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~~6-4-47~~

WIRELESS ENGINEER

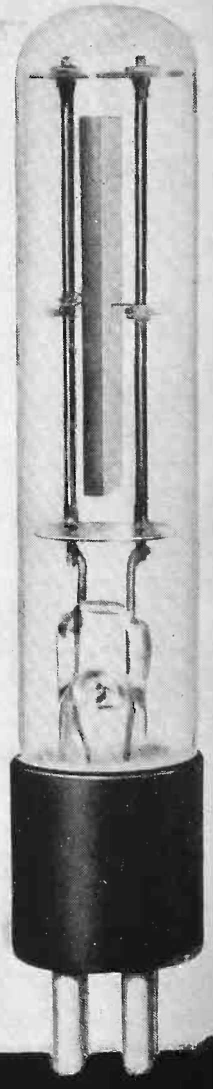
THE JOURNAL OF RADIO RESEARCH & PROGRESS

FEBRUARY 1947

VOL XXIV TWO SHILLINGS AND SIXPENCE · · No. 281

QUARTZ CRYSTAL UNITS

FOR FREQUENCY SUBSTANDARDS



100 Kc/s TYPE JCF/200
LOW TEMPERATURE
COEFFICIENT MODEL

ACCURACY ± ·01%

ADVANTAGES

- Stability.
- Vacuum mounted, performance independent of climatic conditions.
- Low temperature coefficient.
- Compact, takes little space. ⅝" dia. × 3" overall excluding pins.
- Fits standard miniature deaf-aid valve holders.
- Delivery from stock.

MADE IN ONE OF THE MOST UP-TO-DATE CRYSTAL FACTORIES IN THE WORLD.

For further information & prices write to :-

SALFORD ELECTRICAL INSTRUMENTS LTD.
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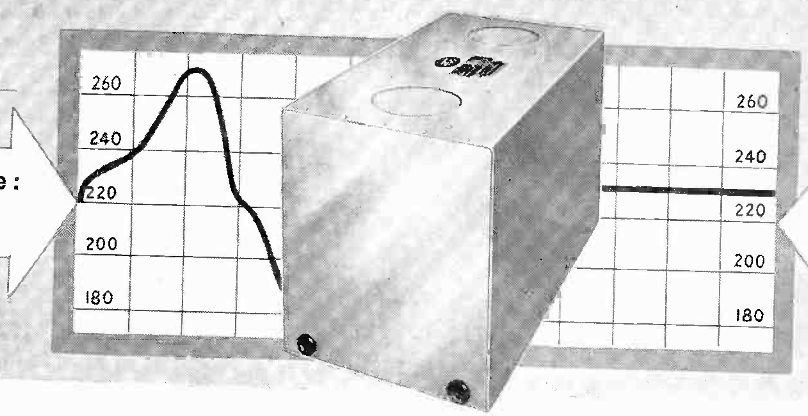
Telephones : BLAckfriars 6688 (6 lines). Telegrams and Cables : "SPARKLESS, MANCHESTER"
Proprietors: THE GENERAL ELECTRIC Co. Ltd., of England

AUTOMATIC VOLTAGE REGULATORS

A·T
'After Test'

B·A·T
'Best After Test'



**nput Voltage :
5 Volts.**

**Constant Output Voltage :
230 Volts ± 0·5%**

General Characteristics

Constant A.C. Output

Example : 230 volts ± 0·5%—50-cycles/sec.—single phase. ny output voltage may be ordered (see below).

Wide A.C. Input Voltage Limits

Example : 190-255 volts, 50-cycles, 1-phase. Other single-hase voltages or frequencies can be dealt with, on special rders.

Entirely Automatic—Quick Action

There are no moving parts. No adjustments need ever be ade and no maintenance is required. The regulating action virtually instantaneous, the time required for adjustment a new voltage, or load condition being so short that it is ite imperceptible by ordinary means.

Load Rating

Eight standard, nominal ratings are carried in stock as listed low. Others can be built, including models giving (example) 5 v. ± 1% on 190-255 v. input : or multiple outputs, all ulated. The regulators also stabilize well under all load nditions, from no-load to 100% load.

General Advantages and Uses, etc.

Constant A.C. input voltage is essential for the effective operation of many electrical devices, both industrial and laboratory patterns. Examples : X-ray apparatus, incandescent-lamp light sources (photometers, photo-printing, colour comparators, photo-electric cell applications, spectrography, etc.), laboratory test-gear (vacuum tube volt meters, amplifiers, oscillators, signal generators, standards of frequency, etc.) : the larger patterns for stabilizing a complete laboratory room or test-bench : the smaller units as integral components of equipment.

Priorities, Etc.

No Priority is now required. "M" Certificates (Iron and Steel Control) are also not now required.

Complete Data

Please request Bulletin VR 10744

EIGHT STOCK MODELS ARE OFFERED

Type	Watts	A.C. Input Voltage	Output Voltage	Net Wt.	Price
VR-10	10	190-255 50~ 1-phase	230 v. ± 0·5 per cent. Or, as ordered (see text above)	3 lbs.	£5 - 15
VR-20	20			7 lbs.	£8 - 0
VR-60	60			17 lbs.	£10 - 10
VR-150	150			42 lbs.	£13 - 10
VR-300	300			62 lbs.	£22 - 10
VR-500	500			68 lbs.	£29 - 10
VR-1000	1000			120 lbs.	£47 - 10
VR-2500	2500			450 lbs.	£175 - 0

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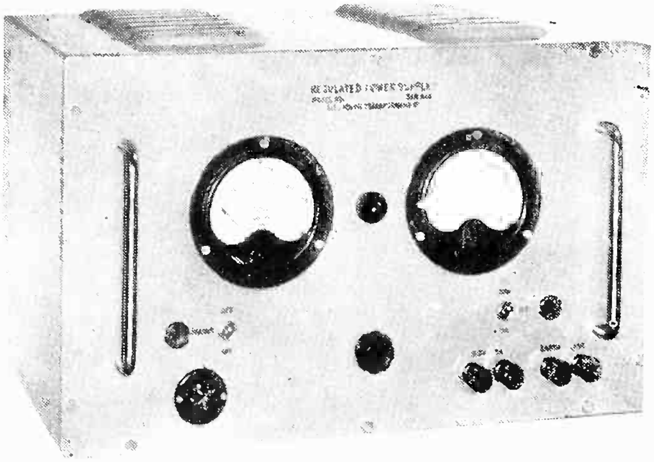
There is an ever increasing need for electronically stabilised Power Supplies for general Laborator use and for inclusion in other electronic equipment.

Whatever your requirement may be, whether for 10,000 Volts at a few milliamperes or for a fe Volts at 20 or 30 Amperes, the unrivalled experience of our design staff is at your instant service

We shall be pleased to advise and assist in any of your problems.



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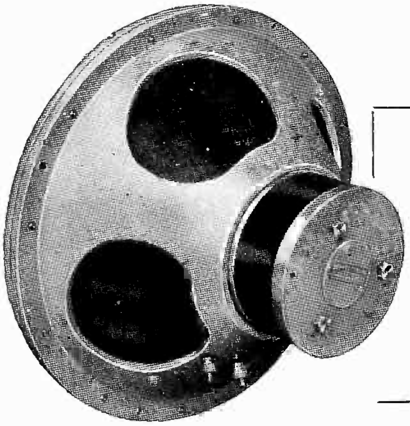
Pedigree

The Goodmans Loudspeaker of to-day is the latest of a long line of instruments, each the product of the same policy of forward-looking research and development adopted by the company at its inception nearly a quarter of a century ago. The 18-inch model illustrated is a thoroughbred that carries on the established Goodmans "tradition of excellence."



Overall Diameter ..
Power Handling Capacity .. 50 w
Flux Density 14,000 ga
Total Flux 270,000 maxw
Weight 35

FIDELITY G EFFICIENCY

GOODMANS *Loudspeakers*

GOODMANS INDUSTRIES LTD • LANCELOT ROAD • WEMBLEY • MID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DUST
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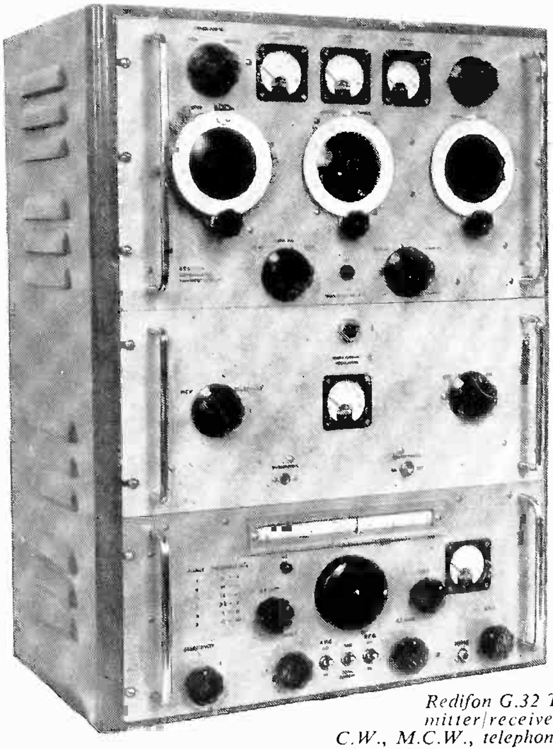

