**

The Indirectly Heated Thermistor as a Precise A.C.-D.C. Transfer Device.—F. C. Widdis. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 693–703. Discussion, pp. 707–709.) Methods are described for eliminating thermal drift in indirectly heated thermistors used as transfer devices for measurements of voltages and currents, thus rendering the device suitable for precision use over a wide range of audio frequencies. The sensitivity is high, but this advantage is to some extent outweighed by the slow response. D.c. reversal errors due to Peltier and Thomson effects are small.

621.317.733 : 621.317.335.3 **529**

A Bridge for the Measurement of Permittivity.—A. M. Thompson. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 704–707. Discussion, pp. 707–709.) "The direct admittance of a 3-terminal capacitor with the sample as dielectric is measured as a complex capacitance, the two components being indicated directly on two 3-terminal variable air capacitors. In addition to these the bridge network comprises transformer ratio-arms and an amplifier whose output voltage is in quadrature with that of the transformer. The bridge operates at ten fixed frequencies from 30 to 10^6 rad/sec."

621.317.733 : 621.317.4 : 538.221 **530**

Investigation of an Alternating-Current Bridge for the Measurement of Core Losses in Ferromagnetic Materials at High Flux Densities.—I. L. Cooter & W. P. Harris. (*J. Res. nat. Bur. Stand.*, Aug. 1956, Vol. 57, No. 2, pp. 103–112.) Accurate values can be obtained at high flux densities if a correction term is included derived from the harmonic components of the exciting current.

621.317.755 **531**

Equipment for the Continuous Vectorial Display of Alternating Voltages in the Frequency Range 5 kc/s to 3 Mc/s.—E. C. Pyatt. (*J. Brit. Instn Radio Engrs*, Oct. 1956, Vol. 16, No. 10, pp. 563–567.) A modified form of the equipment described previously (1826 of 1956).

621.317.755 **532**

Polar-Coordinate Oscilloscopes.—G. F. Craven. (*Electronic Engng*, Oct. 1956, Vol. 28, No. 344, pp. 422–425.) A circular-timebase circuit with radial modulation is described, using a three-phase Magslip generator.

621.317.755 **533**

VIAC—a Variable-Interval Automation Controller.—M. L. Klein, H. C. Morgan & J. R. Wood. (*Electronic*

Engng, Oct. 1956, Vol. 28, No. 344, pp. 425–429.) Designed for use in high-speed oscillograph recording, the unit described permits the actual running time of the recording system to be restricted to periods of particular interest, so as to conserve paper without loss of important information.

621.317.761 **534**

A Precision Frequency Meter Produced by the Noiseau Measurement Centre.—J. Boulin. (*Onde élect.*, June 1956, Vol. 36, No. 351, pp. 532–540.) Description of receiver-type equipment designed by the Direction des Services Radioélectriques des P.T.T. to cover the frequency range 3–27 Mc/s, using harmonics of 10 kc/s calibrated by comparison with a 100-kc/s standard ; an accuracy of 10^{-7} ± 1 c/s is achieved.

621.317.784.029.4 **535**

An Audio-Frequency Dynamometer Wattmeter.—A. H. M. Arnold & J. J. Hill. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 325–333.)

621.317.79 : 537.228.1 **536**

Apparatus for Investigating the Piezoelectric Properties of Crystals.—M. I. Yaroslavski, R. M. Lyutenberg & V. N. Chernyshov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 439–441.) The operation of the apparatus described is based on the fact that vibrations of a piezoelectric crystal continue for a time after the cessation of an excitation pulse.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

538.566.029.6 : 61 **537**

Hazards due to Total Body Irradiation by Radar.—H. P. Schwan & K. Li. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1572–1581.) The modes of propagation of e.m. waves in the various tissues of the human body and the resulting development of heat are discussed. At frequencies $\leqslant 1$ kMc/s or >3 kMc/s about 40% of incident radiation is absorbed at a body/air interface ; over the intervening frequency range the amount absorbed varies between 20% and 100%. Radiation at frequencies <1 kMc/s must be guarded against particularly, since these frequencies produce deep heating and may not be detected by the sensory organs in the skin. It is suggested that an irradiation level of $0 \cdot 01 \mathrm{W/cm^2}$ is tolerable.

621-52 : 061.3 **538**

Progress in Mechanics under the Combined Influence of Mechanical and Electronic Developments.—(*Onde élect.*, July 1956, Vol. 36, No. 352, pp. 567–675.) The main part of this issue comprises 13 papers dealing with theoretical, practical and economic aspects of automation, the use of automatic control apparatus on railways, and specific examples of electronic applications in the testing of fuels and engines, the manufacture of cables, and the classification and retrieval of documents. Several of these papers were presented at a conference held in Paris on 5th November 1955, under the above title.

621.317.79 : 531.771 **539**

An Electronic Governor.—S. C. Hine. (*Electronic Engng*, Oct 1956, Vol. 28, No. 344, pp. 448–449.) A tachometer-generator driven by the motor to be governed feeds a frequency discriminator whose output controls the power supplied to the motor.

621.317.79 : 616-1-9 **540**

A Sensitive Quick-Reacting Cardiotachometer.—M. Manzotti. (*Electronic Engng*, Oct. 1956, Vol. 28, No. 344, pp. 446–448.)

621.384.6 **541**

Theory of Strong Focusing [in particle accelerators].—E. L. Burshtein & L. S. Solov'ev. (*C. R. Acad. Sci. U.R.S.S.*, 1st Aug. 1956, Vol. 109, No. 4, pp. 721–724. In Russian.)

621.384.6 **542**

Experimental Test of the Fixed-Field Alternating-Gradient Principle of Particle Accelerator Design.—L. W. Jones, K. M. Terwilliger & R. O. Haxby. (*Rev. sci. Instrum.*, Aug. 1956, Vol. 27, No. 8, pp. 651–652.)

621.384.612 : 538.56.029.6 **543**

Coherent Radiation from Electrons in the Synchrotron at Centimetre Wavelengths.—A. M. Prokhorov. *Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 71–78.) An experimental investigation is reported of the radiation from 5-MeV electrons travelling in an orbit with a radius of 8 cm. The measured radiated power at 2 and 3 cm λ was about 10^{-6} W, in agreement with calculations. It is suggested that an increase in the radiated power by a factor of 10^6 is possible, and hence powers of 1 W at 1 cm λ, 10^{-2} W at 1 mm λ and 10^{-4} W at $0 \cdot 1$ mm λ should be obtainable.

621.385.833 **544**

Advance Calculation of Magnetostatic Electron-Optical Imaging Systems.—B. v. Borries & F. Lenz. (*Optik, Stuttgart*, 1956, Vol. 13, No. 6, pp. 264–276.) The basic problem in permanent-magnet lenses for electron microscopes is to combine maximum refractivity with minimum external dimensions. Methods are presented for calculating the gap flux from the geometrical arrangement of the magnets and the soft-iron parts. Control of refractivity by displacement of iron parts within the system is discussed.

621.385.833 **545**

A Model permitting Rigorous Calculation of Electronic Immersion Cylindrical Lenses.—H. Grümm. (*Optik, Stuttgart*, 1956, Vol. 13, No. 6, pp. 277–288.) The model involves fields which are conveniently investigated by introduction of elliptic coordinates.

621.387 : 621.398 **546**

The Dekatron in a Digital Data Transmission System.—G. Shand & C. Dean. (*J. Brit. Instn Radio Engrs*, Oct. 1956, Vol. 16, No. 10, pp. 533–542.)

621.387.4 : 519.2 **547**

On a Probability Problem arising in the Theory of Counters.—L. Takács. (*Proc. Camb. phil. Soc.*, July 1956, Vol. 52, Part 3, pp. 488–498.)

621.396.91 : 621.398 **548**

New Design Aspects of Boomerang Radiosondes for Upper Air Research.—H. J. Albrecht. (*Geofis. pura appl.*, Jan.–April 1956, Vol. 33, No. 1, pp. 121–145. In English.) Description of an electronically controlled glider carrying upper-air research equipment. The ascent is by means of normal balloons, and after release the glider is guided in the direction of the base transmitter. The history and details of its aerodynamic and electronic design are given, together with possible applications. The technique affords safe and prompt return of equipment and simplification of the calibration procedure ; a saving of about 60% over normal radio-sonde systems is claimed. 30 references.

621.398 : 621-52 **549**

Integral Control with Torque Limitation.—J. C. West & M. J. Somerville. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 407–419.) "The behaviour of a basic remote-position-control system with velocity-feedback stabilization and integral-of-error control is investigated, taking torque limitation of the servo motor into account. It is shown that the transient response deteriorates as the magnitude of the input signal is increased and becomes unstable above a critical value."

621.56 : 537.311.33 : 537.322.1 **550**

Thermoelectric Micro-refrigerators.—E. K. Iordanishvili & L. S. Stil'bans. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 482–483.) A brief preliminary report on experiments with semiconductor elements for refrigeration.

681.81 : 621.373.431 **551**

The Univox.—A. Douglas (*Electronic Engng*, Oct. 1956, Vol. 28, No. 344, pp. 434–437.) An electronic musical instrument is described using a hard-valve sawtooth generator of high constancy of tuning to produce the tones.

PROPAGATION OF WAVES

621.396.11 + [538.566 : 535.42/.43] + 621.396.67 + [621.372.8 : 538.63 **552**

Symposium on Electromagnetic Wave Theory.—(See 415.)

621.396.11 : 621.396.65 **553**

Tropospheric Scatter Propagation.—J. A. Saxton. (*Wireless World*, Dec. 1956, Vol. 62, No. 12, pp. 587–590.) A non-mathematical review is presented of the theoretical background, and practical aspects of point-to-point tropospheric-scatter radio links are discussed.

621.396.11 554

The Present State of Research in the Field of Tropospheric Scatter Propagation.—J. Grosskopf. (*Nachrichtentech. Z.*, June & July 1956, Vol, 9, Nos. 6 & 7, pp. 272–279 & 315–329.) Summary of results of theoretical and experimental work carried out mainly in the U.S.A.

621.396.11 555

Useful Bandwidth in Scatter Transmission.—J. P. Voge. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1621–1622.) Discussion of recent publications on the subject, with reference to previous work by the author (e.g. 510 and 3666 of 1954).

621.396.11.029.45 : 551.510.535 556

The Polarization of Very Long Radio Waves Reflected from the Ionosphere at Oblique Incidence.—W. C. Bain & C. B.-I. Glass. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 447–448.) A re-examination of the original evidence [2871 of 1952 (Bain et al.)], coupled with a study of additional data, indicates that the mean value of the ratio between the vertical and horizontal electric field is 5.

621.396.11.029.45 : 551.510.535 : 523.75 557

V.L.F. Phase Shifts associated with the Disturbance of February 23rd 1956.—J. A. Pierce. (*J. geophys. Res.*, Sept. 1956, Vol. 61, No. 3, pp. 475–483.) Observations at Cambridge, Mass., on 16-kc/s signals from Rugby are discussed. During the disturbance which followed the solar flare at about 0334 U.T., the phase of the received wave was advanced by about 250°. In contrast to the effects observed with sudden ionospheric disturbances in the daytime, which appear to involve phase-shift as well as height variation of the reflecting layer, the night-time observations can be interpreted on the basis of height variations only. The phenomena are discussed in relation to reports of associated observations [e.g. 2716 of 1956 (Ellison & Reid)].

621.396.029.55 558

Rapid Method of M.U.F. Prediction.—R. Gea Sacasa. (*Rev. Telecomunicación, Madrid*, June 1956, Vol. 11, No. 44, pp. 54–59.) Based on the 'Spanish Method' (see e.g. 3727 of 1955), nomograms (with captions in Spanish and English) are presented for the rapid assessment of m.u.f. and optimum working frequencies for broadcasting, standard-frequency transmissions, amateur and mobile marine services. The Madrid-New York hour chart is shown with examples to explain its use.

621.396.11.029.55 : 551.510.535 559

The Intensity of the So-Called Pedersen Ray.—K. Rawer. (*C. R. Acad. Sci., Paris*, 10th Sept. 1956, Vol. 243, No. 11, pp. 797–798.) A theoretical calculation indicates that while the geometrical attenuation of the Pedersen ray reflected from the ionosphere is greater than that of the normal ray, absorption in the ionospheric layers is greater for the normal ray. The Pedersen ray may in some circumstances be the stronger of the two.

621.396.11.029.6 560

Field-Strength Calculations for V.H.F. and U.H.F. Transmitters over Level Ground.—H. van der Hak. (*PTT-Bedrijf*, July 1956, Vol. 7, No. 2, pp. 64–68.) Formulae are derived to simplify calculations for the interference and diffraction regions, and numerical examples clarify the use of 13 nomograms included as loose sheets with the journal.

621.396.11.029.62 561

Some Aircraft Measurements of Beyond-the-Horizon Propagation Phenomena at 91·3 Mc/s.—B. J. Starkey. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 761–763.) "Field-strength measurements at distances extending far beyond the horizon from a transmitter on a frequency of 91·3 Mc/s have been carried out in an aircraft flying at a height of 10 000 ft. The analysis of the results obtained and their correlation with meteorological data suggest that many phenomena of long-distance propagation could possibly be explained by the simple hypothesis of specular reflection from temperature-inversion layers at the tropopause."