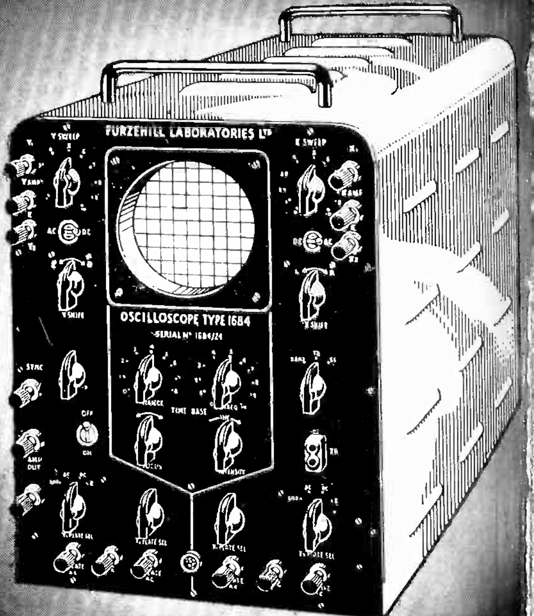
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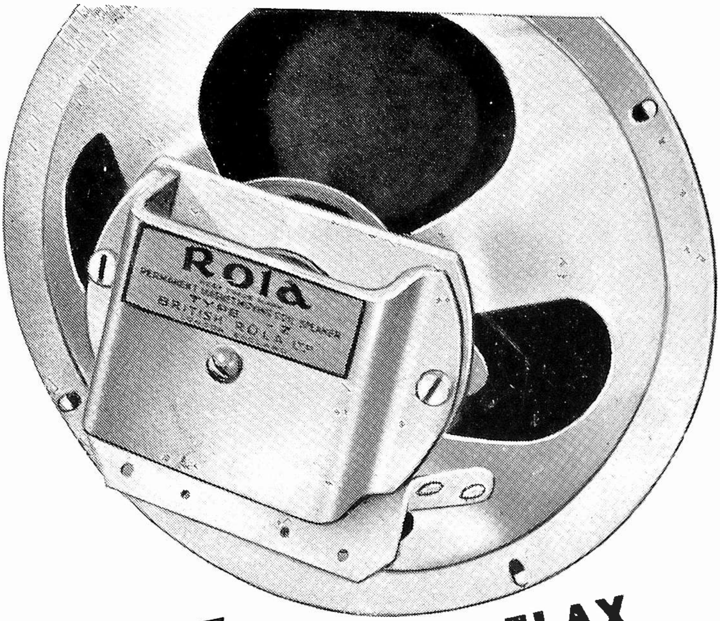
OSCILLOSCOPE TYPE 1684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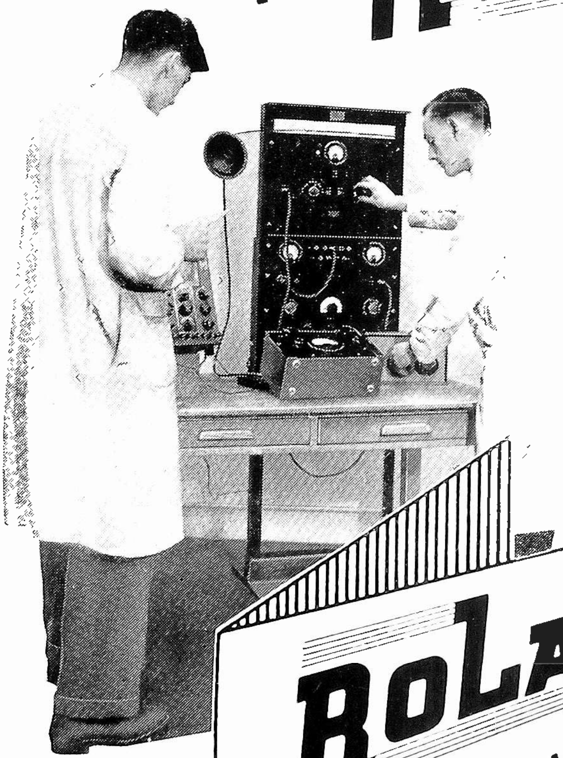
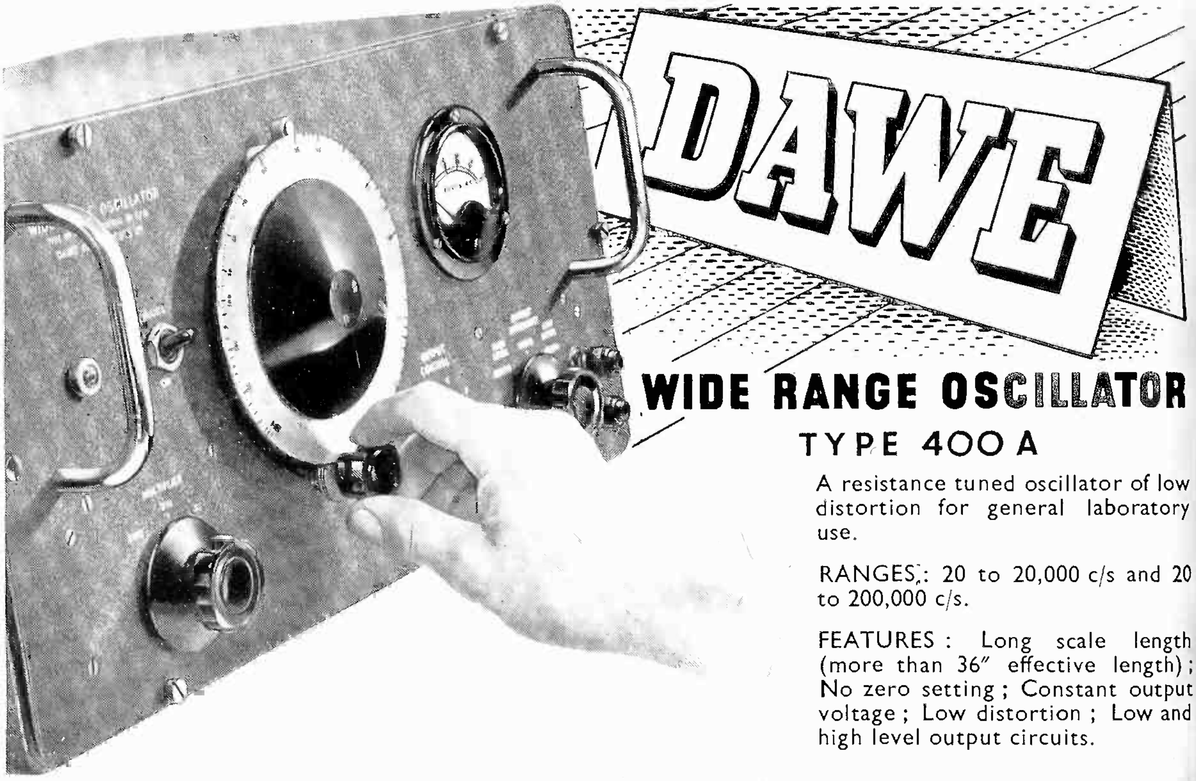
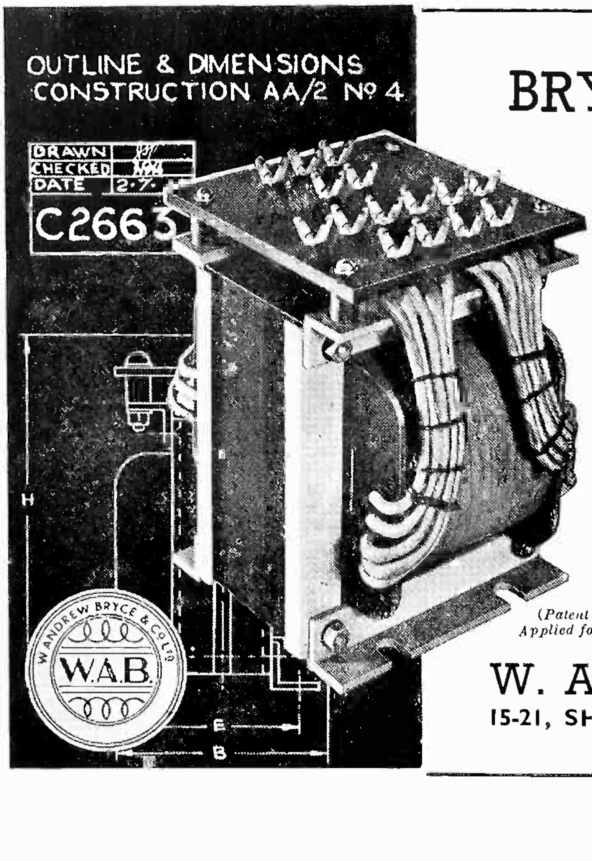
BRITISH ROLA LTD




DAWE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The high permeability of MUMETAL makes it the outstanding material for screening delicate instruments and equipment from uni-directional and alternating magnetic fluxes. A complete range of standard MUMETAL boxes and shields is available, and shields for special requirements can be made to order. If you have a screening problem our technical experts will be pleased to assist in its solution. Your enquiries are invited.

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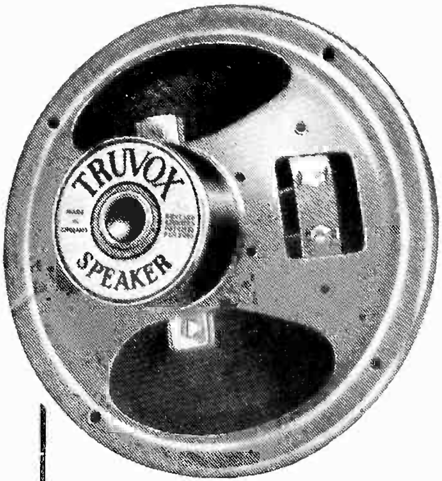

Truvox, pioneers in public address equipment, offer this new range of "Monobolt" permanent magnet moving coil speakers for radio receivers, with a patented assembly making for accurate and economical production and giving unshakeable rigidity in transit and use. Response curves can be adjusted to special requirements, and full technical specifications are available on request.

- Entirely new patented construction with single bolt fixing of components concentrically locates the chassis and complete magnet assembly.
- Brass centring ring prevents magnet being knocked out of centre.
- Special magnet steel gives powerful flux with compactness and light weight.
- Speech coil connections carried to suspension piece, ensuring freedom from rattles, cone distortion and cone tearing.
- Clean symmetrical surfaces, no awkward projections.
- Speech coil and former bakelised to prevent former distortion and speech coil turns slipping or becoming loose.
- Two point fixing to the suspension piece with four point suspension for the speech coil.
- Widely spaced fixing points for the suspension permit maximum movement of the cone, producing the lowest response physically obtainable from each size of speaker.

Supplied in four sizes—5in., 6½in., 8in., and 10in.

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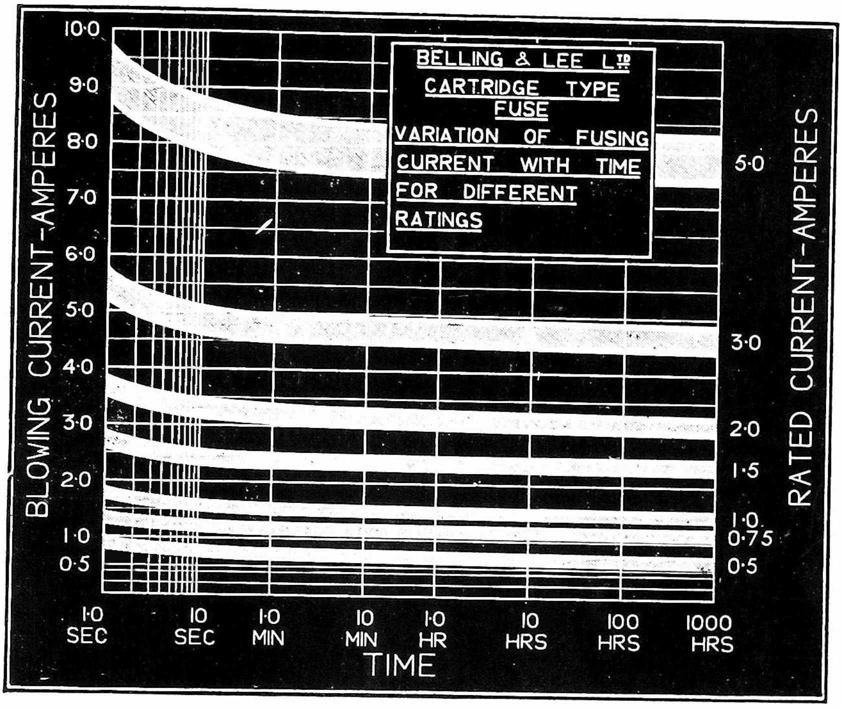
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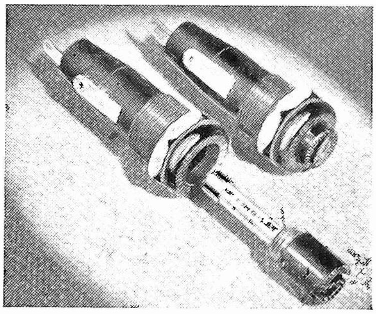
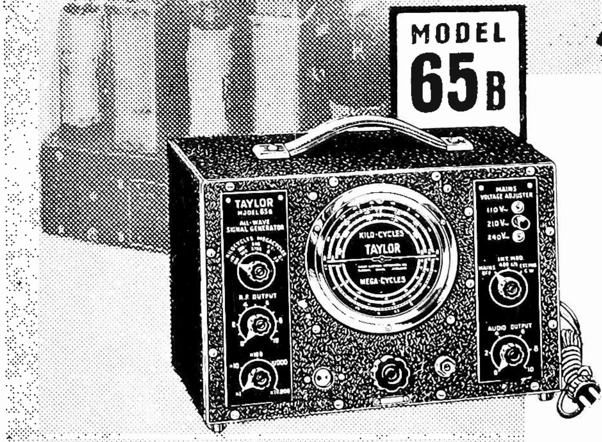
7·0
6·0
5·0
4·0
3·0
2·0
1·0
0·5
RATED CURRENT-AMPERES
5·0
3·0
2·0
1·5
1·0
0·75
0·5
1·0 SEC
10 SEC
1·0 MIN
10 MIN
1·0 HR
10 HRS
100 HRS
1000 HRS
TIME

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TAYLOR MODEL 65B ALL-WAVE SIGNAL GENERATOR
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TAYLOR
MEGA-CYCLES
MAINS VOLTAGE ADJUSTER
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210V
240V
R.F. OUTPUT
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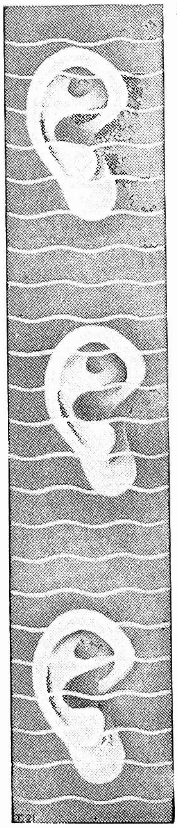
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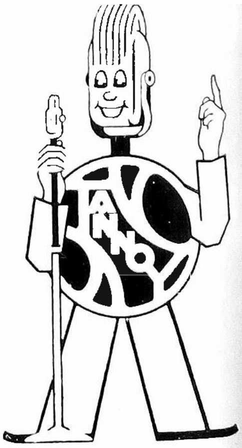

TANNOY

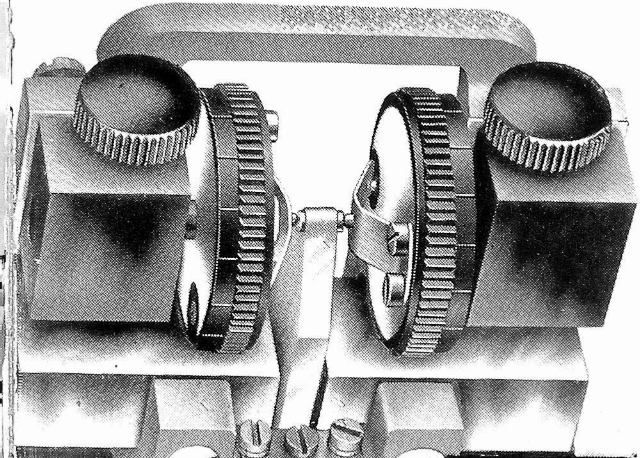
ARPENTER

High Speed Polarised

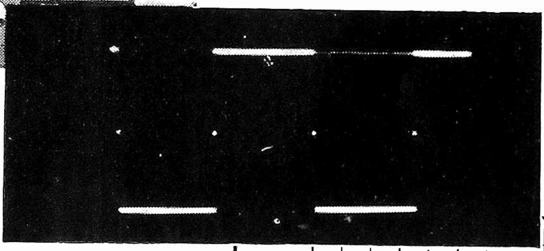
RELAY

The Carpenter Relay in its standard adjustment reproduces, with a 5 AT input, square pulses from less than 2 milli-seconds upwards with a distortion of 0.1mS, i.e., 5% for 2mS pulses or 1% at 10mS.