RECEPTION

621.396.621 : 621.396.822 562

Interference Stability of a Filter Autocorrelator Receiver for Pulse Signals.—V. I. Chaikovski. (*Radiotekhnika, Moscow*, April 1956, Vol. 11, No. 4, pp. 24–30.) The output signal/noise ratio is calculated for fluctuation-type interference in the input of a correlation-type receiver using a low-pass filter in the averaging circuit.

621.396.621.029.55 : 621.314.7 563

Transistor Superregenerative Circuits.—D. F. Page. (*Wireless World*, Dec. 1956, Vol. 62, No. 12, pp. 606–609.) Two receivers suitable for operation at frequencies of 15–25 Mc/s are described. A surface-barrier-transistor oscillator is used (*a*) in a self-quenching circuit or (*b*) in a linear circuit in conjunction with a separate transistor quenching oscillator. Circuit diagrams and a table of typical component values are given.

621.396.621.54 564

A General-Purpose Communication Receiver.—J. B. Rudd & J. B. Stacy. (*Proc. Instn Radio Engrs, Aust.*, June 1956, Vol. 17, No. 6, pp. 207–217.) Description of a 14-valve superheterodyne receiver designed to meet the specification embodied in the U.K. Merchant Shipping (Radio) Rules, 1952. The r.f. ranges are 12–60 kc/s and 100 kc/s–30 Mc/s, and the bandwidth is adjustable between 500 c/s and 8 kc/s in four steps. The turret wave-change unit includes a special mechanism giving a smooth change with positive and precise locking. Additional facilities such as crystal tuning control can be incorporated.

621.396.621.54 565

A Sideband-Mixing Superheterodyne Receiver.—M. Cohn & W. C. King. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1595-1599.) "Microwave receivers having bandwidths as much as 22 times greater than the intermediate-frequency amplifier bandwidth have been constructed by generating sidebands on a local oscillator signal and utilizing these sidebands as virtual local oscillators. Both a microwave and a v.h.f. local oscillator signal are injected on a crystal to generate an infinite set of sideband signals separated by the frequency of the v.h.f. oscillator and centred about the microwave oscillator. The low-level received signal mixes with one of these generated virtual local oscillator signals to produce the desired i.f. signal. The two mixing operations can take place in one crystal or two separate crystals. Measurements have been made of tangential sensitivity and conversion loss and indicate that sensitivities greater than −70 dBm and a continuous bandwidth of 700 Mc/s can be achieved with an intermediate-frequency amplifier having 50 Mc/s bandwidth."

621.396.621.54 : 621.317.4 566

Transistorized Receiver for Vehicular Radio.—S. Schwartz. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 217–219.) Description of a multiple-superheterodyne military communications receiver with transistors from the i.f. stage onwards.

621.396.8 : 621.376.3 567

F.M. Multi-path Distortion.—M. G. Scroggie. (*Wireless World*, Dec. 1956, Vol. 62, No. 12, pp. 578–582.) With a path difference of several miles between two signal components, the comparatively small frequency changes due to f.m. are sufficient to cause maximum signal fluctuations. These lead to distortions, of magnitude depending on the proportion of the a.m. which the limiter fails to remove and on the ratio of the signal components. Experiments carried out by the B.B.C. show that as little as 5% signal delayed by 10 miles can cause unpleasant distortion in a typical receiver. The effect of undesired ph.m. is small in the case considered. Remedies suggested are (*a*) improved amplitude limiting and (*b*) the use of a directional aerial.

621.396.8.029.62 568

Polarization Discrimination in V.H.F. Reception.—J. A. Saxton & B. N. Harden. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 757–760.) "An account is given of measurements in the band 40–200 Mc/s of the discrimination likely to be achievable between common-frequency transmission by the use of orthogonal polarizations. It is shown that the discrimination is determined primarily by the topographical nature of the receiving site, that it is substantially independent of distance from the transmitter and of frequency in the band under consideration, and that the median value is about 18 dB. The perturbing effects of pick-up on the feeder and of receiving aerial misalignment are discussed."

621.396.822 : 551.594.6 569

An Investigation of Atmospheric Radio Noise at Very Low Frequencies.—Horner & Harwood. (See 445.)

621.396.822 : 621.376.23 **570**

An Experimental Study of Intensity Spectra after Half-Wave Rectification of Signals in Noise.—G. E. Fellows & D. Middleton. (*Proc. Instn elect. Engrs.*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 243–248.) "Measurement has been made of the spectral intensity of the harmonic zones which exist at the output of a nonlinear device fed by narrow-band noise and an unmodulated carrier. The spectral shape, the maximum spectral intensity, and the carrier component in each of the first six harmonic zones ($l = 0 \, . \, . \, 5$) have been determined both theoretically and experimentally for a half-wave νth-law rectifier with $\nu = 1/2$, 1 and 2, for a wide range of input carrier/noise ratios. The measuring equipment is discussed in the paper, the theoretical and experimental results are compared, and a number of computed results of practical interest are presented."

STATIONS AND COMMUNICATION SYSTEMS

621.376.56 : 621.396.5 **571**

Transmitting System Uses Delta Modulation.—R. B. Watson & O. K. Hudson. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 164–166.) A system suitable for voice communication uses a transmitter in which positive or negative pulses from a generator are applied via one of two gates respectively to a local detector ; the stepped output from the detector is compared with the modulating signal, the difference voltage controlling the opening of the gates. A pulse repetition rate of 10^5/s is adequate. The remote receiver incorporates a detector similar to that in the transmitter.

621.396.3.029.55 **572**

Investigation of an Eight-Channel Telegraphy System with Automatic Error Correction.—M. Corsepius, H. Logemann & K. Vogt. (*Nachrichtentech. Z.*, July 1956, Vol. 9, No. 7, pp. 306–309.) By combining two sets of T.O.M. (teletype-on-multiplex) equipment [see also 2533 of 1956 (Corsepius & Vogt)] working on F1-duoplex, an eight-channel system with automatic error correction is obtained. Results of tests in both directions over two s.w. radio links are satisfactory.

621.396.41 : 621.376.3 : 621.3.018.78 **573**

Distortion in Frequency-Modulation Systems due to Small Sinusoidal Variations of Transmission Characteristics.—R. G. Medhurst & G. F. Small. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1608–1612.) Curves are plotted relating intermodulation distortion in a 600-channel frequency-division transmission system to the amplitude, periodicity and location of a small sinusoidal variation of either the group-delay or the amplitude characteristic of the system.

621.396.41 : 621.396.822 **574**

Method to Calculate Intermodulation Noise.—A. P. Bolle. (*PTT-Bedrijf*, July 1956, Vol. 7, No. 2, pp. 51–57. In English.) This method is applicable to multichannel frequency-division a.m. telephony systems and to f.m. systems based on them. The noise at zero relative level is determined by complex integration using the characteristic functions of the energy spectra.

621.396.5 **575**

Single-Sideband Communication Equipment.—J. L. Delvaux & M. Byk. (*Onde élect.*, June 1956, Vol. 36, No. 351, pp. 520–531.) Equipment manufactured in France is described. A limit of 50 c/s is set for the permissible frequency deviation, corresponding to a stability of 10^{-5}–5×10^{-6} at 5–10 Mc/s ; a.f.c. is dispensed with. For distances up to 1 000 km a transmitter power of 10 W is sufficient ; a 50-W transmitter gives a range of 2 000 km.

621.396.65 : 621.396.11 **576**

Tropospheric Scatter Propagation.—Saxton. (See 553.)

SUBSIDIARY APPARATUS

621-526 **577**

An Approximate Method for Finding the 'Best Linear Servo Mechanism'.—H. H. Rosenbrock. (*Proc. Instn elect. Engrs*, Part C, Sept. 1956, Vol. 103, No. 4, pp. 260–266.) An elementary graphical method is described for evaluating Wiener's solution for the servomechanism which minimizes the r.m.s. error when the system is following a signal affected by noise (*Extrapolation, Interpolation and Smoothing of Stationery Time Series*, 1950). The minimum phase corresponding to a given attenuation characteristic is determined as an intermediate result of the method.

621.3.013.78 **578**

The Magnetic Field Strength in the Corners of Screened Enclosures (Corner Effect).—H. Kaden. (*Arch. elekt. Übertragung*, July 1956, Vol. 10, No. 7, pp. 275–282.) The screening effect is reduced in the corners when the external magnetic field is perpendicular to the screen. The explanatory theory is developed and the increase of field strength in the corners is found to be inversely proportional to the 4/3rd power of the distance from the corner. Curves show the direction and increase of the field in the corners. This effect is absent when the external field is parallel to the screen.

621.314.634 **579**

The Operation of Selenium Rectifiers at Audio Frequencies.—I. G. Nekrashevich. (*Zh. tekh. Fiz.*, March 1956, Vol. 26, No. 3, pp. 560–567.) A detailed report is presented on an experimental investigation. For sinusoidal voltages over a frequency range of 50 c/s–20 kc/s, the average rectified current is practically independent of frequency, provided the working area does not exceed 1 cm².

621.319.339 **580**

Investigations on Self-Excitation in Band-Type [Van de Graaff] **Generators.**—W. Herchenbach & H. Sigel. (*Z. angew. Phys.*, July 1956, Vol. 8, No. 7, pp. 355–360.) The suitability of various insulating materials is investigated ; a new symmetrical circuit arrangement is described.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 **581**

Pay-As-You-See Television — (*Engineering*, Lond., 5th Oct. 1956, Vol. 182, No. 4726, p. 434.) Outline of a system developed in the U.S.A., in which six groups of signals are transmitted, viz., the coded picture and sound signals, picture and sound program-announcing signals, a decoding signal, and a signal controlling the financial transaction. Technique for preventing unauthorized reception is indicated.

621.397.5 : 535.623 **582**

The Amplitude of the Chrominance Carrier in the N.T.S.C. System.—H. Grosskopf. (*Nachrichtentech. Z.*, July 1956, Vol. 9, No. 7, pp. 289–292.) Calculations and consideration of the colour triangle show that for the transmission of normal television pictures the amplitude of the chrominance carrier is likely to be considerably smaller than that required for a bar pattern of pure colours.

621.397.6 **583**

Improving the Linearity of Vertical Scanning in Television Equipment.—E. Giua. (*Piccole Note Ist. super. Poste e Telecomunicazioni*, May/June 1956, Vol. 5, No. 3, pp. 366–373.) A simple cathode-follower circuit is described which adds a parabolic component to the linear sawtooth voltage waveform, thus linearizing the current waveform in the deflection coils in magnetic deflection systems. The arrangement can also be used to improve e.s. deflection.

621.397.6 **584**

Slow-Sweep TV for Closed-Circuit Use.—H. E. Ennes. (*Electronics*, Nov. 1956, Vol. 29, No. 11, pp. 140–143.) A system for transmitting still pictures uses a line scan at mains frequency and a frame frequency of 2 to 7 per sec, in conjunction with a long-persistence-phosphor c.r.-tube screen. The bandwidth of the picture signal can be accommodated on a program-type telephone line. The camera tube is of vidicon type.

621.397.61.001.4 **585**

Proof of Performance for TV Broadcasting.—J. R. Sexton. (*Electronics*, Nov. 1956, Vol. 29, No. 11, pp. 150–154.) The system of tests imposed by the U.S. F.C.C. before issuing or renewing television broadcasting licences is described.

621.397.611.2 **586**

Ebicon Sees in Dark.—(*Electronics*, Nov. 1956, Vol. 29, No. 11, pp. 206 . . 210.) Brief description of a camera tube with a Cs-Sb photocathode and a semi conductor target within which avalanche effects are produced by the passage of the high-velocity photo electrons. The tube may be associated with an image intensifier.

621.397.62 : 535.623 **587**

Three-Phase Detector for Colour-Television Receivers.—A. A. Goldberg. (*Electronics*, Oct. 1956, Vol. 29, No. 10, pp. 157–159.)

621.397.62 : 535.623 : 621.385.832 **588**

Flat Tube for Colour TV.—(*Wireless World*, Dec. 1956, Vol. 62, No. 12, pp. 570–572.) Outline of a lecture to the Television Society by Gabor. The three-beam c.r. tube is in the shape of a flat glass box which is typically about 4½ in. deep and has a 21-in.-diagonal fluorescent screen. The tube is divided into two halves in depth by a metal plate which carries the whole electron-optical system and serves also as a magnetic screen. The electrons start parallel to the plate from three independently modulated cathodes, pass through an e.s. line-deflection system and then through an e.m. collimator which bends the beam around the edge of the plate. The final bending to cause the beam to strike the fluorescent screen, and the frame scan, are achieved by means of a travelling potential wave. No frame-deflection circuit is required. The shadow mask used for colour control is about 0·025 in. from and fixed directly to the fluorescent screen. A cut-away view of the tube and a sketch illustrating the principle of operation of the frame-scanning array are given.

621.397.62 : 621.397.8 **589**

A Possible Method of Improving the Definition of a Television Picture.—V. F. Samoilov & V. M. Rodionov. (*Radiotekhnika, Moscow*, April 1956, Vol. 11, No. 4, pp. 44–48.) A circuit and method are described for improving the contrast of weak details. The circuit (*a*) differentiates the signal, (*b*) delays the signal derivative for a period equal to the duration of one element of the picture, (*c*) compares the signs of the derivatives of the delayed and direct signals, and (*d*) in the event that the signs are opposite, increases the amplitude of the signal.

621.397.5 **590**

Colour Television Standards. [Book Review]—D. G. Fink (Ed.). Publishers: McGraw-Hill, London, 1955, 520 pp., 64s. (*Nature, Lond.*, 13th Oct. 1956, Vol. 178, No. 4537, pp. 764–765.) A selection of papers and records of the U.S. National Television System Committee; a considerable amount of the material has been published previously (see in particular *Proc. Inst. Radio Engrs*, Jan. 1954, Vol. 42, No. 1). While useful primarily as a reference work for engineers, the book also includes a non-technical description of the N.T.S.C. system.

TRANSMISSION

621.396.61 : 621.373.4 **591**

An Analysis of Pulse-Synchronized Oscillators.—Salmet. (See 386.)

621.396.61.029.62 **592**

An Experimental Assessment of the Linearity of a V.H.F. Transmitter.—D. E. Hampton. (*Proc. Instn elect. Engrs*, Part B, Nov. 1956, Vol. 103, No. 12, pp. 752–756.) "An experimental procedure is described for testing the assumption that a generator behaves as a linear source. The source admittance is obtained from measurements made when the generator is operating normally, and the problem considered is that of matching this source admittance to the characteristic admittance of the feeder connecting it to a wide-band aerial."

VALVES AND THERMIONICS

621.314.632 **593**

Note on Turnover in Germanium Contacts.—P. T. Landsberg. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 763–765.) Discussion of the I/V characteristics of Ge diodes; Burgess's arguments (994 of 1956) are examined and some alternatives are advanced.

621.314.634 **594**

An Electron-Diffraction Investigation of the Layer Adjacent to a Cadmium Electrode in a Selenium Rectifier.—V. A. Dorin & D. N. Nasledov. (*Zh. tekh. Fiz.*, Feb. 1956, Vol. 26, No. 2, pp. 284–292.)

621.314.7 **595**

Internal Oscillations in Transistors.—D. Geist. (*Z. angew. Phys.*, July 1956, Vol. 8, No. 7, pp. 337–339.) Internally excited oscillations observed in point-contact transistors [see e.g. 2540 and 3392 of 1954 (Hollmann)] and in hook transistors [878 of 1953 (Ebers)] cannot be explained on the basis of stability theory; further experiments are required to clarify the phenomenon.

621.314.7 **596**

Transit-Time Transistor.—G. Weinreich. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1025–1027.) Analysis based on that developed by Mason (374 of 1955) is used to show that an appropriately designed transistor can be operated as a three-terminal amplifier in special frequency bands far above α cut-off. These bands lie one on each side of that corresponding to the negative-resistance condition observed when the device is operated as a diffusion-delay diode [3388 of 1954 (Shockley)]. The existence of the bands is generally independent of the magnitude of the base resistance, but their width decreases with increasing base resistance.

621.314.7 **597**

A Note on the Extended Theory of the Junction Transistor.—T. Misawa. (*J. phys. Soc. Japan*, July 1956, Vol. 11, No. 7, pp. 728–739.) The examination of d.c. or l.f. performance at high injection levels may be based on boundary conditions in terms of either e.s. potential or quasi-Fermi levels. At higher frequencies the latter approach is preferable. The author's approach is contrasted with that of Rittner (3390 of of 1954).

621.314.7 : 546.289 **598**

Current Gain in Formed Point-Contact *n*-Type Germanium Transistors.—D. Haneman. (*Proc. phys. Soc.*, 1st July 1956, Vol. 69, No. 439B, pp. 712–720.) "Experiments on Ge point contact transistors in which collector points of pure donor and acceptor elements are formed show that in general donors appear to be essential to obtain current gain improvements. Successful forming was also achieved with pure gold points. It is assumed that the atoms of the material of the collector diffuse into the germanium during forming. This leads to a change in the amount of lowering of the surface barrier due to the holes injected at the emitter, and accounts for the increased current gain."

621.314.7 : 546.289 **599**

Operation of a Crystal Amplifier under Conditions of Carrier Extraction.—V. I. Stafeev, V. M. Tuchkevich & N. S. Yakochuk. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 15–21.) Experiments were conducted with *p-n-p* Ge transistors, based on the extraction of minority carriers as proposed by Angello & Ebert (758 of 1955). The stability of such transistors is good at high temperature; the power amplification is not greatly dependent on temperature and is higher than in amplifiers based on the injection of minority carriers. It is suggested that the principle of extraction can be used in the case of semiconductors with a small energy gap and a high concentration of minority carriers even at room temperature. A combination of extraction and injection enables the dissipated power to be maintained constant, for a given signal level, within a wide range of temperatures.

621.314.7 : 546.289 **600**

Relation between Surface and Volume Recombinations in Germanium Triodes with Alloyed *n-p* Junctions.—A. O. Rzhanov. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 239–240.) It has been suggested in the literature that the effect of the volume recombination of the excess charge carriers on the characteristics is negligibly small in comparison with that of the surface recombination. Experiments confirming this are briefly described.

621.314.7.001.4 (083.74) **601**

I.R.E. Standards on Solid-State Devices: Methods of Testing Transistors, 1956.—(*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1542–1561.) Standard 56 I.R.E. 28. S2.

621.383.2 **602**

Photocells and Photomultipliers with Magnesium Photocathodes for detecting Ultraviolet Radiation.—O. P. Dorf, N. G. Kokina, T. M. Lifshits & D. A. Shklover. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 106–113.) An experimental investigation is reported. The absolute sensitivity and spectral characteristic are not materially affected by the presence of amounts up to a few parts per thousand of Al, Ca, Mn, Zn, Cu, Ni and Fe. The sensitivity is of the order of 0·32–0·38 μA/μW at a wavelength of 253·7 mμ; the photomultiplier can detect amounts of power down to 10^{-15} W.

621.383.2 **603**

Antimony-Lithium Photocathode.—Yu. A. Nemilov & V. E. Privalova. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 61–63.) Antimony-lithium photocathodes were prepared having a basic sensitivity of 35–40 μA/lm for a light-source temperature of 2 850°. The spectral sensitivity characteristic indicates that the red boundary of the photoeffect is near 6 200 Å. The average value of the thermoelectric work function is $1 \cdot 5 \pm 0 \cdot 1$ eV. The average value of the activation energy is $1 \cdot 0 \pm 0 \cdot 1$ eV. The maximum value of the secondary emission coefficient is 15. Heating of the cathode to 100° C decreases the photosensitivity by 50% and increases the work function to 2 eV. The photoconduction processes exhibit appreciable time lag.

621.383.2 **604**

Investigation of the Phenomenon of Fatigue in Silver-Oxide-Caesium Photocathodes.—P. G. Borzyak, V. F. Bibik & G. S. Kramarenko. (*Radiotekhnika i Elektronika,* March 1956, Vol. 1, No. 3, pp. 358–369.) Results of an experimental investigation indicate that the fatigue is due not only to changes in the adsorbed film on the cathode and changes in the work function but also to volume processes in the Cs_2O which take place under the influence of the illumination.

621.383.2 **605**

The Efficiency of Antimony-Caesium Film-Type Photocathodes. — P. G. Borzyak, B. I. Dyatlovitskaya & T. N. Chernysheva. (*Radiotekhnika i Elektronika,* March, 1956, Vol. 1, No. 3, pp. 370–376.)

621.383.4 **606**

The Photo-effect in Lead Sulphide and Related Materials: Part 2.—R. Stein & B. Reuter. (*Z. Naturf.,* Nov. 1955, Vol. 10a, No. 11, pp. 894–896.) Theoretical interpretation of the observed effects described previously (3249 of 1956).

621.383.42 **607**

The Influence on the Properties of Selenium Photocells of Near-Infrared Radiation at Low Temperatures.—G. Blet. (*C. R. Acad. Sci., Paris,* 10th Sept. 1956, Vol. 243, No. 11, pp. 798–800.) An account is given of resensitization effects observed when Se photocells whose sensitivity has been reduced by cooling are subjected to infra-red radiation of appropriate wavelength.

621.383.5 **608**

High Time Constants in Se Photocells.—G. Blet. (*J. Phys. Radium,* May 1956, Vol. 17, No. 5, pp. 430–439.) Observations have been made of various phenomena wth time constants >1 min, including fatigue effects following strong and weak illumination. A qualitative explanation of the observations is provided by a theory based on the density of free electrons and holes in the barrier layer.

621.385 : 537.2 **609**

Potential Distribution between Parallel Planes in Electron Tubes.—P. L. Copeland, L. M. Sachs & E. C. Czech. (*J. appl. Phys.,* July 1956, Vol. 27, No. 7, pp. 816–819.) Formulae and graphs are presented for calculating potential distributions due to space charge between parallel plane electrodes whose dimensions are large compared with their separation.

621.385 : 537.533 : 621.375.2 **610**

Instability in Hollow and Strip Electron Beams.—C. C. Cutler. (*J. appl. Phys.,* Sept. 1956, Vol. 27, No. 9, pp. 1028–1029.) Observations have been made of the breaking up of beams in magnetic fields; the disturbance can be initiated and controlled by applying a space-periodic deflecting voltage. Use of the effect to produce d.c. amplification is discussed.

621.385 : 537.533.087.5 **611**

A Photographic Method of Studying the Spread of Trochoidal Electron Beams.—N. Strandell. (*Kungl. tek. Högsk. Handl., Stockholm,* 1956, No. 106, 13 pp.) The vertical and lateral spread of the beam in the trochotron is studied by a photograph method which is applicable at pressures as low as 10^{-5} mm Hg.

621.385 : 537.533.8 **612**

Influence of Secondary Electron Emission of Insulators on the Stability of the Parameters of Electronic Valves.—N. V. Cherepnin. (*Radiotekhnika i Elektronika,* Jan. 1956, Vol. 1, No. 1, pp. 38–50.) Experimental results are presented for several types of valve. Steps recommended for effecting improvement include the use of the shortest possible oxide coating on the cathode, increasing the surface resistance and screening of the supports, use of several types of getters and decreasing the operating voltages.

621.385 : 621.317.39.082 **613**

Calculation of Fundamental Parameters for Electronic Valves used for the Measurement of Acceleration.—L. A. Goncharski. (*Radiotekhnika, Moscow,* April 1956, Vol. 11, No. 4, pp. 49–58.) See also 2076 of 1955.

621.385.029.6 **614**

The Relativistic Magnetron and the Effective Mass Anisotropy.—L. Gold. (*J. Electronics,* July 1956, Vol. 2, No. 1, pp. 17–32.) Development of the analysis presented previously (3203 and 3401 of 1954). Effective mass anisotropy arises as a consequence of the relativistic condition, the magnitude of the anisotropy being governed by the direction and magnitude of the particle injection velocity and the ratio of the electric and magnetic fields. The cut-off relation for the cylindrical magnetron is deduced.

621.385.029.6 **615**

Some Properties of Magnetrons using Spatial-Harmonic Operation.—R. G. Robertshaw & W. E. Willshaw. (*Proc. Instn elect. Engrs,* Part C, Sept. 1956, Vol. 103, No. 4, pp. 297–306.) The design of multi-circuit magnetrons for low-power operation at frequencies of the order of 10 kMc/s with voltages <1 kV is difficult because of the close tolerances imposed. A design having advantages from this point of view uses an anode with only a few gaps, e.g. two or four, the electron stream interacting with the Fourier space harmonics of the travelling field. A useful tuning range is achieved by adjustment of an external cavity. Some performance details are given for experimental valves.

621.385.029.6 **616**

On the Possibility of Extending the Concepts of Similarity to Multi-resonator Magnetrons with Different Numbers of Resonators.—I. E. Rogovin. (*Radiotekhnika i Elektronika,* Jan. 1956, Vol. 1, No. 1, pp. 51–70.)

621.385.029.6 **617**

Oscillations of the Space-Charge Cloud in a Cylindrical Magnetron.—Tychinski & Yu. T. Derkach. (*Radiotekhnika i Elektronika,* Feb. & March 1956, Vol. 1, Nos. 2 & 3, pp. 233–244 & 344–357.) Report of a theoretical and experimental investigation. The conclusions drawn from an approximate calculation of the natural oscillation frequencies of the electron cloud in the magnetron, based on consideration of a small perturbation of the static state, are: (*a*) the oscillation frequencies are principally determined by the characteristics of the interaction space and are approximately subject to the Hartree threshold-voltage formula, and (*b*) the dispersion of waves in the electron stream leads to limiting of the excited spectrum and deviation from Hartree's formula. The experimental results confirm the theoretical conclusions.

621.385.029.6 **618**

Periodic Focusing of Beams from Partially Shielded Cathodes.—K. J. Harker. (*Trans. Inst. Radio Engrs,* Oct. 1955, Vol. ED-2, No. 4, pp. 13–19. Abstract, *Proc. Inst. Radio Engrs,* Feb. 1956, Vol. 44, No. 2, p. 274.) Analysis covering both shallow and deep beam scalloping is presented. The relation between the magnetic-field coefficient and the space-charge coefficient is shown in graphs.