This unequalled performance is due to inherent features of the design of the relay, ensuring short transit time, high sensitivity and low hysteresis.

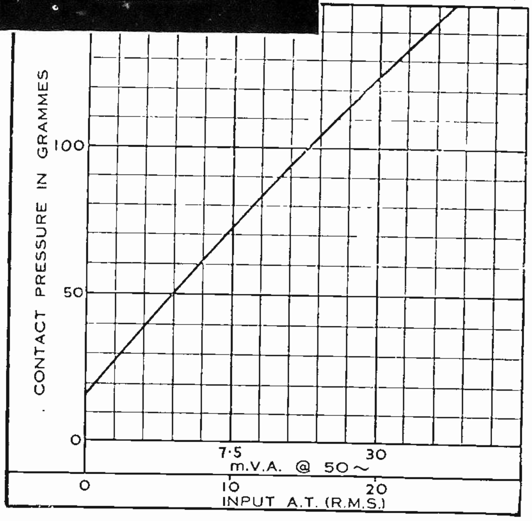


Above) *Contact mechanism of Relay showing* *ed compliant mountings of side contacts.*



ight) *Unretouched photograph (3 sec. exposure)* *illogram showing contact performance of Relay* *cial adjustment for a measuring circuit; coil* *18 AT (25 mVA) at 50 c/s.*

● (Below) *Graph showing contact pressures developed at 50c/s against mVA and ampere turns input for type 3E Carpenter Relay.*



re is complete absence of contact rebound any input power and contact pressures exceptionally high *(see graph)*. Adjust-t can be made with great ease. Moreover, e the armature is suspended at its centre ravity, the relay has high immunity from cts of mechanical vibration and there o positional error. Effective screening is vided against external fields. Because of se characteristics, the Carpenter Relay many applications in the fields of measure-t, speed regulation, telecontrol and the in addition to the obvious use in telegraph uits; details of models suitable for such oses will be supplied willingly on request.

NSIONS IN COVER: 2$\frac{3}{8}$×1$\frac{5}{16}$×4$\frac{1}{4}$. WEIGHT with standard socket: 22 ozs.

Ask for Booklet 1017 W.E.

EPHONE MANUFACTURING CO. LTD.

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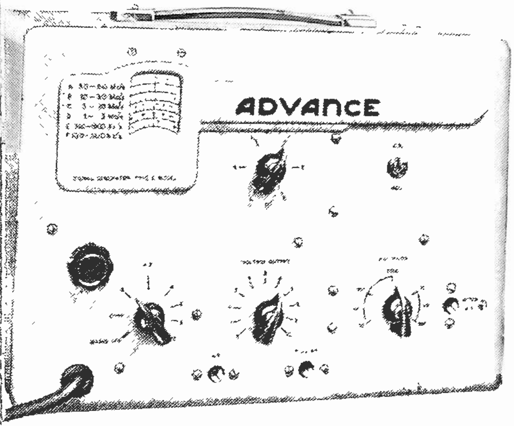
GRADE 1

A "*Laboratory*" INSTRUMENT. . .

but *NOT* "Laboratory" Price!



The newest addition to the "Advance" range of Signal Generators places an instrument of laboratory class within the financial scope of every radio service engineer and experimenter. The discerning engineer will appreciate its accuracy and stability, its **exceptionally wide range** which covers all frequencies required for radio and television receivers, and its accurate attenuating system which enables sensitivity measurements to be made on highly sensitive receivers up to 60 Mc/s. Send for fully descriptive pamphlet.

SUMMARY OF MAIN FEATURES:

RANGE: 100 Kc/s—60 Mc/s on fundamentals (up to 120 Mc/s on Second Harmonic).

ACCURACY: Guaranteed within ±1%.

ATTENUATION: Constant impedance system embodying a matched 75 ohms transmission line.

INTERNAL MODULATION: 30% at 400 c/s.

STRAY FIELD: Less than 3 microvolts at 60 megacycles.

ILLUMINATED DIAL: Total scale length 30."

POWER SUPPLY: 110-210-230-250-volts. 40-100 c/s consumption approx. 15 watts.

DIMENSIONS: 13" x 10½" x 7¾" deep overall.

WEIGHT: 15 lbs.

FINISH: Attractive steel case, sprayed durable cream enamel. Leather carrying handle.

PRICE **19 Gns.**

The New Advance TYPE 'E' *Signal Generator*

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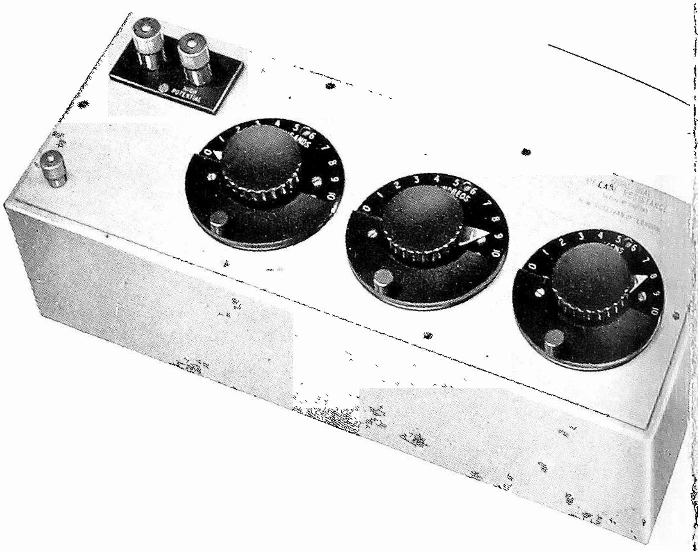
ALL ACCURACIES
AND ALL FREQUENCIES

SULLIVAN-GRIFFITHS
DUAL DIAL NON-REACTIVE
DECADE RESISTANCES
FOR ALL FREQUENCIES

NOVEL AND PATENTED

ACCURACY BETTER THAN 0.1%



Screened Resistances of guaranteed accuracy exactly similar to our well-known Decade Resistances but specially arranged so that one box of a given number of dials gives many different values of maximum resistance. Thus a three dial box (as illustrated) may be used for instance for

three decades of	**Thousands,**	**Hundreds**	and **Tens**	a total of 10000 ohms.
or three decades of	**Hundreds,**	**Tens**	and **Units**	a total of 1000 ohms.
or three decades of	**Tens,**	**Units**	and **Tenths**	a total of 100 ohms.
or three decades of	**Units,**	**Tenths**	and **Hundredths,**	a total of 10 ohms.

The advantages of such a system will be obvious, for in addit to the economy involved much space is saved and the resic resistance and inductance is much reduced.

The resistances are available in 3 dial, 4 dial and 5 dial types w subdivision of 0.001% to 0.1% depending of course on the num of dials incorporated.

THESE INEXPENSIVE DECADE BOXES ARE AD FOR ECONOMY AS GENERAL PURPOSE RESISTA AND FOR ALTERNATING CURRENT BRIDGE BALAN

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WIRELESS ENGINEER

The Journal of Radio Research & Progress

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FEBRUARY 1947

Vol. XXIV. No. 281

CONTENTS

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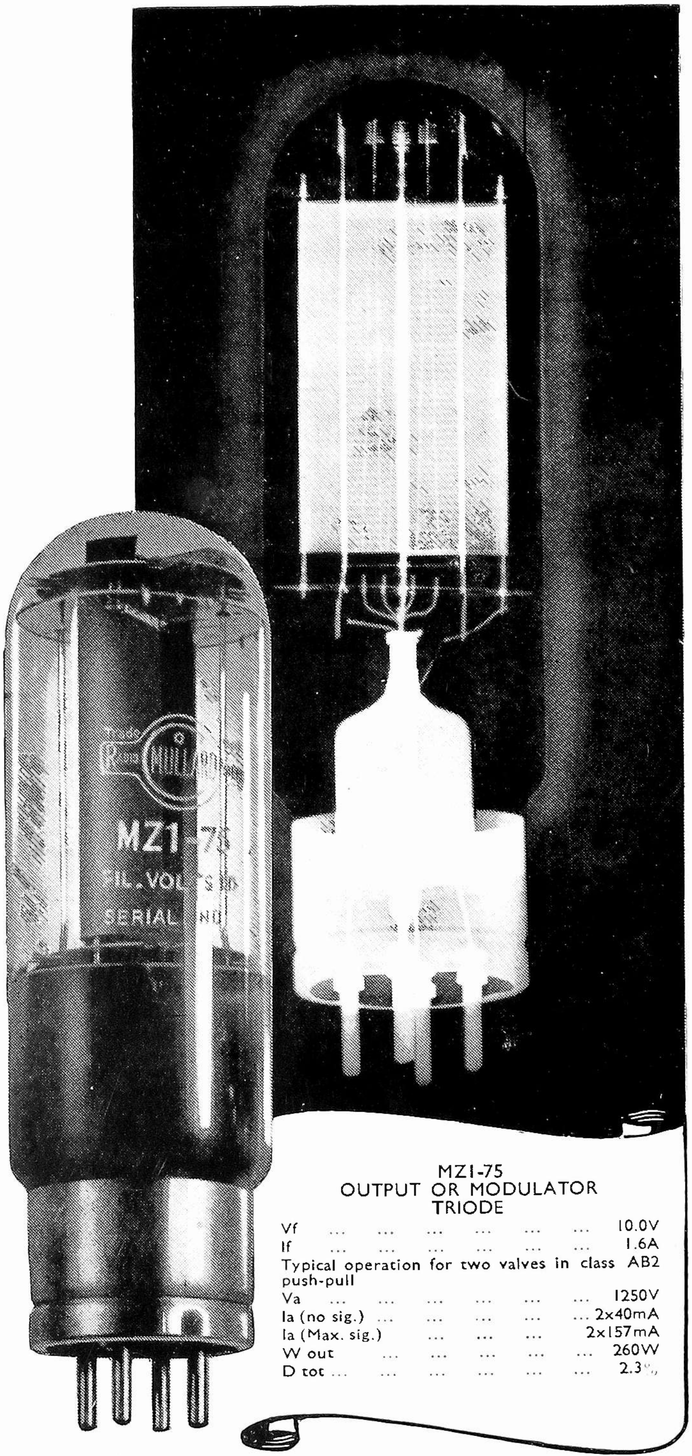


MZ1-75
OUTPUT OR MODULATOR
TRIODE

Vf	10.0V
If	1.6A

Typical operation for two valves in class AB2 push-pull

Va	1250V
Ia (no sig.)	2x40mA
Ia (Max. sig.)	2x157mA
W out	260W
D tot	2.3%

For modulation and L.F. amplification

HERE'S A BETTER VALVI

All things being equal, the real measure a valve's performance is the length of tin it will operate with undiminished efficienc In this respect the MZ1-75 scores heavil Like all Mullard transmitting and industri valves, it has been designed with an eye cost per life-hour.

Modern manufacturing methods ensure reliability and offer the additional adva tage that all valves of the same type a characteristically consistent. The long-lif oxide-coated filament is unaffected fluctuations in the mains supply, and al permits operation at an economical ano voltage.

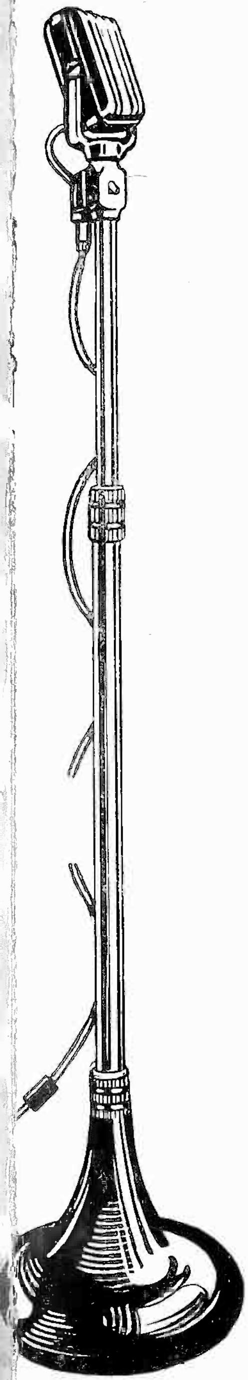
A glance at the data panel with the factors in mind will explain why the MZ 75 wins the approval of communicatio engineers who want a better valve f modulation and L.F. Amplification.

For further developments watch **Mullar**

THE MASTER VALV

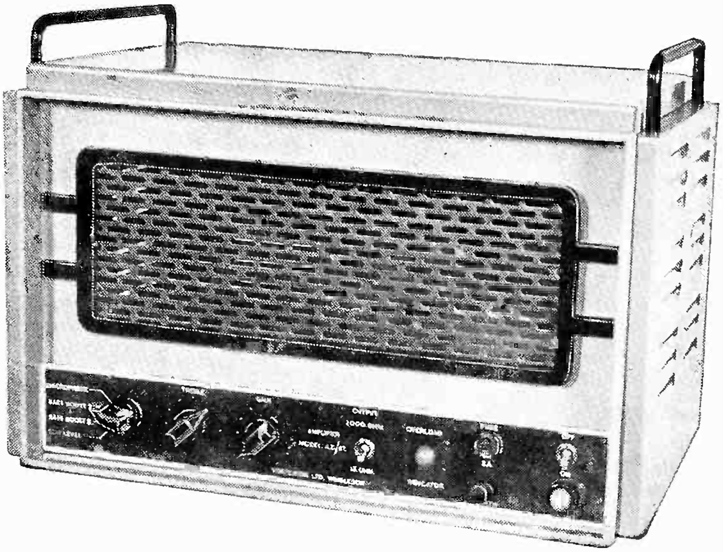
Mullard

Technical data and advice on the applications of the MZ1-75 Triode can be obtained from
THE MULLARD WIRELESS SERVICE CO., LTD., TRANSMITTING AND INDUSTRIAL
VALVE DEPARTMENT, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2



Virtually Distortionless

A.D/47 AMPLIFIER



This is a 10-valve amplifier for recording and play-back purposes for which we claim an overall distortion of only 0.01 per cent., as measured on a distortion factor meter at middle frequencies for a 10-watt output.