621.385.029.6 **619**

Space-Charge Waves in Velocity-Modulated Electron Beams.—P. V. Bliokh & Ya. B. Fainberg. (*Zh. tekh. Fiz.,* March 1956, Vol. 26, No. 3, pp. 530–535.) Analysis shows that, for a definite law of velocity modulation, waves with exponentially increasing amplitude can be generated. By taking into account, in the hydrodynamic approximation, the thermal motion of electrons it is possible to determine the frequency dependence of the amplification factor and also the upper frequency limit of amplification.

621.385.029.6 **620**

An 8-mm Klystron Power Oscillator.—R. L. Bell & M. Hillier. (*Proc. Inst. Radio Engrs,* Sept. 1956, Vol. 44, No. 9, pp. 1155–1159.) A floating-drift-tube single-cavity klystron suitable for use in a low-noise c.w. radar transmitter is described. The beam current is $0 \cdot 1$ A and the beam voltage $3 \cdot 5$ kV; the output power is 12 W. Aluminosilicate glass was used in the construction, to permit baking out at 700°C. A high-convergence electron-optical system permits use of a sprayed-oxide cathode with 1 000-h life.

621.385.029.6 **621**

A Five-Cavity X-Band Klystron Amplifier.—G. O. Chalk, B. W. Manley & V. J. Norris. (*J. Electronics,* July 1956, Vol. 2, No. 1, pp. 50–64.) Design details and performance figures are presented for a klystron giving an output of several watts with a gain of 70 dB. The gain per stage can be predicted with fair accuracy, and the overall performance can be determined by considering each stage as independent.

621.385.029.6 **622**

Generation of Electromagnetic Oscillations by a Travelling-Wave Valve with an External Sectionalized Helix.—V. S. Mikhalevski & D. N. Venerovski. (*Zh. tekh. Fiz.*, March 1956, Vol. 26, No. 3, pp. 526–529.) Experiments indicate that by dividing the helix into a number of sections with suitably chosen parameters it is possible to ensure the generation of an oscillation whose frequency remains constant when the anode voltage and the intensity of the magnetic field vary within fairly wide limits.

621.385.029.6 **623**

Experimental Investigation of Noise Reduction in Travelling-Wave Tubes.—N. B. Agdur. (*Chalmers tek. Högsk. Handl.*, 1954, No. 139, 12 pp.) The noise power output of the valve is studied as a function of the distance between the anode and the helix input. This measurement gives a determination of the length of the space-charge waves in the drift region, the ratio between the minimum and maximum noise factors, and the distance from the anode to the first noise minimum.

621.385.029.6 **624**

The Nature of Power Saturation in Travelling-Wave Tubes.—C. C. Cutler. (*Bell Syst. tech. J.*, July 1956, Vol. 35, No. 4, pp. 841–876.) Report of experiments made using a large-scale model of a travelling-wave valve with a helix 10 ft. long and $1\frac{1}{2}$ in. in diameter, operated at a frequency of 100 Mc/s with a beam voltage of 400 V. Measurements were made of the efficiency and power output, and of the spent beam velocity and current as a function of r.f. phase and amplitude. The best value of efficiency, about 38%, is obtained with a value 0·14 for the gain parameter C.

621.385.029.6 **625**

Nonlinear Wave Propagation in Travelling-Wave Amplifiers.—A. Kiel & P. Parzen. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. ED-2, No. 4, pp. 26–34.) "A method is given for computing the efficiency of travelling-wave amplifiers with high gain and low C, including the effects of space charge and attenuation. The ballistics of the electrons is governed by the Boltzmann transport equation which, together with the circuit equation, is solved in a power series expansion of the input voltage. Only the first two terms of this series are computed and various nonlinear results are given in the form of curves. It appears that for small C and small convergence parameters, overtaking affects the nonlinear operation slightly."

621.385.029.6 **626**

Recent Developments in O-Type Carcinotron Tubes.—P. Palluel. (*Ann. Radioélect.*, April 1956, Vol. 11, No. 44, pp. 145–164.) See 1904 of 1956 (Palluel & Goldberger).

621.385.029. : 537.533 **627**

The Electronic Theory of Tape-Helix Travelling-Wave Structures.—M. Scotto & P. Parzen. (*Trans. Inst. Radio Engrs*, Oct. 1955, Vol. ED-2, No. 4, pp. 19–25. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1956, Vol. 44, No. 2, p. 274.)

621.385.029.6 : [621.372.2+621.372.8 **628**

Electron Waves in Retarding Systems.—Vainshtein. (See 338.)

621.385.029.6 : 621.372.2 **629**

Investigation of an Interdigital Delay Line.—F. Paschke. (*Arch. elekt. Übertragung*, May 1956, Vol. 10, No. 5, pp. 195–206.) The investigation is directed mainly to the possibilities of obtaining a wide tuning range in backward-wave valves. Analysis is presented for the all-pass line; the first backward-wave harmonic can be largely suppressed by suitable design. Modification of the all-pass line to give a band-pass characteristic is discussed. An oscillator with an f.m. characteristic similar to that of a reflex klystron can be produced. High-power wide-band amplifiers can also be designed.

621.385.029.6 : 621.372.2 **630**

The Dimensions of Helices in Travelling-Wave Valves.—W. Klein. (*Arch. elekt. Übertragung*, June 1956, Vol. 10, No. 6, pp. 261–265.) The importance is examined of the proportions and accuracy of the helices where high-power amplification is to be achieved over a given frequency range without risk of self-excitation and undesired f.m. Curves show the relation between valve characteristics and helix parameters. See also 1823 of 1955 (Klein & Friz).

621.385.029.6 : 621.372.413 **631**

A Method of Tuning Resonant Cavities.—W. M. Haywood. (*Electronic Engng*, Sept. 1956, Vol. 28, No. 343, pp. 395–397.) Tuning arrangements for cavities associated with klystrons are discussed. The effect of enclosing an inductive tuning rod in a fixed glass dome projecting into the cavity, instead of in a bellows, is investigated. The main disadvantage with the glass used was a reduction in cavity shunt impedance of 5–20%; this could be materially reduced by the use of glass with low dielectric loss. The method would not be suitable at high d.c. power levels, and mechanical difficulties might prevent its use for $\lambda < 3$ cm.

621.385.029.6 : 621.372.413 : 621.376.32 **632**
621.318.134

Magnetic Tuning of Resonant Cavities and Wide-Band Frequency Modulation of Klystrons.—G. R. Jones, J. C. Cacheris & C. A. Morrison. (*Proc. Inst. Radio Engrs*, Oct. 1956, Vol. 44, No. 10, pp. 1431–1438.) A detailed account of work previously reported briefly [3441 of 1955 (Cacheris et al.)]. Theoretical and experimental results are presented. Linear frequency deviations up to 240 Mc/s are obtained with only 13% amplitude variation.

621.385.029.6 : 621.385.2 : 621.396.822 **633**

Monte Carlo Calculation of Noise Near the Potential Minimum of a High-Frequency Diode.—P. K. Tien & J. Moshman. (*J. appl. Phys.*, Sept. 1956, Vol. 27, No. 9, pp. 1067–1078.) Details are given of a method suitable for carrying out the calculation with a high-speed electronic computer, starting with the generation of random numbers to simulate the electrons emitted by the cathode. Figures were obtained for a total of 3 000 unit time intervals. The reduction of noise current due to space-charge smoothing is estimated. Application of the results to microwave beam valves leads to a minimum-noise-figure/frequency curve exhibiting a sharp minimum at about 2·5 kMc/s and a flat maximum at about 4 kMc/s and an approach to the full shot-noise value of 6·3 dB at higher frequencies.

621.385.029.6 : 621.396.822 **634**

Klystron Oscillator Noise Theory.—R. L. Bell. (*Brit. J. appl. Phys.*, July 1956, Vol. 7, No. 7, pp. 262–266.) The principal sources of undesired a.m. and f.m. in a floating-drift-tube klystron are shot and partition noise in the beam at the oscillation frequency and its harmonics, except at lowest modulation frequencies where flicker noise predominates in the a.m. Formulae are presented for the background noise temperature generated by the a.m. and for the f.m. spectral density.

621.385.029.6 : 621.396.822 **635**

Spurious Modulation in Q-Band Magnetrons.—T. M. Goss & P. A. Lindsay. (*Proc. Inst. Radio Engrs*, Oct. 1956, Vol. 44, No. 10, pp. 1474–1475.) Further evidence is presented confirming the occurrence of the effects reported by Cutler (1256 of 1956).

621.385.029.6 : 621.396.822 : 621.372.5 **636**

The Equivalent Noise Quadripole of Transit-Time Valves.—H. Bauer & H. Rothe. (*Arch. elekt. Übertragung*, July 1956, Vol. 10, No. 7, pp. 283–298.) Application of previous work (380 above) to various types of transit-time valves. The network parameters are used to analyse the sources of noise, as illustrated by the example of a defective low-noise travelling-wave valve. Fundamental laws of transit-time valves applicable to the small-signals case are examined.

621.385.032.21 : 537.533 **637**

Field Emission and Field-Emission Cathodes.—D. V. Zernov & M. I. Elinson. (*Radiotekhnika i Elektronika*, Jan. 1956, Vol. 1, No. 1, pp. 5–22.) A review is presented of theoretical and experimental work. 54 references, including 8 to Russian literature.

621.385.032.213 **638**

The Physical Properties of a Porous Metallic-Film Thermionic Cathode: Part 1.—N. D. Morgulis. (*Zh. tekh. Fiz.*, March 1956, Vol. 26, No. 3, pp. 536–548.) Various aspects of the operation of a cathode consisting of a W base coated with a Ba monolayer in a state of dynamic equilibrium are considered. Experimental data are given on the formation of Ba in the cathode material, its subsequent diffusion to the surface of the cathode, evaporation from this surface, etc., and on the operation of these cathodes in electronic devices. A brief report is also presented on an electron-diffraction investigation into the structure of the cathode.

621.385.032.213 **639**

Bariated Tungsten Cathode: Part 1—General Studies.—Y. Koike & T. Shibata. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B.*, Sept. 1955, Vol. 7, No. 2, pp. 67–74.) The effect of Si, Zr and WC, used as reducing agents, on the emission of capillary cathodes formed of sintered mixtures of barium silicates and tungsten is described ; good results are obtained with Si and Zr.

621.385.032.216 **640**

Measurement of the Electrical Conductivity of the Oxide-Coated Cathode.—T. B. Tomlinson & R. E. J. King. (*Brit. J. appl. Phys.*, July 1956, Vol. 7, No. 7, pp. 268–269.) Two similar Ni annuli with the oxide sandwiched between them formed the cathode, which was heated by 1-Mc/s eddy currents. Conductivity and emission were measured at temperatures from 300° to >1 000°K.

621.385.032.216 **641**

Investigation of an Oxide Cathode on a Core of Tungsten-Activated Nickel.—Yu. G. Ptushinski. (*Zh. tekh. Fiz.*, Jan. 1956, Vol. 26, No. 1, pp. 232–234.) A detailed report on an experimental investigation of the activating mechanism of W in oxide cathodes.

621.385.032.216 **642**

The Evaporation of Barium from 'L' Cathodes.—I. Brodie & R. O. Jenkins. (*J. Electronics*, July 1956, Vol. 2, No. 1. pp. 33–49.) The possibility of reducing the evaporation rate by altering the porosity of the tungsten disk or by varying the Ba compound used to supply the activating Ba has been investigated experimentally. Differing theories regarding the mechanism of limitation of Ba evaporation are discussed and their range of validity indicated. See also 2918 of September.

621.385.032.216 **643**

Thermionic Emission from Oxide Cathodes as a Function of Core-Metal Impurities.—H. Bender. (*Le Vide*, May/June 1956, Vol. 11, No. 63, pp. 112–128. In French and English.) A review including tables showing the effect of various core impurities on emission.

621.385.032.216 **644**

Internally Coated Cathodes.—P. O. Hawkins & J. S. Thorp. (*Nature, Lond.*, 18th Aug. 1956, Vol. 178, No. 4529, pp. 380–381.) Measurements were made of the emission from hollow cathodes for different values of temperature, electric field and magnetic immersion field. The results confirm the view advanced previously [1260 of 1956 (Bright & Thorp)] that the emission occurs mainly at the edges of the hole. Currents much in excess of the space-charge-limited values may be obtained because of the predominance of the edge effect.

621.385.032.216 : 621.385.029.6 **645**

The Mechanism of Pulse Temperature Rise on the Surface of Thermionic Cathodes.—R. Dehn. (*Brit. J. appl. Phys.*, June 1956, Vol. 7, No. 6, pp. 210–214.) Spontaneous fluctuations observed in the cathode surface temperature of pulsed magnetrons are probably caused by resistive heating due to the passage of current through a highly resistive surface layer ; the phenomenon probably occurs in other thermionic emitters, particularly of the oxide-coated type, and must affect both operation and life.

621.385.032.216 : 621.396.822 **646**

Notes on a Source of Intermittent Noise in Oxide-Cathode Receiving Valves.—M. R. Child. (*Proc. Instn elect. Engrs*, Part B, Sept. 1956, Vol. 103, No. 11, pp. 667–668.) "One form of 'spike' noise in high-grade valves is shown to be due to intermittent leakage between electrodes caused by the deposition of barium or magnesium, or both, on the supporting micas. The magnitude of the effect is shown to increase with the anode voltage between 100 and 300 volts. No effect can be detected below 60 volts in the case of passive cores. The effect may be successfully avoided by the use of mica shields."

621.385.032.24 **647**

Study of the Surface of the Grid in a Vacuum Tube.—M. Wada & A. Sato. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, 1955, Vol. 6, Nos. 3/4, pp. 137–156.) In an experimental investigation of grid emission due to contamination by cathode material, it was found that at the same working temperature a control grid of gold wire is deactivated, presumably by the diffusion of gold atoms through the contaminated layer, while a molybdenum grid is activated. The results are discussed in relation to factors affecting work function.

621.385.3/.5 **648**

Determination of the Thermal Behaviour of the Control Grid of a Valve from its Emission Current Measured by a Pulse Method.—V. Ya. Kunin & M. O. Ratsun. (*Radiotekhnika i Elektronika*, March 1956, Vol. 1, No. 3, pp. 377–380.) The results obtained in a typical valve by the pulse method described agree with those calculated from an equation given by Wagener (*Z. tech. Phys.*, 1937, Vol. 18, No. 9, pp. 270–280 ; Abstract 4112 of 1937.)

621.385.83 **649**

Some Problems in the Theory of Focusing of Electron Beams.—P. P. Kas'yankov. (*C. R. Acad. Sci. U.R.S.S.*, 11th June 1956, Vol. 108, No. 5, pp. 813–816. In Russian.)

621.385.832 **650**

Limits of Electron Beam Focusing.—U. Pellegrini. (*Piccole Note Ist. super. Poste e Telecomunicazioni*, May/June 1956, Vol. 5, No. 3, pp. 346–360.) Factors limiting the reduction of the spot size in c.r. tubes are examined, and a simple equation for the spot radius is derived, taking account of the spherical aberration of the electron lens. A nomogram is given for evaluating the minimum attainable spread due to space-change effects under any beam conditions. The possibility of compensating spherical aberration by means of space-charge effects is mentioned [see also 1365 of 1956 (Dolder & Klemperer)].

621.385.832 : 621.397.62 : 535.623 **651**

Flat Tube for Colour TV. (See 582.)

621.385.832.032.7.002.2 **652**

The Choice of a Mould for the Manufacture of Glass Cones for Cathode-Ray Tubes with a Rectangular Screen by the Centrifugal Method.—V. Ya. Savel'ev. (*Zh. tekh. Fiz.*, March 1956, Vol. 26, No. 3, pp. 640–645.) Difficulties arise when the centrifugal method is applied to the manufacture of tubes with a rectangular screen, since the liquid glass tends to concentrate at the edges of the pyramid to which the screen is to be sealed. A calculation is made of the shape of a mould which would ensure that glass would reach all points of the wide part of the tube simultaneously. Some photographs of cones for 21-in. tubes produced in this manner are shown.

621.387 **653**

Thyratron Behaviour at Low Anode Voltages.—(*Mullard tech. Commun.*, July 1956, Vol. 2, No. 19, pp. 242–247.) A discussion of effects including delayed onset of anode conduction and delayed attainment of full conduction, resulting from use of anode voltages as low as or lower than twice the grid voltage.

621.387 **654**

Firing Delay and Build-Up Time of the Discharge in the Thyratron.—H. Appel & E. Fünfer. (*Z. angew. Phys.*, July 1956, Vol. 8, No. 7, pp. 322–327.) Measurements were made of the relation between the amplitude of the firing pulse and the delay and build-up times. For tetrodes, the delays are of the order of 10^{-7} s ; for tetrodes, of the order of 10^{-8} s ; they are nearly independent of grid bias. Over the range investigated, the build-up time varies with the pulse amplitude in triodes, but not in tetrodes.

621.387 **655**

Confirmation of the Laws developed by Rogowski and Fucks for Firing in Commercial Cold-Cathode Discharge Tubes.—W. Kluge & A. Schulz. (*Z. angew. Phys.*, July 1956, Vol. 8, No. 7, pp. 328–331.)

621.387 : 681.142 **656**

Gas-Diode Voltage Characteristics.—(*Elect. Rev., Lond.*, 15th June 1956, Vol. 158, No. 24, pp. 1029–1030.) An inexpensive method has been developed at the National Bureau of Standards for equalizing and stabilizing the voltage characteristics of low-cost indicator lamps, such as neon tubes, so as to render them suitable for use as computer elements. The process involves the application of pulses simultaneously to a large number of tubes.

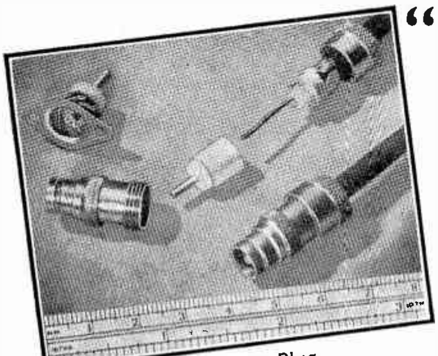
MISCELLANEOUS

621.3.002.2 **657**

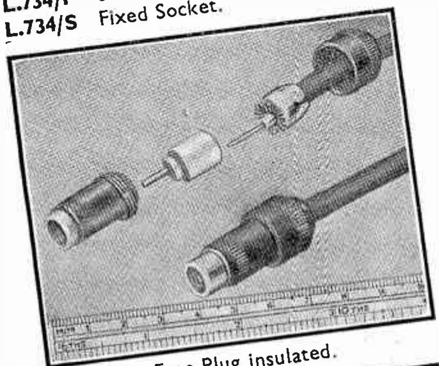
Quality Control in Electronics.—M. N. Torrey. (*Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1521–1530.) A review, with 65 references, discussing the objects and techniques of quality control in the manufacture of electronic equipment

"BELLING-LEE"

Coaxial Plugs & Sockets

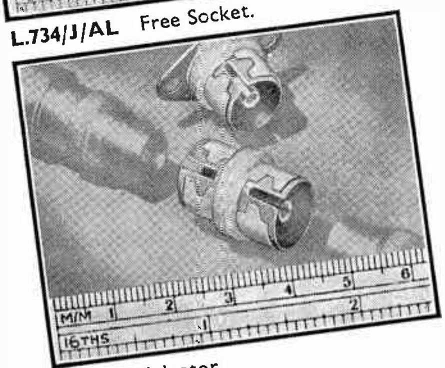


L.734/P Standard Free Plug.
L.734/S Fixed Socket.



L.781/P2 Free Plug insulated.

L.734/J/AL Free Socket.



L.616 Adaptor.
L.604/S Fixed Socket.

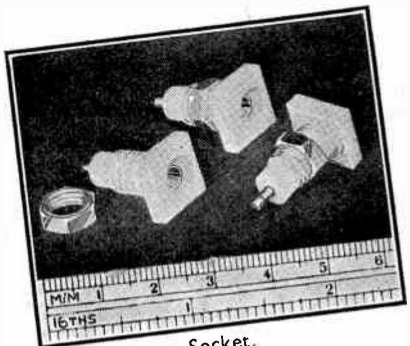
Our range of plugs L.734/P and L.781/P2 conform to the draft R.E.C.M.F. specification for television inlets. The insulated body and cap of L.781/P2 are made of nylon and are very robust.

Coaxial feeders of outside diameter from 0.312 in. Semi-airspaced to 0.156 in. solid can be accommodated in both L.734/P and L.781/P2. Complementary sockets for the above range of plugs are L.734/S, L.604/S (fixed) and L.734/J (free).

The range of plugs and sockets was originally devised to provide for television aerial feeders in domestic installations. For wavelengths very large in comparison with the dimensions of the plug and socket, the matching of cable and plug/socket characteristic impedances is of negligible importance. The main requirement is for low total self-capacitance, which is 1.0 pF in our design. This feature of low-capacitance is equally important in many other plug and socket applications in radio and electronic equipment, such as for the aerial input circuit to car radio installations. The characteristic impedance of the plug/socket combination is of the order of 50 ohms.

An adaptor, L.734/J, will be found extremely useful in extending coaxial cable runs in workshops and demonstration rooms. Any number of cable lengths may be connected.

The fixed socket L.604/S is the complementary mating member to our coaxial plugs. It is incorporated as a standard input by many manufacturers of television receivers and electronic apparatus. Type L.734/S is flush mounting.



L.1317 3 mm. Socket.
L.1318 4 mm. Socket.

Nylon Sockets

These are replacements for the well-known L.315 and L.316 sockets. They are moulded from high melting point nylon in a choice of 6 colours: white, green, yellow, red, blue and black. Other colours are available in quantities of 100 or more. Sockets have square flanges to facilitate neat group-mounting. Drilling centres should be not less than 0.5 in. nominal. The brass resilient socket is silver plated, and will accommodate plugs of two or three prong construction in addition to "O-Z" types. Solder spill is tin-dipped. Rated at 10 amps. Peak working 1.5 kV.

1922 — 1956

SPECIALISTS IN COMPONENTS

BELLING & LEE LTD

GREAT CAMBRIDGE ROAD, ENFIELD, MIDDX., ENGLAND

Telephone: Enfield 3322 · Telegrams: Radiobel, Enfield

A complete service
to Research and Industry

Measurements

Instrument Design

Design and development of instruments, microwave components and equipment.

Manufacturing capacity for prototypes and batch quantities. Full A.I.D. approval.

Specifications accepted at any stage and translated into your final requirements.

Investigations of dielectric materials over a wide range of temperature and frequency.

Specialist experience available to undertake component measurements.

Microcell Electronics

A DIVISION OF MICROCELL LIMITED

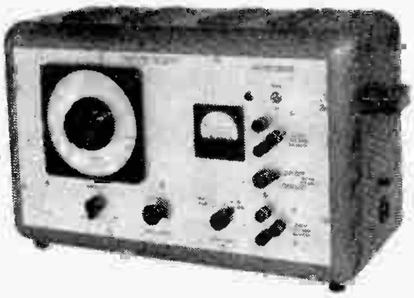
IMPERIAL BUILDINGS, 56 KINGSWAY, W.C.2

TELEPHONE BISHOPSGATE 6801

MIC 7899

5T

SIGNAL GENERATOR



LO 63G

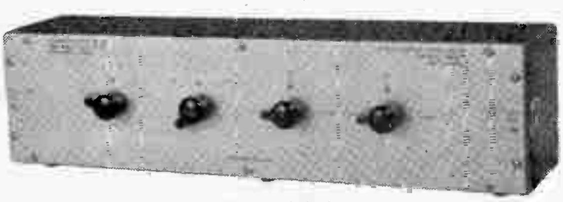
FREQUENCY 10 Cys to 110 Kc/s
OUTPUT 20 volts into 6 000 ohms
DISTORTION less than 1% over 30 Cys
ACCURACY ± 1½% or 0·5 cycle whichever the greater
OUTPUT LEVEL within ·5dB over 50 Cys

FREQUENCY METER

FM 406B Mk II

RANGE 0 to 100 Kc/s
ACCURACY ± 1%
INPUT VOLTAGE Min. 75 mV
Max. 15 volts
Provision for external recorder.

ATTENUATOR



RA 104

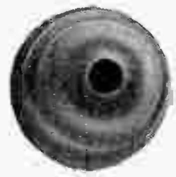
ATTENUATION 1dB to 99dB in 1dB steps
ACCURACY ± 2% to 100 Mc/s
± 5% to 250 Mc/s
INPUT VOLTAGE 3 volts maximum
CHARACTERISTIC IMPEDANCE 75-ohm
CONNECTIONS 75-ohm co-axial sockets

BRITISH PHYSICAL LABORATORIES

RADLETT HERTS

P.B.COW

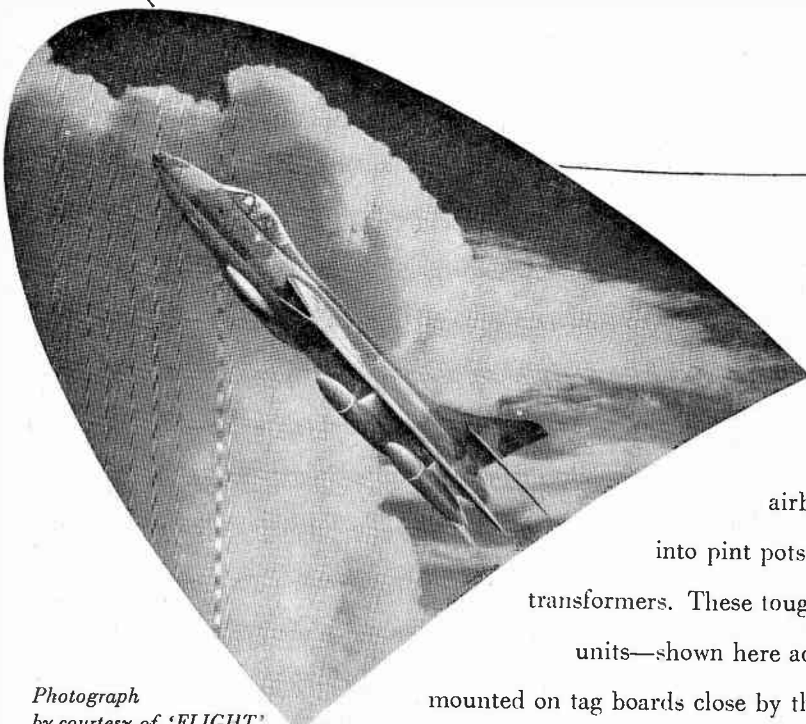
for



rubber

P. B. COW & COMPANY LIMITED
RUBBER MANUFACTURING SPECIALISTS FOR EVERY INDUSTRY.
INDUSTRIAL DIV: 470 STREATHAM HIGH ROAD, S.W.16. POLLARDS 4481