The internal noise and amplitude distortion are thus negligible and the response is flat plus or minus nothing from 50 to 20,000 c/s and a maximum of .5 db down at 20 c/s.

A triple-screened input transformer for 7½ to 15 ohms is provided and the amplifier is push-pull throughout, terminating in cathode-follower triodes with additional feedback. The input needed for 15 watts output is only 0.7 millivolt on microphone and 7 millivolts on gramophone. The output transformer can be switched from 15 ohms to 2,000 ohms, for recording purposes, the measured damping factor being 40 times in each case.

Built-in switched record compensation networks are provided for each listening level on the front panel, together with overload indicator switch, scratch compensation control and fuse. All inputs and outputs are at the rear of the chassis.

Send for full details of Amplifier type AD/47.

Vortexion
LIMITED

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WIMBLEDON, LONDON,
S.W.19.

Telephones : LIBerty 2814 and 6242/3.
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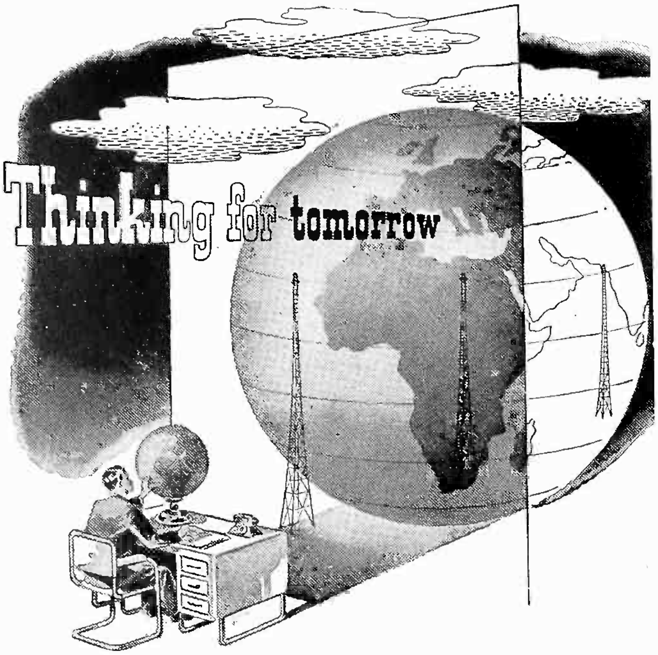
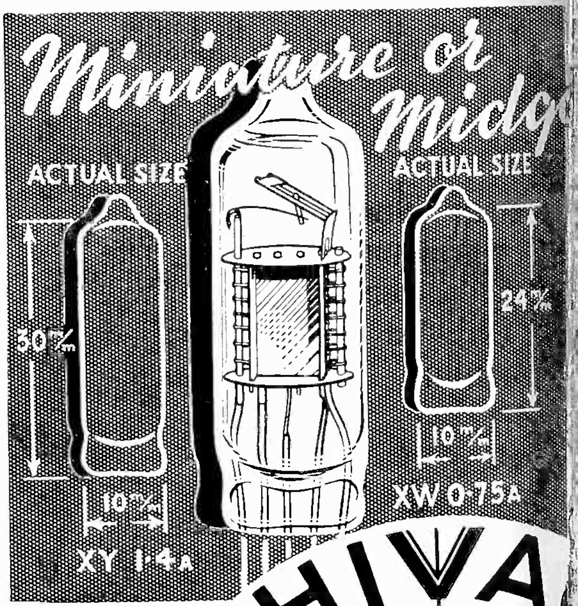
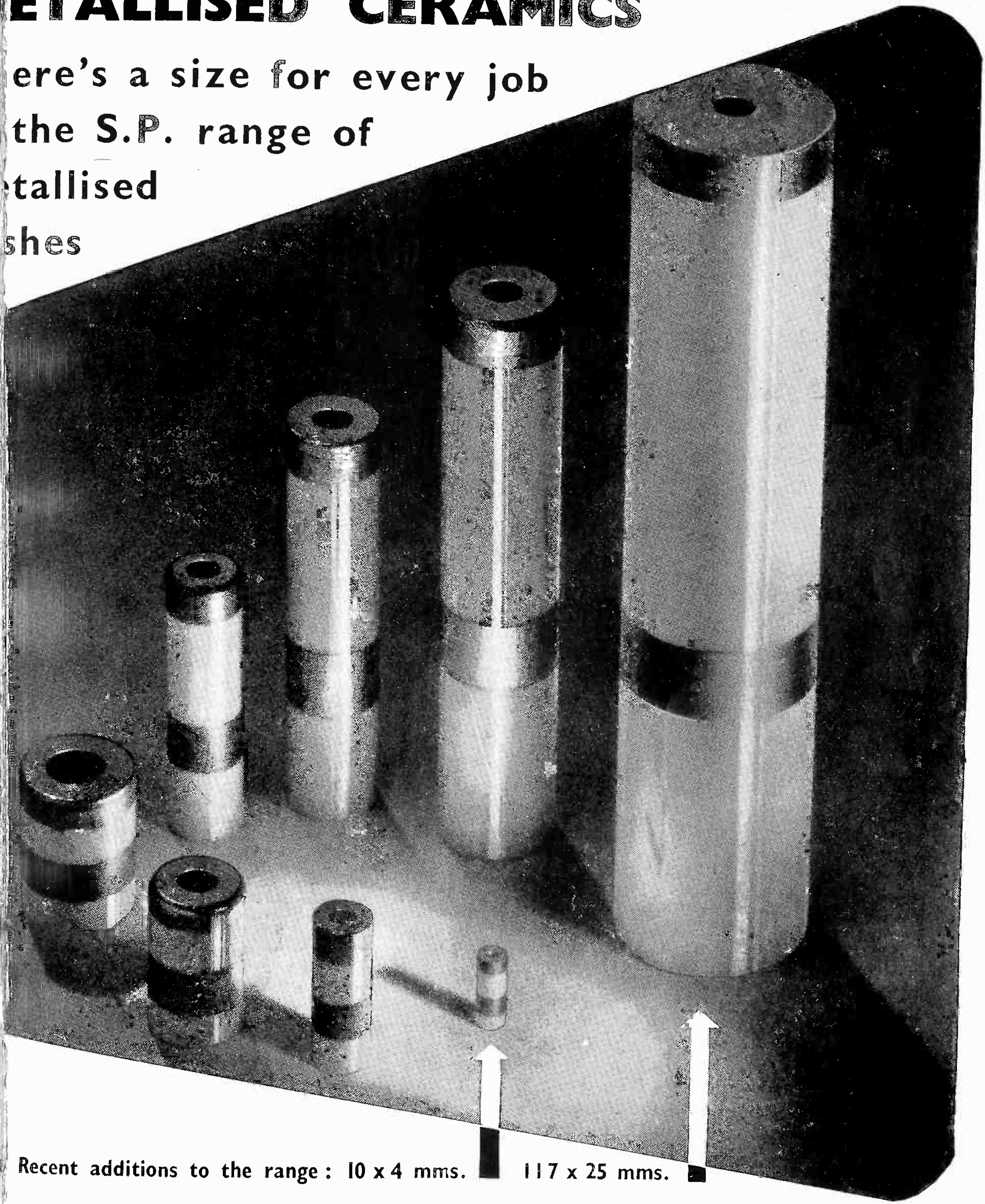
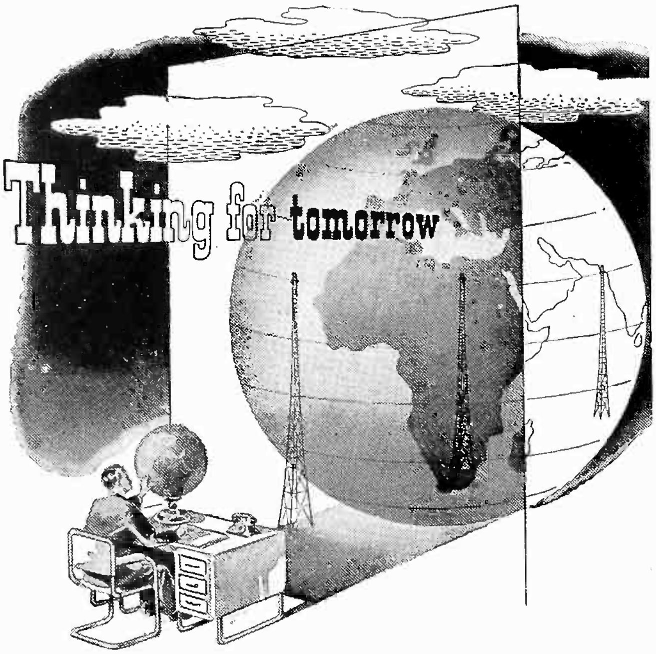
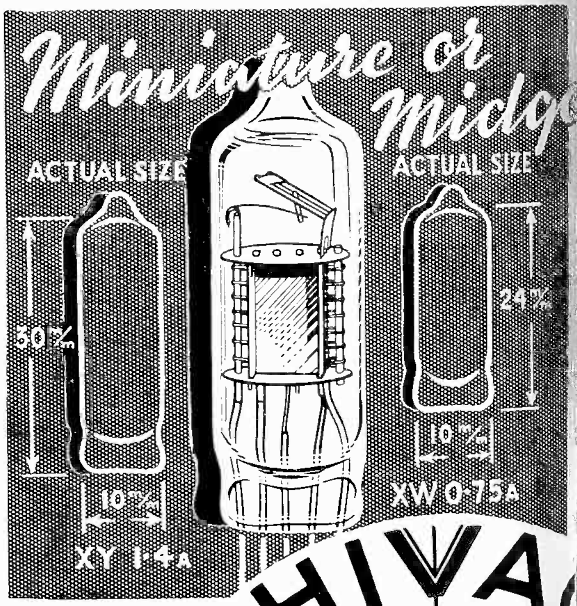
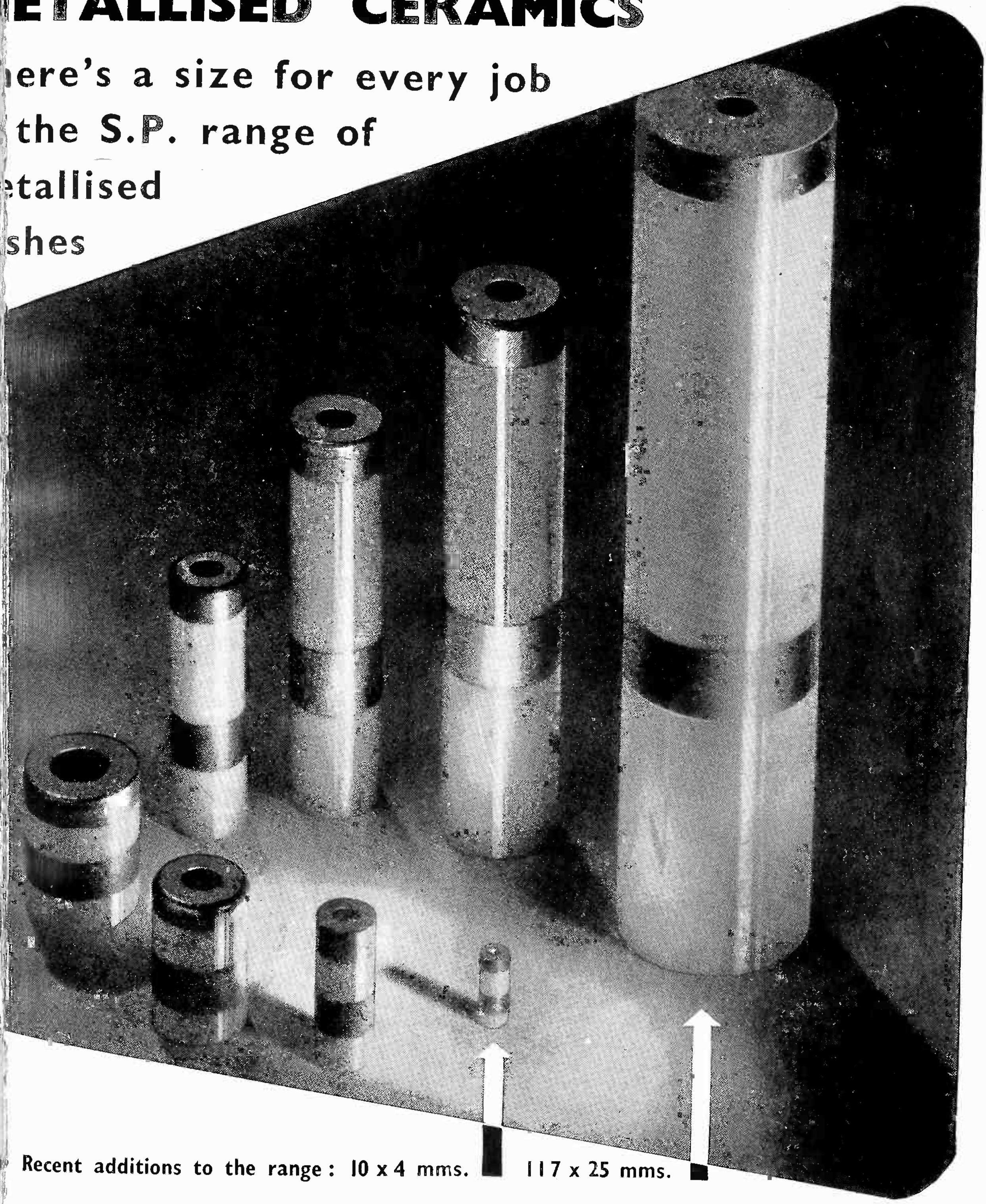