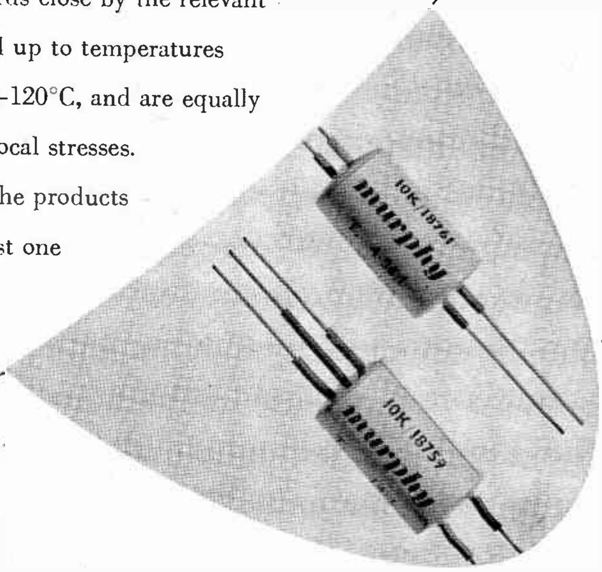
murphy miniature engineering helps aircraft



Photograph by courtesy of 'FLIGHT'

Designers of airborne radar put quarts into pint pots with Murphy potted transformers. These tough little resin-moulded units—shown here actual size—are mounted on tag boards close by the relevant valves. They stand up to temperatures as low as −65°C, as high as +120°C, and are equally unaffected by moisture and local stresses.

Potted transformers are just one of the products of the Murphy Electronics Division—just one more reason why you should keep in touch with Murphy.



keep in touch with **murphy**

Aircraft navigation equipment
Mobile radio telephones
Communications receivers
Distance measuring equipment
Electronic test gear
Interference tracing equipment

MURPHY RADIO LIMITED (ELECTRONICS DIVISION) · WELWYN GARDEN CITY · HERTFORDSHIRE

CRC30E

G.E.C.

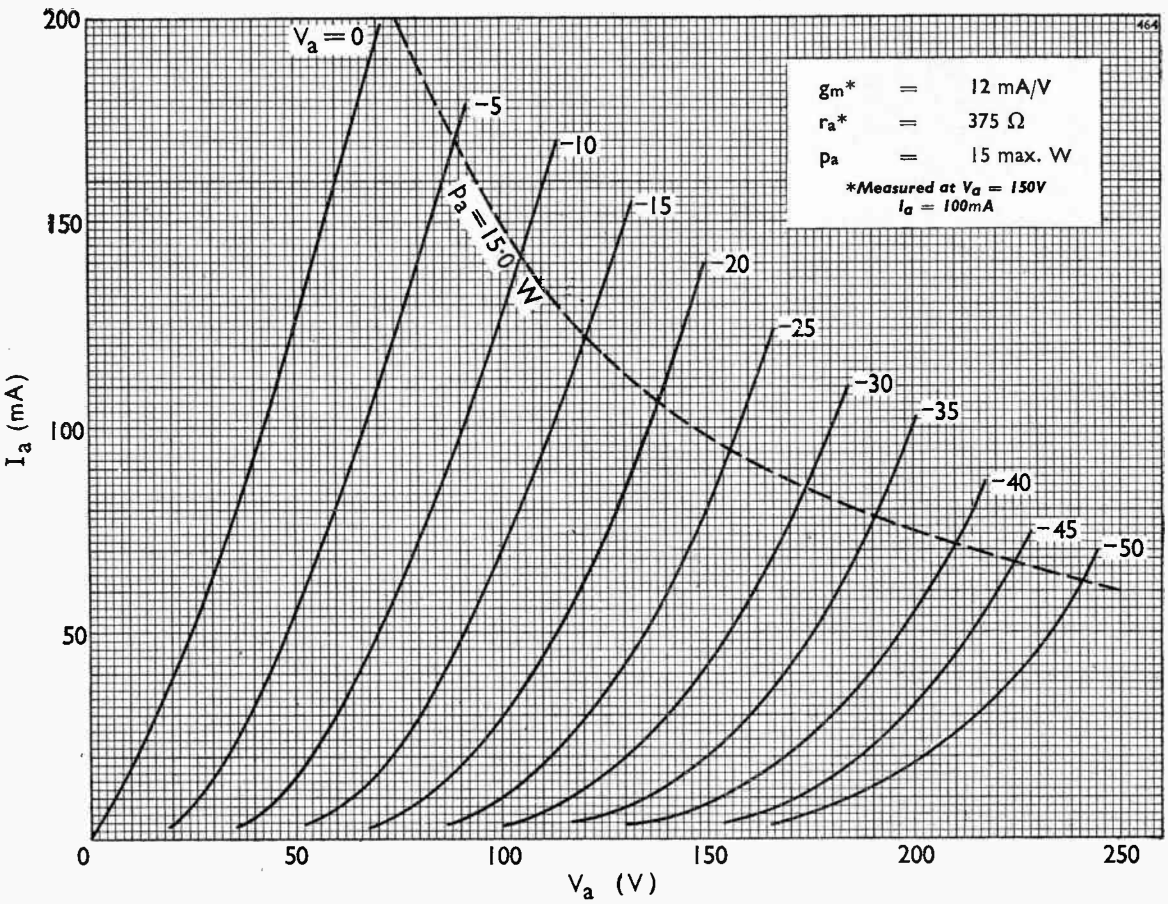
Valves for Voltage Stabilisation

A 2293

THE A2293 is a new low impedance triode particularly suitable as the series valve in stabilised power packs. List price 27/-.

RATINGS

V_h	6.3	V
I_h	0.95	A
V_a	300 max.	V
I_a	120 max.	mA
Base	B9A	



For further details write to the G.E.C. Valve & Electronics Dept.

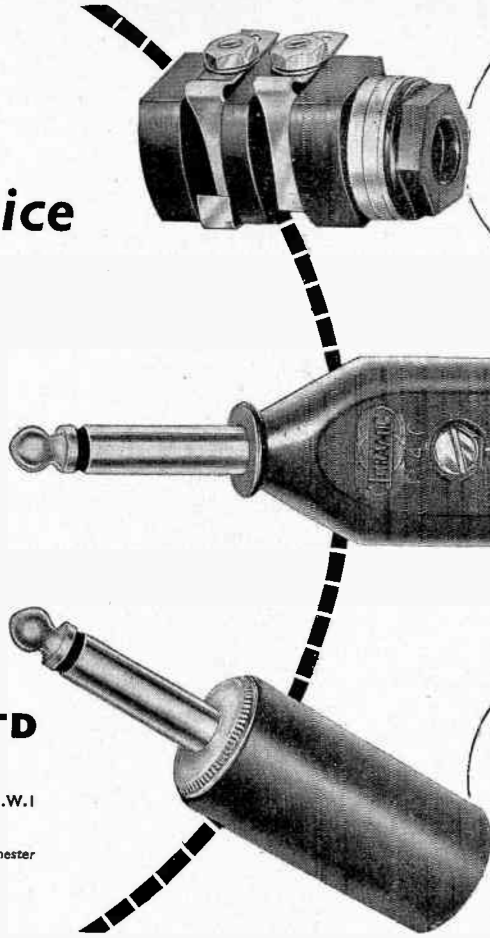
THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON. W.C.2

IGRANIC

. . . for every service

For radio, television, communications and the many other plug and jack applications on innumerable electrical appliances the choice has long been Igranic.

Now increased production facilities ensure immediate delivery plus the continuance of that meticulous standard of reliability which has always characterised Igranic Plugs and Jacks.



MIDGET JACK P73 Moulded Bakelite. Suitable for switching-in high frequency circuits. Capacity between springs eliminated. Silver contacts, one hole fixing, perfect contact.

TYPE P40 PLUG Moulded Bakelite. Nickel plated metal parts. Especially suitable for extension speakers, headphones, and similar applications.

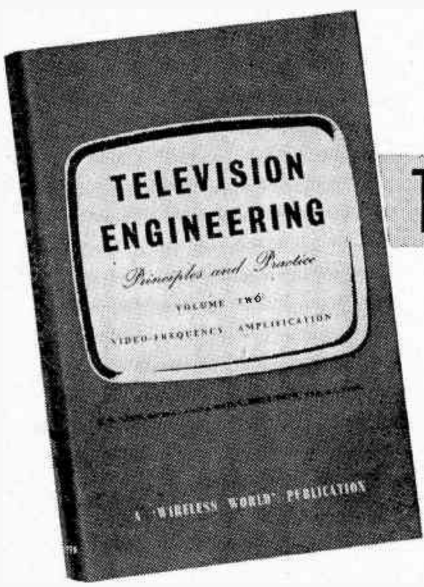
TYPE P50 PLUG Cylindrical Bakelite case. Nickel plated metal parts. Ideal for amplifiers and other applications where concentric cable is used.

IGRANIC ELECTRIC CO LTD
HEAD OFFICE & WORKS, BEDFORD

LONDON & EXPORT OFFICE:
VICTORIA STATION HOUSE, 191 VICTORIA STREET, LONDON, S.W.1
Grams: Igranic London
Branch Offices:
Birmingham · Bristol Cardiff · East Anglia · Glasgow · Leeds · Manchester
Newcastle · Sheffield

A METAL INDUSTRIES GROUP COMPANY

IG/53 P2838



A BBC Training Manual By S. W. Amos, BSc (Hons) AMIEE and D. C. Birkinshaw, MBE MA MIEE

TELEVISION ENGINEERING

Principles and Practice
Vol. II: Video-Frequency Amplification

Here is the second volume of a series of four which will form the most comprehensive survey ever compiled of modern television principles and practice. Originally written for instruction of the B.B.C.'s own operating and maintenance staff, this volume describes the fundamental principles of video-frequency amplifiers, and examines the factors which limit their performance at the extreme of the passbands. A wide variety of circuits is described and particular attention is paid to the use of the feedback. There is also a section dealing with the special problems of camera-head amplifiers.
Self-contained mathematical derivations are included at the ends of chapters.

Second volume of a comprehensive work

$8\frac{3}{4}'' \times 5\frac{1}{2}''$ 272 pp. Illustrated

35s net BY POST 36s 2d

Published for 'Wireless World'

Obtainable from booksellers or direct from Iliffe & Sons Limited, Dorset House, Stamford Street, London, SE1

ADVANCE COMPONENTS LTD., ROEBUCK ROAD, HAINAULT, ILFORD, ESSEX TELEPHONE HAINAULT 4444

10 to 300 Mc/s DIRECTLY CALIBRATED

the Advance V.H.F. SIGNAL GENERATOR

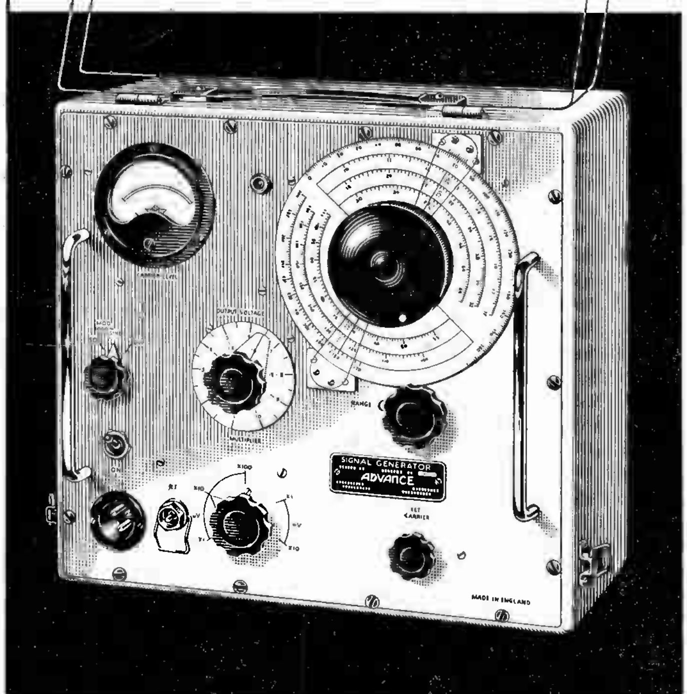
The type D1/D is a V.H.F. Signal Generator designed for making measurements in the frequency range 10 to 300 Mc/s. Its outstanding features are:

- 50 : 1 slow-motion drive
- Linear scale and vernier for high resetting accuracy
- Sine and square wave modulation
- Attenuator variable over 100 db.
- Negligible stray field
- Rugged construction and light weight (only 34 lb.)

NETT PRICE IN U.K.