Thinking for tomorrow

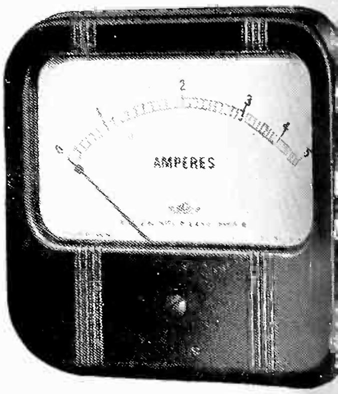

Miniature or Midg
ACTUAL SIZE
30 m/m
10 m/m
XY 1·4A
ACTUAL SIZE
24 m/m
10 m/m
XW 0·75A




Thinking for tomorrow


Miniature or Midg
ACTUAL SIZE
30%
10%
XY 1·4A
ACTUAL SIZE
24%
10%
XW 0·75A

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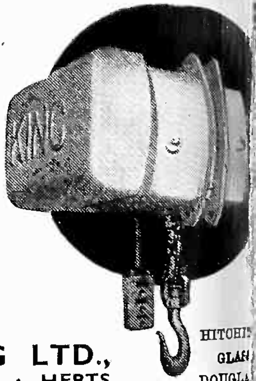
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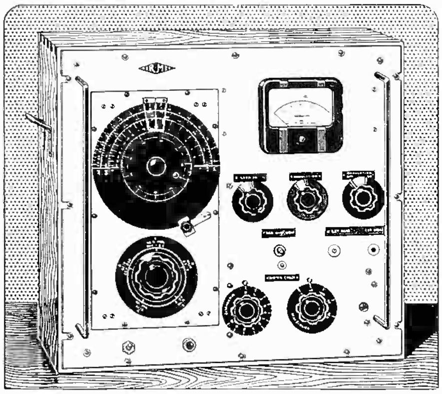
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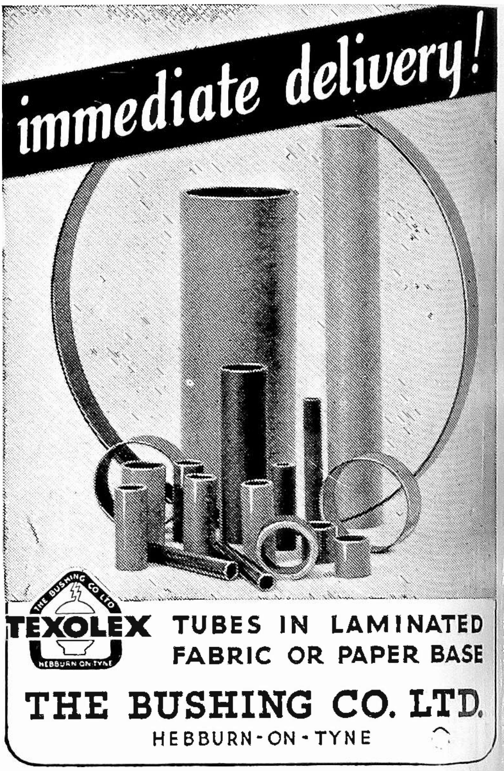

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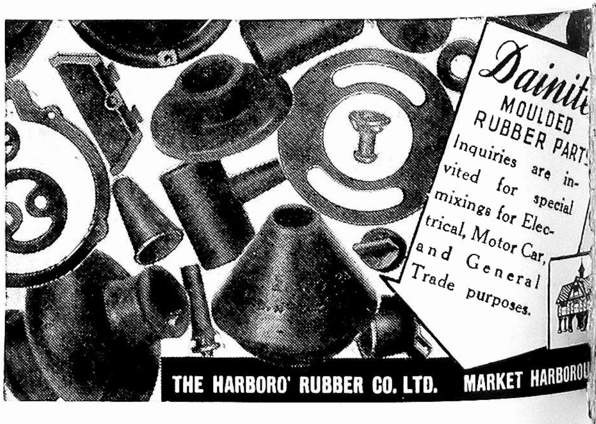

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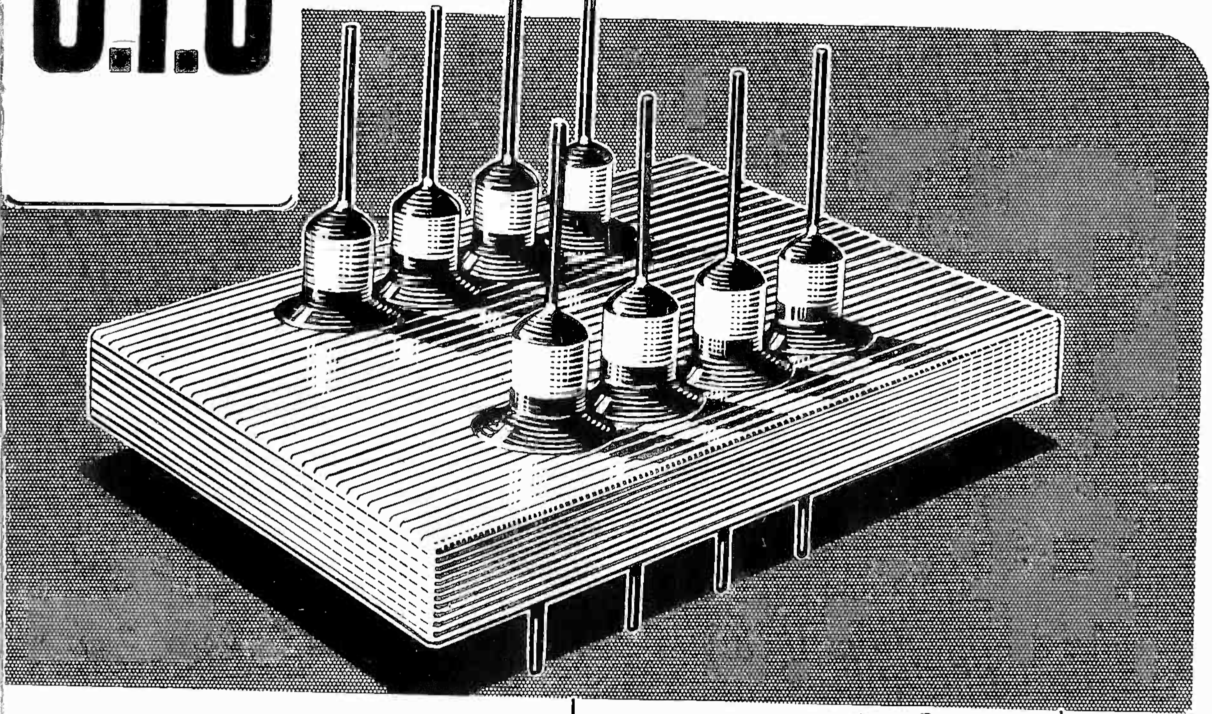

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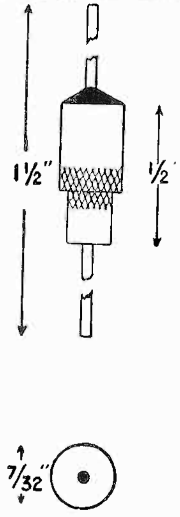

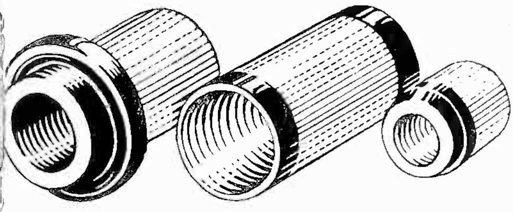

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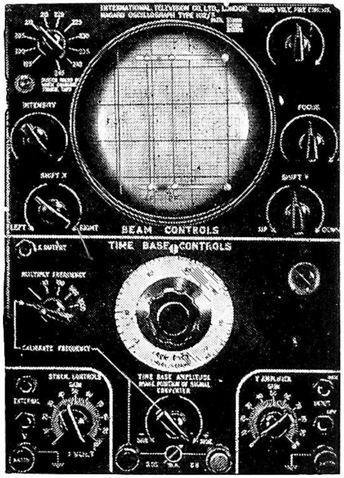

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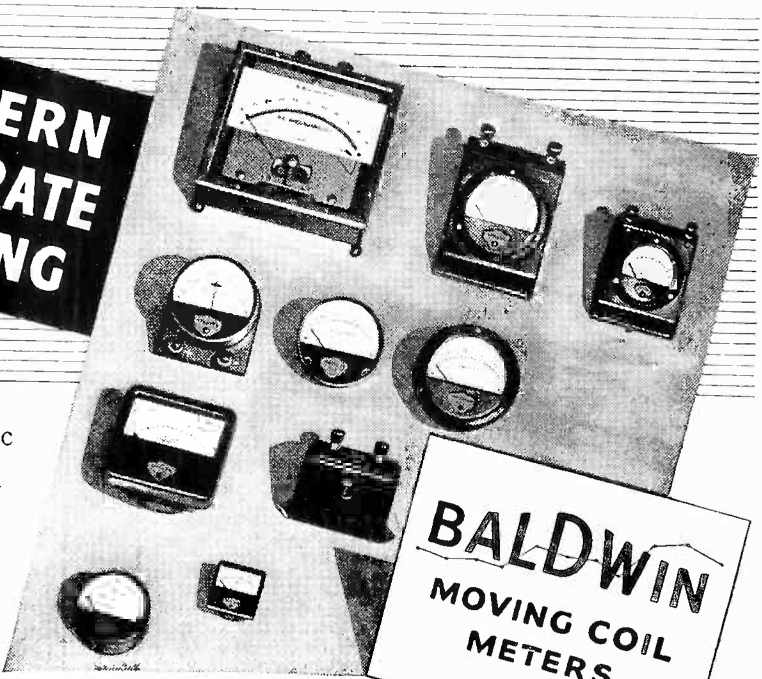

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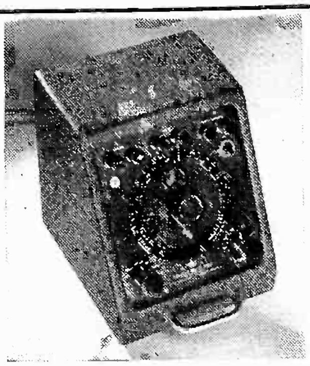

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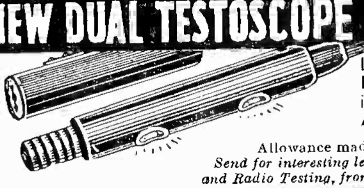

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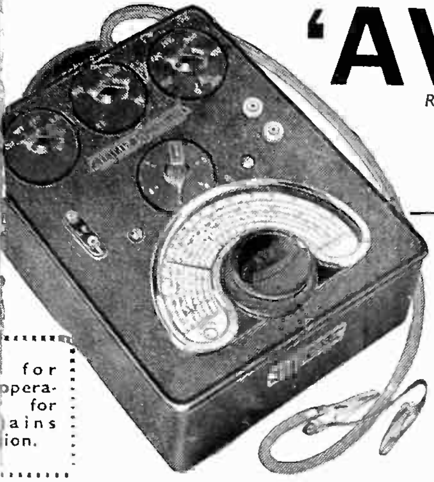

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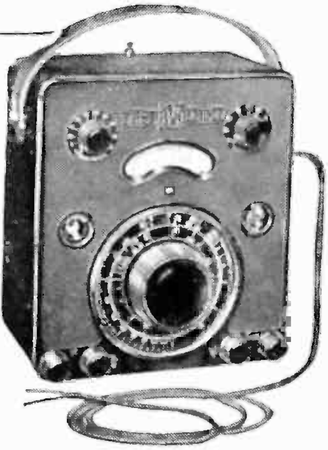

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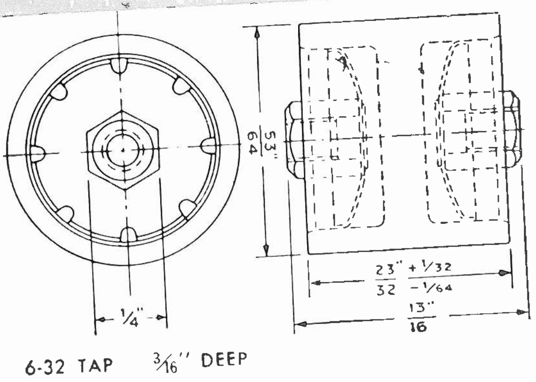

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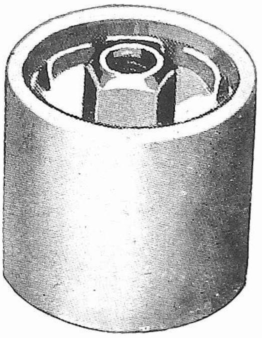

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WIRELESS ENGINEER

Vol. XXIV. FEBRUARY 1947 No. 281

EDITORIAL

Permeability of Dust Cores

In this number we publish an interesting letter from P. R. Bardell in which this question is discussed on the basis of experimental results obtained in the Research Laboratories of the General Electric Company. In the November editorial we referred to results obtained in America by Legg and Given which indicated that the permeability of dust cores was considerably higher than the value calculated on the assumption that the particles were uniformly distributed spheres or cubes. We expressed dissatisfaction with the explanation given and suggested that the results could only be obtained by giving up the assumption of uniformly distributed spheres or cubes and assuming some linking up of the particles in the form of threads in the direction of the field.

We are pleased to see that Mr. Bardell comes to practically the same conclusion. He says that the results agree with the calculated values if it is assumed that the particles are rectangular slabs of dimensions $10 \times 2 \times 1$ aligned in the direction of the field. It is interesting, but surprising, to know that photomicrographs show that such a flattening and alignment may be caused by the high pressures employed in the manufacture. We must confess that we find it rather difficult to picture the iron particle being changed into little strips five or ten times as long as they are wide, and obligingly arranging themselves in the desired direction, however great the applied pressure, but we write in ignorance of the manufacturing processes. It is as easy to picture a small extension in the desired direction squeezing out the insulating material in the end-to-end gaps and thus giving metallic continuity along the field.

It is fortunate that this unexpected practical departure from the theoretical values based on cubes or spheres is such as to rectify to a considerable extent the main disadvantage of dust cores, viz. their low effective permeability.

This alignment of the particles calls to mind the material known as Ferrocart which some of our readers may remember. It was developed by Hans Vogt and described by A. Schneider in the *Wireless Engineer* of April 1933. In this material the iron particles, which were stated to be ellipsoidal, were sprinkled on a strip of paper moving horizontally while their insulation was still liquid; the paper strip then passed through a solenoid carrying a direct current which aligned the particles along the strip before the insulating material dried and fixed them in the aligned position. A number of these paper strips were then built up with a hot liquid binder. The space factor was small and it was stated that the permeability could not be increased much above 18 without increasing the losses to an extent far outweighing the advantages of the higher permeability. The permeability now obtained in dust cores is a multiple of this, and we look forward to the publication of further particulars of the permeability and losses of dust cores as now constructed and more detailed information as to the shape and alignment of the particles, on which the increased permeability depends.

With regard to the Ferrocart cores we drew attention in September 1941 to the fact that a sample core, received from the manufacturer in 1933, and kept in a cardboard box in a dry laboratory cupboard, had completely disintegrated into a loose heap of paper and what appeared to be rust, and that in less than eight years. We asked at the time if any readers who had inductances fitted with these cores would make measurements and let us know the results, but as we received no such information we presumed that Ferrocart cores had not been used to any extent in this country.

Wherever measurements of effective permeability of dust cores are given, measurements of the losses should also be given, in order to ensure that the increased permeability is not being obtained by sacrificing the very advantages because of which dust cores are employed.

G.W.O.H.

The Use of Standard Terms and Symbols

IN the October number of the *Proceedings of the Institution of Radio Engineers, Australia*, we are glad to see an article by a member, advocating a more rigid adherence to standardized terms, abbreviations and symbols. After discussing the resistor with its resistance, the conductor with its conductance, the reactor with its reactance, the inductor with its inductance, and the capacitor with its capacitance, the author says: "Other bad practices are concerned with abbreviations. For microfarad we may get mf, mfd, mF, μf, μF, and a similar range for micromicrofarad, μ is the accepted symbol for micro and F is the accepted abbreviation for farad. Therefore use μF and $\mu\mu$F. In typewritten matter use uF *and* uuF; these are to be preferred to mF and mmF. The 'diehards' will resist any encroachment on their bad habits:—'Why argue—you know what we mean, etc.' Even so, what is the objection to being correct? In this case, do we know what is meant? The abbreviation mF means millifarad, and mmf means magnetomotive force. The possibilities for confusion are real in this instance. None of those who use mF for microfarad would dream of using mV for microvolt."

Our Australian friend might have quoted a more horrible example for it is quite common in American journals and text books to find m used simultaneously for both milli and mega, and to see a frequency of 50 Mc/s referred to as a frequency of 50 mc.

There is one case in which one cannot but sympathize with the transgressor, and that is in the use of K instead of the standard k for a thousand. It would have been reasonable to have adopted small letters, μ and m, for submultiples of unity and capitals, K and M for the multiples, but the standardizing authorities decided on k and M, with the result that those who are careless in such matters are quite likely to use K and m, for a thousand and a million respectively.

G.W.O.H.

Correction.

In last month's Editorial the solidus was unfortunately omitted in the last expression in column 1, page 3. The last sentence here should have read "For the energy per cm^3 we have in one case $\mu H^2/8\pi$ and in the other $\kappa\mathcal{E}^2/8\pi$."

H.F. RESISTANCE AND SELF-CAPACITANCE OF SINGLE-LAYER SOLENOIDS*

By R. G. Medhurst, B.Sc.

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

SUMMARY.—This paper contains the results of high-frequency resistance and self-capacitance measurements on about 40 coils, wound with copper wire on grooved Distrene formers. The measuring instrument was a twin-T impedance bridge.

For coils whose turns are widely spaced, the high-frequency resistance measurements are in good agreement with the theoretical values of S. Butterworth.[3] For closely-spaced coils, the measured values are very considerably below those of Butterworth.

A table of values of high-frequency resistance of coils having various values of length/diameter and spacing ratio is derived from these measurements.

It is shown that a good approximation to the high-frequency Q of coils of the type measured is given by the simple expression

$$Q = 0.15\, R\psi\sqrt{f}$$

where R is the mean radius (cm), f the frequency (c/s) and ψ depends on the length/diameter and the spacing ratios. A table of ψ has been calculated.

Measurements of self-capacitance were made with one end of the coils earthed. These measurements show a very considerable divergence from the formula of A. J. Palermo[14] though they are in quite good agreement with other previous experimental work. The self-capacitance of coils of this type is shown to be substantially independent of the spacing of the turns. It is given by an expression of the form

$$C_0 = HD \text{ picofarads}$$

where D (cm) is the mean coil diameter and H depends on the length/diameter.

A table of H is given, based on these measurements.

1. Introduction.

A GREAT deal of theoretical and experimental work has been published concerning the resistances of coils and their variation with frequency. The experimental work, in general, suffers both from its restricted application and from uncertainty as to the absolute error inherent in the method of measurement. The theoretical work, even where it is in reasonable agreement with experiment, tends to produce complicated formulae which lead to very considerable computation. Even now, after over a quarter of a century of work on every type of coil that has been used or proposed, the present writer knows of no reliable data from which Qs of even the simplest coils can be easily and quickly predicted.

The only comprehensive theory extant is that of S. Butterworth[1–5]. He gave formulae which purported to cover single-layer solenoids, wound with round wire, for any frequency, coil dimensions and spacing of turns. The only restriction was that the number of turns had to be large, the case of few turns only being dealt with when the length of the coil was small compared with its diameter, and the turns were not too closely spaced. He suggested modifications to include multi-layer coils and coils wound with stranded wire. All these formulae only dealt with copper losses, dielectric losses being assumed negligible. Dielectric loss must, if necessary, be allowed for separately.

This theoretical work has become so generally accepted that it is quoted as a basis for calculation in standard reference books (see, *e.g.*, ref. 12, pp. 78–80). It will be shown experimentally that Butterworth's theory is only applicable to coils having widely spaced turns (roughly $d/s < 0.5$). More closely spaced coils have a lower high-frequency resistance than that predicted by Butterworth, the discrepancy increasing as the coil length decreases relative to the diameter. For coils having $l/D = 1$, when $d/s = 0.6$ Butterworth's value is too high by 15 per cent, when $d/s = 0.7$ by 25 per cent, when $d/s = 0.8$ by 55 per cent and when $d/s = 0.9$ by 190 per cent.

During the determination of high-frequency resistance and inductance it was necessary to make allowance for the self-capacitance of the coils measured. It was

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* MS accepted by the Editor, July, 1946

thought that self-capacitances calculated from the formula of A. J. Palermo[13] would be sufficiently accurate for this purpose. However, it was found that use of Palermo's formula led to variations, larger than the experimental error, of the apparent measured inductances over quite a small frequency range.

Measurements of self-capacitance of a wide range of single-layer coils were consequently carried out. The results failed to confirm Palermo's claim that the self-capacitance varies steeply with the spacing of turns. They are, instead, in quite good agreement with previous work, which had shown the self-capacitance to be very nearly independent of d/s. For coils having length/diameter = 1, Palermo's formula gives results which are greater than the measured value by 4 : 1 when $d/s = 0.9$, and smaller than the measured value by 1.6 : 1 when $d/s = 0.1$.

2. List of Symbols

D	represents mean diameter of coil	(cm)
R	represents mean radius of coil	(cm)
l	represents overall length of coil	(cm)
n	represents number of turns	
d	represents diameter of each wire	(cm)
s	represents distance between centres of adjacent turns	(cm)
d/s	represents spacing ratio of turns	
ρ	represents resistivity of wire	(ohm-cm)
f	represents frequency	(c/s)
τ	represents power factor of material of coil former	
C_0	represents self-capacitance of coil	(pF)
L_s	represents equivalent series inductance of coil	(μH)
R_s	represents equivalent series resistance of coil	(ohms)
f_0	represents self-resonant frequency of coil	(c/s)
ϕ	represents ratio of h.f. coil resistance to resistance at same frequency of same length of straight wire.	
ψ	is a function of l/D and d/s, occurring in the formula for Q,	

$$i.e.,\ Q = 0.15\,R\,\psi\sqrt{f}$$

Where $Q = 2\pi f L_s/R_s$.

$$z = \pi d\sqrt{\frac{2f}{10^9\rho}} = \frac{1}{\sqrt{2}}\ \frac{\text{wire diameter}}{\text{current penetration depth}}$$

3.—Butterworth's Work on Single-Layer Solenoids

3.1. S. Butterworth's series of papers on solenoidal coils are based on two sets of formulae which he developed for single-layer solenoids. In both cases there is no restriction on the frequency. The first[1] apply to coils having any specified number of turns, the turns being "not too closely spaced," and the coils having lengths small compared with their diameters. The second[3] were evolved as a consequence of some measurements by C. N. Hickman, which were made on coils outside the range of conditions assumed in the formulae of Ref. 1, and consequently failed to agree with the results predicted by these formulae[2,7]. This second group of Butterworth formulae extended the theory to coils having arbitary spacing ratio, and arbitary ratio of length to diameter. The number of turns, however, had now to be assumed to be large. Butterworth's method of deriving his second group of formulae is as follows:

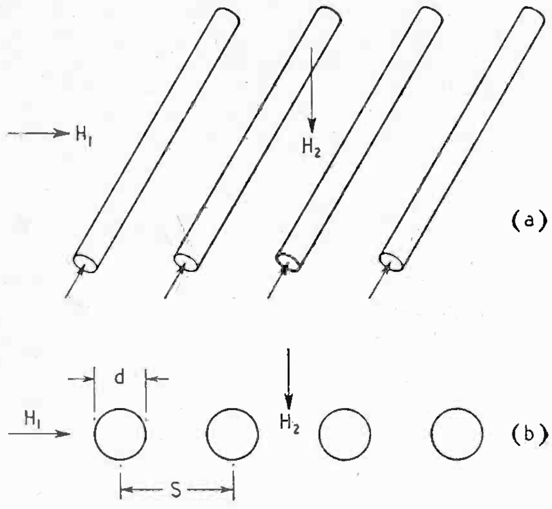

Fig. 1. *Views from above (a) and transverse to the wires (b) of Butterworth's infinite plane system of parallel wires.*

He took as his starting-point a system consisting of an infinite number of parallel wires of equal diameters, equally spaced and lying in the same plane as shown in Fig. 1, which shows a portion of the system seen from above and end-on. He set out to solve three problems, namely, to determine the losses in the system (*a*), when the wires carry equal alternating currents, i, flowing in the same direction; (*b*), when they are situated in a uniform alternating magnetic field H_1 parallel to the plane of the wires and perpendicular to their axes; and (*c*), when they are situated in a similar uniform field H_2 perpendicular to the plane of the wires. We shall call H_1 and H_2 the axial and transverse fields respectively.

Each of these problems involved the solution, by a method of successive approximations, of a set of an infinite number of linear equations, each containing an infinite number of variables. Butterworth's solutions are contained in three tables, for a range of d/s from 0.1 to 1.0, in steps of 0.1 (*i.e.*, from widely separated turns to turns touching).