£97

Full technical details available in leaflet R26



MODEL D1/D

The ADVANCE V.H.F. SIGNAL GENERATOR TYPE D1P/2

Directly calibrated in six ranges

2 Mc/s to 190 Mc/s

NETT PRICE IN U.K.

£110

This is a special version for the alignment of narrow band communication receivers which incorporates:

- CRYSTAL MODULATOR ELIMINATING SPURIOUS F.M.
- 2 Mc/s CRYSTAL REFERENCE OSCILLATOR
- BUFFER STAGE

Full technical details available in leaflet R37

ADVANCE COMPONENTS LTD., ROEBUCK ROAD, HAINAULT, ILFORD, ESSEX TELEPHONE HAINAULT 4444

Iliffe books for the radio and television engineer

Television Receiver Servicing

E. A. W. Spreadbury M BRIT IRE

volume one

Mainly intended for the professional radio service engineer who, having already become skilled in the art of fault tracing in radio receivers, wishes to extend his activities to television servicing. Others interested in television will, however, also find it a fund of information not available in other current books on the subject. It does not attempt to teach the principles of radio servicing, but extends them to the more complex circuits and techniques of television. This first volume covers the time-bases and their associated circuits only; and probably at least half the servicing problems likely to be met by the engineer occur in these sections.

volume two

Deals with all the other sections of the modern receiver, including the video stage, tuning circuits, sound channel, power supplies and aerial arrangements. Attention is also paid to such matters as vision interference suppression, the various multi-channel tuning systems now in use, vision automatic gain control, and the problem of reflections and "ghosting". A final chapter gives much valuable information on the technique of circuit alignment. The text is presented in a practical and straightforward manner, and the numerous illustrations include a wide variety of actual circuits, each of which is discussed in detail. These two volumes form a complete exposition of the subject, and they can be strongly recommended to service engineers who intend to take the Television Servicing Certificate Examination conducted by the City and Guilds of London Institute and the Radio Trades Examination Board, particularly in the practical test.

21s net each volume by post 22s 1d

Studio Engineering for Sound Broadcasting

A BBC Engineering Training Manual by members of the Engineering Division BBC

This book has been compiled for the primary purpose of training BBC technical staff in the general principles underlying operational procedures at the Corporation's studio centres. It is now made available outside the Corporation in the belief that broadcasting staff throughout the world, on both the engineering and non-engineering sides, will find a great deal of interest and practical value in its pages. Some of the information is specific in that it relates to equipment and procedures specially designed to meet BBC requirements, but the greater part of the text, dealing with principles of audio-frequency engineering, has a very general application.

25s net by post 25s 11d

from your bookseller

OR DIRECT FROM ILIFFE & SONS LIMITED

DORSET HOUSE, STAMFORD STREET, SE1

FULL LIST OF BOOKS AVAILABLE ON REQUEST

EXCELLENT REPRODUCTION *with the*

LOCKWOOD

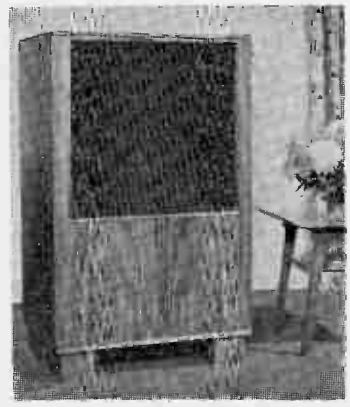
Standard Loudspeaker Cabinet

The Lockwood Standard Loudspeaker Cabinet has been designed to give reproduction of a very high order and can be "tuned" to suit any combination of L.S. Units.

Accepted as a standard for high-quality monitoring by broadcasting, television and recording studios throughout the world, this cabinet is also suitable in every way for the home.

* THE LOCKWOOD STANDARD LOUDSPEAKER CABINET has been developed from the Monitoring Loudspeaker Cabinet used by the B.B.C. (B.B.C. Patent No. 696,671).

* *Wireless World* Nov. and Dec. 1950.



Two versions are available: Major Model . . £35 Minor Model . . £25

Brochure free on request.
Export and Tropical Models available. Trade enquiries invited.

Demonstrations in London by City Sale and Exchange Ltd., 93/94 Fleet Street, E.C.4
Telephone FLE. 9391/2

Two new model cabinets, a Console for housing complete equipment, also a Radio-gram cabinet will be ready during the early part of February. Enter your name on our mailing list now, for details when ready.

LOCKWOOD *Acoustically Designed Cabinets*

LOCKWOOD & COMPANY (Woodworkers), LTD., LOWLANDS ROAD, HARROW, MIDDX. *BYRon* 3704

THE WORLD'S GREATEST BOOKSHOP

FOYLES

★ ★ FOR BOOKS ★ ★

FAMED CENTRE FOR

Technical Books

JOIN THE SCIENTIFIC BOOK CLUB!
You buy Books published at 10/6, 12/6, 15/- and more—*for ONLY* 4/-. Write for details.

119-125 CHARING CROSS ROAD, LONDON, WC2
GERrard 5660 (20 lines) Open 9–6 (including Saturdays)
Two minutes from Tottenham Court Road Station

INDUCTA

A.I.D. Approved

TRANSFORMERS *of all types up to 25 KVA for Single or Three Phase operation, Phase conversion, etc.*

MAINS *Output and Special Purpose Transformers for Radio Equipment; Chokes, etc.*

COILS *for Contactors, E.M. Brakes, Air Valves, etc., and coil WINDINGS for all purposes.*

SOLENOIDS *for A.C. and D.C. Operation.*

W. F. PARSONAGE & Co LTD
INDUCTA WORKS
PARK RD BLOXWICH WALSALL
TELEPHONE: BLOX. 66464

A New Wide Range Delayed Square Pulse Generator

Model 5001

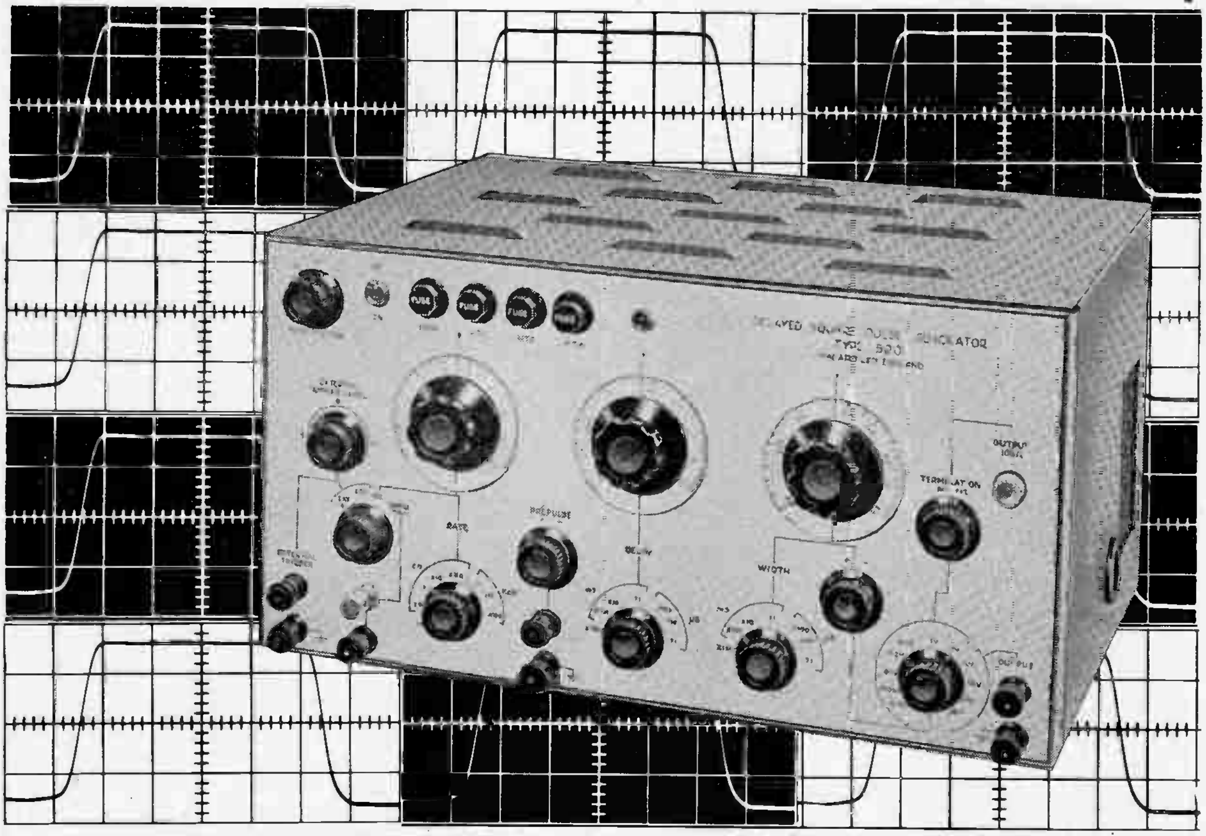
WITH ACCURATE TIME AND VOLTAGE CALIBRATIONS

RISE TIME 10 mμsec independent of pulse width

SQUARE WAVE OUTPUT—0·25 c/s to 2·5 Mc/s

Waveforms show 0·2 μsec pulse on 25 cm/μsec sweep

10 million to 1 range of pulse rate, width & delay calibrated by direct reading dials within 5%



Internal Multivibrator of new type gives highly stable frequencies continuously variable from 0·1 c/s to 1 Mc/s

External Trigger from signals of any waveform and polarity at amplitudes down to 0·2 V and frequencies up to 2·5 Mc/s

Single Pulses at any range setting by push button

Delay of Pre-pulse to main pulse—jitter free and continuously variable from 0·2 μsec to 2 secs

Pre-pulse output 20 volts positive or negative—0·2 μsec wide

Main Pulse amplitude—20 mV to 50 V positive or negative

OUTPUT VOLTAGE CALIBRATED TO WITHIN ± 2%

Negligible overshoot on any range — no sag on long pulses. Width continuously variable from 0·2 μsec to 2 secs. ± 5%

The most accurate and versatile box of pulses yet made available to electronic engineers

NAGARD LTD
OSCILLOSCOPES

NAGARD LIMITED
18 Avenue Rd., Belmont, Surrey
Telephone VIGilant 9161/2

RPA 11330

ELECTRONIC & RADIO ENGINEER

CLASSIFIED ADVERTISEMENTS

Advertisement Rates. *6d. per word, minimum charge 6/-, each paragraph charged separately. Remittances payable to Iliffe & Sons Ltd., Dorset House, Stamford Street, S.E.1. Series discount of 15% is allowed for 12 consecutive insertions.*

Box Numbers *are available at an additional charge of 2/- to defray cost of registration and postage. Replies should be addressed Box No. 0000, c/o "Electronic & Radio Engineer", Dorset House, Stamford Street, London, S.E.1. The Publishers are not responsible for clerical or printers' errors although every care is taken to avoid mistakes.*

Press date for March 1957 issue first post Friday, 22nd February, 1957

SITUATIONS VACANT

DIPLOMATIC WIRELESS SERVICE

APPLICATIONS are invited from qualified candidates to fill, by competitive interview, the following posts.

1. ELECTRONIC ENGINEER to supervise small development laboratory. Candidates must have a degree or a Higher National Certificate or equivalent qualification in Electronic Engineering or Physics and some experience in the design of Electronic Equipment.

STARTING salary: £950 rising to £1,160 per annum.

2. ENGINEERS with HIGHER NATIONAL CERTIFICATE or equivalent qualification for development work and inspection of existing installations at home and abroad. Some experience desirable in one or more of the following subjects:

Telephone installation (manual and automatic)
Radio and electronic engineering
Audio engineering (sound systems)

SALARY £790 (at age 30) to £925 plus £50 per annum qualification allowance and overseas subsistence when travelling.

3. ENGINEERS with NATIONAL CERTIFICATE or equivalent City and Guilds Certificates, to maintain installations at various overseas stations. Overseas tours usually of thirty months' duration, with up to one year in the United Kingdom between tours. In most cases families may accompany husbands. Candidates must have some experience in one or more of the following subjects:

Telephone installations (manual and automatic)
Machine telegraph equipment
Maintenance of electrical apparatus
Radio engineering
Audio engineering (sound systems)

SALARY £510 (at age 21) to £790 per annum or £415 (at age 21) to £690 per annum according to experience. Plus £50 per annum special allowance when employed on certain types of equipment.

FOREIGN Service Allowance paid during overseas service.

ALL first appointments are on a temporary basis with possibilities of establishment subsequently.

SALARIES quoted are London rates. Provincial rates are slightly lower.

CLOSING date for applications February 21st, 1957.

WRITE giving age, qualifications and experience to:

CHIEF ESTABLISHMENT OFFICER,
DIPLOMATIC WIRELESS SERVICE,
HANSLOPE PARK, HANSLOPE,
WOLVERTON,
BUCKINGHAMSHIRE

[1023

ROTAX, LTD.

Aircraft Electrical Engineers

SERVO ENGINEERS

SERVO Engineers, with experience of magnetic amplifiers and with Degree or Higher National Certificate in Electrical Engineering, required for the design and development of speed, voltage and temperature control units for aircraft purposes. Housing accommodation in the New Town for successful applicants within a reasonable time, preference being given to those persons registered on an approved housing list in the London area.