In order to apply these solutions to solenoidal coils, Butterworth worked out the field associated with the coil by adding to the field associated with an infinitely long solenoid a modifying field produced by its ends, considered as a circular disc of poles. This field was resolved into two components, one parallel to the axis of the coil (the axial field) and the other perpendicular to the axis (the transverse field), and the mean-square value of each over the length of the coil deduced.

Now, he pointed out that each short section of wire may, if the wire diameter is small compared with the coil diameter, be treated as part of a plane system, of the kind already considered. He considered that, as a sufficiently close approximation, the axial and transverse fields associated with the coil could be replaced by their mean-square values, these being considered to act uniformly along the length of the equivalent plane system, now taken as being infinitely long. Under such conditions, he showed that the total losses in the system equivalent to the coil could be obtained by summing the separate losses deduced from the solutions of his three problems.

His results for very high frequencies are summarized in a table which is reproduced here as Table I. The quantity tabulated is the ratio of the high-frequency resistance of a coil, assumed to have a large number of turns, to the resistance at the same frequency of a straight wire of the same length and diameter as the wire forming the coil. This straight-wire resistance can be calculated from a well-known formula. The variables of Table I are the ratio length/diameter of the coil, and the spacing ratio d/s.

"Very-high frequency" has to be defined in terms of the diameter and electrical constants of the wire. It is a frequency higher than that at which the current penetration depth is some arbitrary fraction, say, 1/10th, of the wire diameter. It is convenient to express the high-frequency resistance of a round wire in terms of a quantity z, which is defined by the relation

$$z = \pi d \sqrt{\frac{2f}{10^9 \rho}} = 0.107\, d\sqrt{f} \text{ for copper.}$$

Now, the current penetration depth in copper at frequency f

$$= \frac{1}{2\pi}\sqrt{\frac{10^9\rho}{f}}$$

Hence, it follows immediately that the criterion, given above, that the frequency should be "very high" may be written in the form

$$z > 10/\sqrt{2}$$

$$\text{i.e., } z > 7 \text{ approximately.}$$

3.2. Certain curious features are apparent in this Butterworth table. Particularly surprising are the high values that appear when the turns are closely spaced. Suppose for example, that we take a coil having a length/diameter $= 0.4$ and spacing ratio $= 0.8$—that is to say, with turns quite close. If we bring the turns a little closer to give a spacing ratio of 0.9, the length/diameter ratio being thereby only slightly changed, we are to expect the h.f. resistance to increase in the ratio of about 2.7 to 1. This would be surprising. For a spacing ratio of 1.0 the value infinity appears in the table; *i.e.*, when the turns are brought very close the h.f. resistance becomes infinitely large.

TABLE I

$\frac{d}{s}$	Coil Length/Coil Diameter											
	0	0.2	0.4	0.6	0.8	1.0	2	4	6	8	10	∞
1.0	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	3.41
0.9	18.2	17.5	16.1	14.6	13.2	11.9	8.02	5.27	4.39	3.96	3.78	3.11
0.8	6.49	6.32	5.96	5.57	5.23	4.89	3.91	3.20	3.04	2.97	2.92	2.82
0.7	3.59	3.53	3.43	3.29	3.17	3.07	2.74	2.61	2.51	2.51	2.50	2.52
0.6	2.36	2.35	2.32	2.29	2.26	2.23	2.16	2.15	2.14	2.16	2.16	2.22
0.5	1.73	1.74	1.75	1.75	1.75	1.76	1.77	1.85	1.85	1.86	1.86	1.93
0.4	1.38	1.39	1.41	1.42	1.44	1.45	1.49	1.56	1.57	1.59	1.60	1.65
0.3	1.16	1.19	1.21	1.22	1.22	1.24	1.28	1.34	1.34	1.35	1.36	1.39
0.2	1.07	1.08	1.08	1.10	1.10	1.10	1.13	1.16	1.16	1.17	1.17	1.19
0.1	1.02	1.02	1.03	1.03	1.03	1.03	1.04	1.04	1.04	1.04	1.04	1.05

Butterworth's theoretical values of the ratio of the h.f. coil resistance to the resistance at the same frequency of the same length of straight wire.

However, although this infinite value of the h.f. resistance holds for coils whose length varies from zero to a value indefinitely large, when the length actually becomes infinite there is a discontinuity, the h.f. resistance assuming a value 3.41 times the straight-wire resistance.

It will be useful to consider where, in Butterworth's calculation, these unexpectedly high values of h.f. resistance arise.

We have said that Butterworth evaluates separately three sets of losses, which he subsequently combines. These are (1) the losses due to the current in the wire under consideration and the currents in adjacent wires, (2) the losses due to the axial field (H_1 in Fig. 1) and (3) the losses due to the transverse field (H_2). Losses (1) and (2) show no surprising behaviour when the wires are closely spaced ; the abrupt rise in h.f. resistance for close spacing is all due to loss (3). Butterworth tabulates a quantity g, varying with d/s, which when multiplied by $(d/s)^2$ and a factor depending on the length/diameter ratio of the coil, gives the contribution of the transverse field losses to the total losses. This is reproduced as Table II.

TABLE II

d/s	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
g	1.017	1.069	1.166	1.326	1.585	2.03	2.87	4.83	12.5	∞

That part of the resistance due to the transverse field rises steeply for spacing ratios over 0.7, becoming infinite for $d/s = 1.0$. In this latter case, the parallel-wire system becomes a continuous infinite metal screen at right angles to the field.

We can show, qualitatively, that Butterworth's high h.f. resistance values, for coils having closely-spaced turns, may be expected to be absent in practice. Butterworth has substituted for the actual transverse field of a coil a uniform field whose square is the mean-square value—obtained by a method of approximate integration—of the transverse field. This uniform field is supposed to be imposed on a system consisting of an infinite number of parallel wires, and we have to consider the effect on any one wire of this field as modified by the eddy-currents set up in that wire and in all other wires of the system. Now, we shall show that the high losses predicted by Butterworth in each wire of this system are due chiefly to the presence of the more remote wires.

Table II gives values, worked out by Butterworth, of the ratio of the losses in one wire of his infinite parallel-wire system, acted on by a transverse field, to those in an isolated wire acted on by the same field. The table shows the variation of this quantity with the spacing ratio. If we work through the theory again, taking account only of the two adjacent wires (besides the wire in question), we find for a spacing ratio of 1.0 that g comes out as 3.40 instead of ∞. Values of g for wider spacings will now lie between 3.40 and 1. Consequently, it is the more remote wires that, for close spacings, make the largest contribution to Butterworth's values of g given in Table II. In the case of a coil, the transverse field will be concentrated near the ends of the coil, that is to say, it will be effective over the last few turns. Consequently, the contribution of the effect of the transverse field to the total coil losses would be expected to be of the order of the value of g that we have just worked out, rather than of that given by Butterworth.

So far, we have only considered the results given by Butterworth for "very high frequency." We shall see later (Section 14) that it is also necessary to proceed with caution when trying to make use of his low-frequency results.

4. Previous Experimental Work on the A.C. Resistance of Single-layer Solenoids

Butterworth, in his second paper[3], compares his theoretical values of the a.c. resistances of single-layer solenoids with two sets of experimental results, those of C. N. Hickman[7] and G. W. O. Howe.[6]

C. N. Hickman used coils wound with very thick wire (0.518 cm diameter), each coil being 96 cm in length, the ratio of length/diameter varying from 3 to 17. He used a d/s value of 0.86. He employed a bridge method of measurement, at frequencies of 1, 2 and 3 kc/s. The coils were wound on "well-seasoned wooden cylinders." Comparison of Butterworth's predicted values of resistance and Hickman's measured values shows that the former are from 2 to 13 per cent higher than the experimental.

G. W. O. Howe, using a thermal method, measured coil resistances at radio frequencies. He gave results for two coils, each having a length/diameter ratio of about 10, wound with wire of diameters 0.163 cm and 0.264 cm respectively. The respective values of d/s were 0.49 and 0.90. The results for the widely-spaced coil are close to those predicted by Butterworth. Those for the closely-spaced coil are lower than the theoretical values by 5½ per cent at the low-frequency end of Howe's frequency range, and 20 per cent at the high-frequency end. Howe made his measurements on long coils because, at that time, no satisfactory formulae had been suggested for short coils. He pointed out that short coils, such as occur almost invariably in practice, would be expected to give results considerably different from those predicted by the long-coil theory, and he suggested a tentative modification of this theory to make it applicable to short coils.

Not a great deal of additional experimental work has been published, since the publication of Butterworth's papers. The most important is that of Dr. Willis Jackson.[8] He pointed out that Butterworth's formulae had not hitherto been satisfactorily verified. The two principal difficulties that he mentioned were that " precision uses of bridge networks are not available at radio frequencies," and that the losses in a tuning capacitor, which can at radio frequencies be comparable with those of the coil being measured, could not usually be measured separately. He avoided these difficulties by using an ingenious method suggested by E. B. Moullin, involving measurements on a number of coils having the same dimensions but wound with wire of different metals. The method is elaborate, and it would not be practicable to use it for measuring more than a small number of coils. It constitutes a check on an existing theory, rather than a method of making absolute measurements, and in addition Jackson found that it did not give results sufficiently accurate to allow more than tentative conclusions to be drawn. He worked at about 1 Mc/s, his coils having a spacing ratio of 0.63.

Sets of Q-meter readings, corresponding to coils of various dimensions, have been published from time to time. Typical of these are the values quoted in an article by Art H. Meyerson.[9] Results are given from 25 to 60 Mc/s in the form of a table, and some very irregular curves are based on the measurements. These results seem characteristic of the Q-meter rather than of the coils.

Of the methods of measurement so far considered, only the thermal method of Howe seems likely to give reliable results. The objection to Howe's method is the practical one of the length of time required for each measurement.

5. Description of Coils used in the Present Series of Measurements

The intention of the present series of measurements was to provide an empirical substitute for Butterworth's theoretical h.f. resistance table (Table I). We shall see that the conditions that need to be fulfilled before Butterworth's table becomes applicable—i.e., that z should be high and the number of turns large (see below)—tend to become incompatible over part of the range of the table, more especially in the bottom left-hand region. That is to say, practically useful coils cannot be wound such that they work at a large z value, have a large number of turns, have a wide turn spacing and have a small length/diameter. To cover this region, some compromise had to be made, and the results are of theoretical rather than practical interest. Butterworth, constructing his table exclusively from theoretical formulae, did not encounter this difficulty. However, most high-frequency single-layer coils actually used do fall within the region covered by the body of the table, which is the practically important region.

It is specified in Butterworth's table that the number of turns shall be large, though there is no indication of the effect on the h.f. resistance of employing a finite number of turns. We can form a very rough estimate of the order of magnitude of this effect as follows. If we assume that the part of the losses in each wire due to proximity effect is to be attributed largely to the two immediately adjoining wires, one on each side, the effect of using a finite number of wires will be, principally, to diminish the proximity effect in two turns, those at each end of the coil. As a first approximation, the proximity effect in each of these end turns will be diminished by half, since there is only one wire adjacent to each. Thus the total proximity effect losses will be diminished by $2 \times \frac{1}{2} \times \frac{100}{n}$ %; i.e., by $\frac{100}{n}$ %.

Since, in practice, the proximity effect on each turn of more remote turns is not negligible, this expression will be too low. Since, however, proximity losses form only part of the total losses, this expression should give the order of magnitude of the effect of using a finite number of turns. It is not in violent disagreement with Butterworth's figures for very short coils, of not too close spacing, having a finite number of turns.

From this consideration, it was decided that the minimum number of turns that would be used was 30. In practice, the number of turns ranged from 30 for the smallest length/diameter coils to 50 for the largest.

The condition that the number of turns shall be large may, over part of Butterworth's table, be difficult to reconcile with the condition that the frequency shall be high, or, more correctly, that z should be large. From the expression for z, i.e.,

$$z = 0.107\, d\sqrt{f}$$

it is evident that both the wire diameter and the frequency must be as large as possible. As regards the frequency, since as we shall see later, we shall want to make use of a large tuning capacitance, in order to work at a high enough frequency our coil inductance must be as low as possible. That is to say, we must use the smallest permissible coil diameter and the smallest number of turns. The minimum number of turns has already been decided. As for the coil diameter, since the number of turns has a lower limit, and the spacing of turns and the ratio of coil length to coil diameter are determined by the position of the coil in Table I, we can only decrease the coil diameter by decreasing the diameter of wire. But it is evident from the form of the expression for z, that, for satisfying the "high-frequency" criterion, a large d is more important than a large f.

Specifically, since for a given number of turns and a given spacing ratio, the length of coil, l, is proportional to the diameter of wire, d, then the coil diameter D, for a given l/D ratio, will also be proportional to d. But f is proportional to $1/\sqrt{L}$, i.e., to $1/\sqrt{D}$, and hence to $1/\sqrt{d}$. So $\sqrt{f}$ is proportional to $1/(d)^{\frac{1}{4}}$, and hence z is proportional to $(d)^{\frac{3}{4}}$.