APPLY to

PERSONNEL MANAGER
MAYLANDS AVENUE
HEMEL HEMPSTEAD, HERTS

[1017

ASSISTANT Instrument Engineer is required for duties in the Development Department involving the design and development of instruments up to the prototype stage for measurements on chemical and metallurgical plants. A young person recently qualified at degree or professional level in Physics, Electronic or Electrical Engineering would be preferred and National Service obligations should be completed. Applications with brief details to Personnel Manager, Imperial Smelting Corporation Limited, St. Andrew's Road, Avonmouth, Bristol, quoting reference AIE/ERE. [1030

SITUATIONS VACANT

MECHANICAL DESIGNERS AND DRAUGHTSMEN

PHILIPS CROYDON WORKS LIMITED invite applications from Mechanical Designers and Draughtsmen for a number of vacancies now available in the Design Laboratories of their new Radio and Television plant at Croydon, Surrey.

DRAUGHTSMEN—these posts are concerned with manufacturing development for mass production from designers' sketches or models of radio/electronic equipment, and applicants should have experience in light engineering. Production experience would be an advantage.

DESIGNERS—to design electro/mechanical equipment for production in large quantities by flow-line manufacture. Applicants should have a knowledge of press work, automatics, plastic moulding and die casting, and experience of wood cabinet construction and assembly methods would be an added advantage. Candidates should preferably be of HNC standard with workshop experience.

THE starting salaries for draughtsmen of the standard required would be £850 per annum, and for designers with the requisite experience and qualifications the minimum starting salary would be £1,000 per annum.

IN addition to a progressive salary policy, the Company operates a generous pension and life assurance scheme, together with extended sick-pay and holiday plans.

APPLICANTS who are interested in these opportunities are invited to write to:

THE PERSONNEL OFFICER,
PHILIPS CROYDON WORKS LIMITED,
COMMERCE WAY,
PURLEY WAY,
CROYDON, SURREY.

QUOTING reference: No. DD/R. [1029

MULLARD RESEARCH LABORATORIES

require

Engineers, Physicists

and

Mathematicians.

THE Telecommunications Division of Mullard Research Laboratories has some vacancies in expanding research teams engaged in radar, microwave, telecommunications and particle accelerator programmes. Engineers, physicists and mathematicians who enjoy working in an atmosphere of enthusiasm and who wish to extend their interests and experience to new fields are invited to apply. Recent research or advanced development experience will be an advantage. In general, university graduates will be appointed to fill these vacancies, but applications from holders of the Higher National Diploma or Certificate will be sympathetically considered.

EXCELLENT conditions of employment, including Superannuation and Life Assurance Scheme. Apply Mr. G. A. Taylor, Personnel Officer, Mullard Research Laboratories, Cross Oak Lane, Salfords, Redhill, Surrey, quoting reference RNG. [1020

ATOMIC ENERGY RESEARCH ESTABLISHMENT, Harwell, has vacancies in the Electronics Division in a team working on instrument and system "Post Design" studies and special maintenance and reliability investigations covering a wide field of nucleonic equipment.

APPLICANTS should possess G.C.E. in five subjects, including two scientific subjects at Advanced level, or have equivalent qualifications. Experience in the electronics field or in similar instrumentation and/or circuit problems is desirable.

THE post will be graded, according to age, qualifications and experience, as: Experimental Officer: £940–£1,155 p.a. Assistant Experimental Officer: £375 (at age 18)–£815 p.a. (Highest starting salary: £665.)

SEND Post Card for further details and application form which must be returned by February 20th, 1957, to Establishment Officer, A.E.R.E., Harwell, Didcot, Berks, quoting reference 691/45. [1022

SITUATIONS VACANT

TANGANYIKA BROADCASTING CORPORATION

APPLICATIONS are invited for a vacancy for a Broadcasting Engineer in the service of the Tanganyika Broadcasting Corporation, with salary scale £981 rising to £1,863 a year.

THE successful candidate will be appointed on contract terms with gratuity at the rate of 13½% of total salary drawn, and will enter the salary scale at a point determined by qualifications and experience. The term of contract will be for one tour of thirty to thirty-six months and passages by air or sea will be granted from the U.K. and return for the officer and his family. Housing or rent assistance will be provided.

QUALIFICATIONS: Applicants should be over the age of 28 and be Graduates of the Institution of Electrical Engineers or have an engineering degree or diploma granting exemption from Sections A and B of the Institution's examinations and have had not less than two years' experience which can be directly related to broadcasting.

DUTIES: Include staff management and responsibility for the maintenance, installation and operation of broadcasting studios and transmitters.

WRITE to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/42128/WJ [1021

TRANSISTORS AND COMPUTERS

THE BRITISH TABULATING MACHINE COMPANY, LTD., is expanding activities in the field of transistor applications to digital computers. We, therefore, are looking for junior and senior engineers to help build up this Section and to create careers for themselves. Whilst experience in pulse and/or transistor circuit technique would, of course, be a great advantage, we are quite prepared to train you at full salary if you are bringing an open mind and enthusiasm to bear on this fascinating new field. Our well equipped Laboratories are modern and spacious and are situated in pleasant country surroundings. You can live in the modern Stevenage New Town in a house or flat and you are still within striking distance of London. Our holidays run from two weeks to four weeks according to grade, and we have a good contributory Pension Scheme. You are invited to write in, quoting reference ER/509, to the Personnel Superintendent, The British Tabulating Machine Company, Ltd., Icknield Way, Letchworth, Herts, to arrange an interview. [1031

BRITISH SCIENTIFIC INSTRUMENT RESEARCH ASSOCIATION

Nucleonic Instrumentation

ELECTRONIC engineers and physicists with a good knowledge of electronics who wish to enter the field of nucleonic instrumentation are invited to apply for an important post in this rapidly expanding subject.

THE successful candidate will be given the opportunity of working at A.E.R.E. for a period. He is expected eventually to become the head of the department of nucleonics at B.S.I.R.A. The salary range is £800 to £1,300 per annum, with F.S.S.U. benefits, and promotion to higher grades is dependent solely upon merit.

APPLICATIONS, including two references, should be addressed to the Director, J. Thomson, M.A., D.Sc., F.Inst.P., M.I.E.E., at the Association's laboratories, Sira, South Hill, Chislehurst, Kent, and should be received not later than 31st March, 1957. [1024

ELECTRONIC Engineers and Physicists required by Ministry of Supply Research and Development Establishments chiefly at Malvern, Worcs, Farnborough, Hants, Sevenoaks, Kent. Candidates should have or be obtaining 1st or 2nd class honours degree or equivalent with experience or interest in Radio, Radar and Communications; instrumentation for telemetry and other measurements; electronic devices; application of advanced techniques to other fields, e.g. armament. Appointments initially in grade of Scientific Officer (minimum age 21) with salary according to research experience, etc., in range £565–£995 p.a. (Superannuable). Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting D 514/6A. [1018

SITUATIONS VACANT

KUWAIT OIL COMPANY require a Radio Technician for service in Kuwait. Candidates must possess O.N.C. in radio engineering subjects in addition to full apprenticeship. Five years' post-apprenticeship experience is essential and this should include assembly and testing of V.H.F. equipment, medium power transmitters with associated communications receivers. Duties will include supervision of operation, maintenance and repair of Marine and Land V.H.F. and H.F. and will involve practical work. Age 25–32. Salary according to experience plus generous allowances, Pension Scheme, kit allowance. Write for application form giving brief details and quoting K.2072 to Box P/33, c/o 191 Gresham House, E.C.2. [1025

TV Development Engineers required, primarily for wired TV systems. To be based on laboratory in Jersey, but must be prepared to do field work in United Kingdom. Assistance with housing in Jersey. Salary according to qualifications, with a minimum of £900 per annum. All expenses paid whilst on field work. Write Box 6057. [1026

E.M.I. COLLEGE OF ELECTRONICS. Assistant Lecturer, graduate or equivalent, required to teach Radio and Telecommunications Principles to our Three-Year and Four-Year courses. Applicants should preferably possess industrial, and some instructional, experience. Salary £761—£25—£1,148, with appropriate allowances for honours degree, training and experience. Applications stating age, qualifications and experience to: The Principal, The E.M.I. College of Electronics, 10 Pembridge Square, London, W.2. [1028

SITUATIONS VACANT

RADIO Maintenance Technician required by Police Department, Government of Northern Rhodesia, for one tour of thirty-six months in first instance. Salary, according to age and experience, in scale £705 rising to £1,200 a year. Free passages. Liberal leave on full salary. Candidates, preferably aged 25 to 30, must possess academic qualifications in Mathematics and Physics of matriculation standard, together with sound knowledge of installation and maintenance of modern low- and medium-powered V.H.F. static and mobile equipment, H.F. transmitters and receivers, petrol generators and diesel electric sets. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/41913/WJ. [1019

BOOKS, ETC.

"TELEVISION Explained." By W. E. Miller, M.A. (Cantab), M.Brit.I.R.E. The sixth edition of a book which assumes a knowledge of the ordinary sound radio receiver but no previous knowledge of television circuits. It is non-mathematical, written in simple language, and comprehensively illustrated by many diagrams and photographs. It will prove of great assistance to all students of television, to radio service engineers who wish to embark upon television work and want to understand the principles and circuits involved, and to knowledgeable owners of television receivers who would like to understand the working of their set. 12*s*. 6*d*. net from all booksellers. By post 13*s*. 3*d*. from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

BOOKS, ETC.

"TELEVISION Engineering: Principles and Practice." Volume II: Video-Frequency Amplification. This volume describes the fundamental principles of video-frequency amplifiers and examines the factors which limit their performance at the extremes of the passband. A wide variety of circuits is described and particular attention is paid to the use of feedback. There is a section dealing with the special problems of camera-head amplifiers. 35*s*. net from all booksellers. By post 36*s*. 2*d*. from Trader Publishing Co., Ltd., Dorset House, Stamford Street, London, S.E.1.

"RADIO Circuits: Step-by-Step Survey of Superhet Receivers," 3rd Edition. By W. E. Miller, M.A. (Cantab), M.Brit.I.R.E., Editor of *The Wireless and Electrical Trader*. Although this book deals mainly with the superhet receiver it is equally applicable to the straight set. The circuit of the superhet is dealt with section by section up to the complete receiver. 5*s*. net from all booksellers, or 5*s*. 7*d*. by post, from Trader Publishing Co., Ltd., Dorset House, Stamford Street, London, S.E.1.

"INTRODUCTION to Valves." By R. W. Hallows, M.A.(Cantab), M.I.E.E., and H. K. Milward, B.Sc.(Lond), A.M.I.E.E. Describes the principles, construction, characteristics and uses of most types of radio valves. The approach is simple and, as far as possible, non-mathematical, but the book provides the student with a thorough understanding of valves and how they work. 8*s*. 6*d*. net from all booksellers. By post 9*s*. 2*d*. from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

Index to Advertisers

Printed in Great Britain for the Publishers, Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1 by Gibbs & Bamforth, Ltd., St. Albans.

UPRIGHT MOUNTING ELECTROLYTICS

Catering for the unusual

The saving of space resulting from the use of these Upright Mounting Electrolytic Condensers is one of the chief reasons for their popularity.

Types CE170 to CE173 include a number of single and dual section capacities in current use in the European markets: a threaded moulded boss of $\frac{5}{8}''$ diameter ensures interchangeability with Continental types.

Types 928 and 526 are of particular interest to designers of rectifier units as small and efficient substitutes for large high voltage paper condensers. Type 526 ($\frac{1}{2}''$ and $\frac{3}{4}''$ diam. boss) will be suitable for the majority of circuits, but in the exceptional cases of higher outputs or where something 'in hand' is required, Type 928 ($\frac{3}{4}''$ diam. boss) with 800v. peak working is recommended.

All these condensers have high gain etched foil electrodes and are of "All-Aluminium" internal construction. The maximum working temperature of all types is 60°C.

Cap. in µF.	Pk. Wkg. Volts	Surge Volts	Ripple M/A	Dimns. in Ins. Lgth.	Dimns. in Ins. Diam.	T.C.C. Type No.
50	350	400	260	$3\frac{7}{16}$	1	CE171LE
16	450	550	120	$2\frac{3}{16}$	1	CE170PEA
25	450	550	150	$2\frac{3}{16}$	1	CE170PE
32	450	550	210	$3\frac{7}{16}$	1	CE171PEA
50	450	550	260	$3\frac{7}{16}$	1	CE171PE
50—50	350	400	300	$3\frac{7}{16}$	$1\frac{1}{4}$	CE172LE
25—25	450	550	180	$3\frac{7}{16}$	1	CE171PEB
50—50	450	550	310	$3\frac{7}{16}$	$1\frac{3}{8}$	CE173PE
8	800	900	150	$4\frac{1}{2}$	$1\frac{1}{2}$	928
8	600	700	100	$4\frac{1}{2}$	1	526
16	600	700	160	$4\frac{1}{2}$	$1\frac{1}{2}$	526
32	600	700	240	$4\frac{1}{2}$	$1\frac{1}{2}$	526

THE TELEGRAPH CONDENSER CO. LTD

RADIO DIVISION · NORTH ACTON · LONDON W3 · Tel: ACOrn 0061