It is apparent that the upper limit to d is determined by the maximum permissible coil diameter. In the present work, the largest formers used had a diameter of 2½in. This involved the use of wires of 18 and 20 S.W.G. for most of the coils. Furthermore, since for a given maximum coil diameter, the upper limit of z becomes increasingly severely diminished with decreasing value of length/diameter, no coils were constructed having a length/diameter less than 0.4.

The coils were wound on Distrene rod, diameters ranging from 2½in to ⅝in. In one case, to attain a sufficiently high length/diameter ratio with a spacing ratio of 0.9, a coil of 20 S.W.G. double-silk-covered wire was wound on a ¼-in diameter former. The special virtues of Distrene rod for the present purpose are its low power factor (about 0.0003) and, from the mechanical point of view, the ease with which it can be grooved and the ends of the coil anchored.

The effect of dielectric losses on the total losses may be estimated if we assume that the coil turns are completely embedded in the former. Since in reality, each turn is roughly half surrounded by air and half by former material, we may expect that this assumption will cause us to over-estimate the actual dielectric losses. With this limitation, the percentage increase in the copper-loss series resistance due to dielectric losses is given by

$$\frac{\tau\omega^3 L^2 C_0}{R} \times 100\ \%$$

where τ is the power factor of the former material,
ω is the angular frequency,
L is the coil inductance,
C_o is the coil self-capacitance,
R is the equivalent series resistance due to copper losses.

This may be written as

$$\tau Q(f/f_o)^2 \times 100,$$

where f is the working frequency and f_o the self-resonant frequency,
or as

$$\tau Q(C_o/C) \times 100$$

where C is the tuning capacitance at the working frequency. Q, for the coils measured, was never higher than about 250, and C_o was usually about 3 or 4 pF. Minimum C was about 850 pF. Thus, the maximum value of the percentage dielectric losses that we may expect is

$$\frac{0.0003 \times 250 \times 4 \times 100}{850}$$
$$= 0.035\ \%\ \text{approx.}$$

The ends of the wires (mostly 18 and 20 gauge copper wires) were soldered to leads of 12 or 14 gauge copper wire, which had been previously tinned and sunk about $\frac{1}{4}$in into the former (using the heat of a soldering iron pressed against the lead just above the former). There is a tendency for the leads to twist in their holes, if they are not bent carefully.

For spacing ratios up to 0.8, the formers were grooved and the coils were wound with bare wire. For a spacing ratio of about 0.9, double-silk-covered wire was wound on ungrooved formers, the turns being as close as possible. This procedure gave spacing ratios ranging from 0.885 to 0.92. One coil (length/diameter = 1.30) was wound with single-silk covered 20 gauge wire (d.s.c. wire, from which the outer layer was stripped) on an ungrooved former, a spacing ratio of about 0.95 being obtained.

There is an appreciable tolerance on wire sold by gauge number, and in any case, the wires are stretched before winding to remove kinks. Consequently, the wire diameter for each coil was taken as the mean of three or four roughly equally spaced measurements, by a centimetre micrometer, along the length of the wire, these measurements being made during the winding.

Each coil was dried for about twelve hours in a desiccator, before measurement.

6. Use of the Twin-T Impedance Measuring Bridge

The twin-T Impedance-Measuring Circuit manufactured by the General Radio Company, Cambridge, Mass., is one of the most recent developments in the technique of measuring high-frequency impedances. Detailed accounts of the theory and its practical application are given in references 10 and 11. We shall very briefly describe its use for the measurement of high-frequency coil impedances.

The twin-T operates over a frequency range from 460 kc/s to 30 Mc/s. It is a null instrument, a balance being obtained by the adjustment of two capacitors. One of these capacitors is calibrated in micro-mhos, and, after multiplying by a factor involving the square of the frequency, gives the effective parallel conductance of the measured impedance. The other, calibrated in picofarads, gives directly the effective parallel capacitance.

The capacitance dial has a range of from 100 to 1,100 pF, and it is calibrated at intervals of 0.2 pF. The scale of the conductance dial is not linear, the calibration intervals ranging from $2\frac{1}{2}$ to 10 per cent of the measured conductance. This dial can usually be read to 1 per cent or better.

In the present series of measurements, the oscillator consisted of a Marconi Signal Generator, covering a frequency range from 85 kc/s to 25 Mc/s. A number of receivers were used from time to time, the necessary qualifications being that the receiver should be well shielded, that it should have a sensitivity of the order of 1 to 10 microvolts, and that it should be provided with a local oscillator to beat with the incoming signal, so as to produce an audible note.

7. Method of Measurement

Each coil was measured over a small band of frequencies at the low-frequency end of the available working range; i.e., at frequencies at which it tuned with capacitances of 800–1,000 pF. There were two reasons for working at the lowest available frequencies: (1) because the conductance-dial reading falls off rapidly as the frequency increases (being inversely proportional to $f^{3.5}$, for the present type of coil) and the error in the reading becomes correspondingly larger, and (2) because the effect of the resistance of the twin-T tuning capacitor is minimum at the lowest frequencies.

Each set of measurements was entered up on a standard sheet. We have reproduced, as a typical example, that relating to coil No. 31. Nine measurements were carried out on each coil, the first at a frequency at which the coil tuned with about 1,000 pF, and the remainder at frequencies increasing progressively by the smallest dial intervals of the signal generator. It was thought preferable to perform each measurement at a different, rather than at the same, frequency to avoid, if possible, systematic errors. The values of $Q/\sqrt{f}$ thus obtained, after various corrections had been made (see over), usually showed a spread of from 3 to 5 per cent.

Various necessary formulae were reproduced, for convenience, on each sheet.

8. Corrections Applied to the Twin-T Measurements

Six corrections had to be applied to the original measurements. Four of them will be described in this section, and the remaining two will be given a section each.

TABLE III

Coil No. 31.

29 . 8 . 45.
Mean temperature, 20.5° C.

Freq. Mc/s	C_{p1} (pF)	C_{p2} (pF)	Conductance dial reading	$C_{p2}-C_{p1}$ + 3.4 (pF)	Corrected conductance dial reading	$-\delta G$	True conductance (μmhos)	Q	$\frac{Q}{\sqrt{f}}$	L (μH)
0.78	100	1,080.3	34.9	983.7	21.2	0.1	21.1	228	0.258	42.32
0.79	100	1,056.2	32.9	959.6	20.5	0.1	20.4	233	0.262	42.29
0.80	100	1,031.8	32.0	935.2	20.5	0.1	20.4	230	0.257	42.32
0.81	100	1,007.9	30.8	911.3	20.2	0.1	20.1	231	0.257	42.36
0.82	100	984.8	29.1	888.2	19.6	0.1	19.5	235	0.260	42.41
0.83	100	962.6	28.0	866.0	19.3	0.1	19.2	235	0.258	42.46
0.84	100	943.5	27.0	846.9	19.1	0.1	19.0	235	0.256	42.39
0.85	100	923.4	26.0	826.8	18.8	0.1	18.7	236	0.256	42.40
0.86	100	904.0	25.2	807.4	18.6	0.1	18.5	236	0.255	42.42
								Mean	0.2577	42.37

No. of turns = 40
Wire gauge = 20 s.w.g.
$D = 5.19 - 0.09$ cm
$= 5.1$ cm
$R = 2.55$ cm
length = 7.01 cm
$\frac{\text{Length}}{\text{diameter}} = 1.375$
$d = 0.0910$ cm
$s = \frac{6.92}{39}$ cm

$$\frac{d}{s} = \frac{0.0910 \times 39}{6.92} = 0.513$$

$$Q = \frac{6.283\, fC}{G}$$

$$L = \frac{0.02533}{f^2\, C}$$

$$R_s = \frac{6.283L}{Q/\sqrt{f}}\sqrt{f}$$

$$\phi = \frac{[(\text{resist})/10^{-6}\ \sqrt{f}] \times d}{0.5218\ Rn}$$

$R\,exp. = 1{,}033 \times 10^{-6}\sqrt{f}$ ohms
Resistance of leads
$= 7 \times 10^{-6}\sqrt{f}$ ohms
Resistance of coil
$= 1{,}026 \times 10^{-6}\sqrt{f}$ ohms
$\phi = 1.745$
$= 1.743$ at 20° C
$= 1.71$ at 20° C $f \to \infty$
Resistance of leads
$= 0.1661 \times 10^{-6}\, \frac{l}{d}\sqrt{f}$
where $l = \frac{1}{2}$ (total length of leads).

8.1. The conductance-dial reading has to be multiplied by a factor of the form $\left(\frac{f}{f_o}\right)^2$, where f is the working frequency and f_o is either 1, 3, 10 or 30 Mc/s according to the frequency range which is used. The results of this correction are in column 6 of the measurements sheet.

8.2 The corrected conductance value thus obtained has to be further corrected on account of the resistance, R_c, of the metal structure of the main capacitor. According to Sinclair's paper,[11] R_c, in a twin-T whose residual parameters were measured by him, had the value 0.026 ohm at 30 Mc/s. As will be shown later, even a large departure from this value in the machine actually used, will not seriously affect the present measurements. Assuming this resistance to be proportional to the square root of the frequency, the error it introduces into the conductance reading can be corrected by adding algebraically a factor δG, which has the form

$$\delta G = -\{0.184(f)^{2.5}\}\,(C_{p2}{}^2 - C_{p1}{}^2) \times 10^{-6}\ \mu\text{mhos}.$$

f represents the frequency (Mc/s), and C_{p1} and C_{p2} are respectively the initial and final settings of the tuning capacitor (pF).

This is a very cumbersome expression to use, if one has to work out a large number of values of δG. The labour of evaluation can be considerably decreased by using a graphical procedure. The first part of the expression, $0.184(f)^{2.5}$, is plotted on double-logarithmic graph paper (Fig. 2), for a range of f from 0.1 to 10. The second part, $(C_p{}^2 - C_{p1}{}^2) \times 10^{-6}$, is plotted as the third line of a nomograph (Fig. 3) the two base lines being C_{p1} and C_{p2}, each ranging from 100 to 1,150 pF. δG is now obtained as the product of the two quantities read off from Figs. 2 and 3.

As an example: for coil No. 31, at a frequency of 0.78 Mc/s C_{p1} was 100 pF, and C_{p2} 1,080.3 pF.

$$\text{Now, } 0.184(f)^{2.5} = 0.184(0.78)^{2.5} = 0.1 \quad \text{from Fig. 2}$$

and $(C_{p2}{}^2 - C_{p1}{}^2) \times 10^{-6} = 1.16$ from Fig. 3
so $\delta G = -0.1 \times 1.16$
$= -0.1\ \mu$mho approx.

While the value of R_c, for the particular twin-T used, was probably not identical with that of the twin-T measured by Sinclair, it was not thought necessary to repeat Sinclair's measurements. There were two reasons for this: (1) the correction for R_c, at the frequencies used, is a small fraction of the measured conductance (usually of the order of 1 or 2 per cent), and the correction would not be appreciably affected by any likely deviation of R_c from Sinclair's value, and (2) the value assumed for R_c, at frequencies of the order of 1 Mc/s is, in any case, an approximation, since R_c has to be measured at a frequency round about 30 Mc/s and the doubtful assumption is made that R_c will vary precisely as the square root of the frequency.

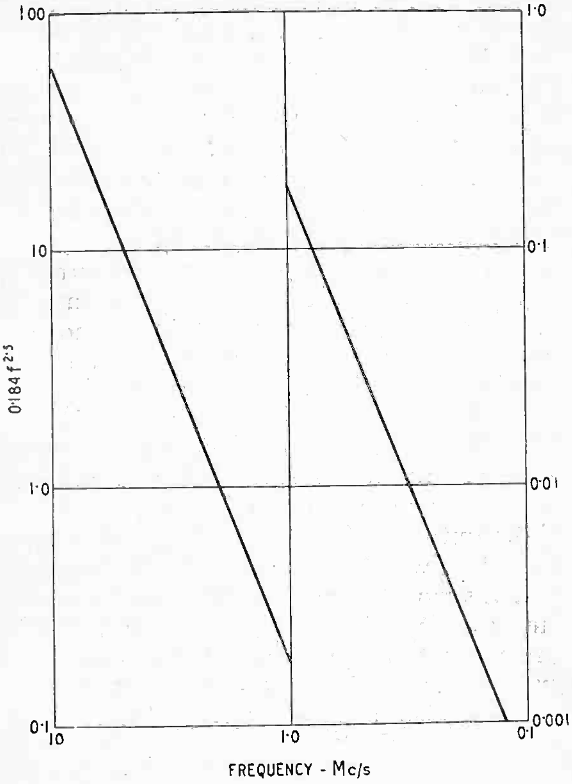

Fig. 2. *Correction for R_c (1).*

8.3 The correction for losses in the leads is most conveniently applied by subtracting it from the equivalent series resistance. The expression for the h.f. resistance of a straight isolated copper wire was considered a good enough approximation to this loss. The correction was usually less than 1 per cent of the total series losses.

8.4 Temperature variation of the dimensions of the coils will not produce an appreciable effect on the series resistance over the temperature range (from about 16° to 26° C) encountered. However, temperature variation of resistivity has to be taken into account. Taking the temperature coefficient of resistivity of copper as 0.0039 at 20° C, we have to multiply the apparent value of ϕ (the ratio of the coil resistance to the resistance of the same length of straight wire at the same frequency) by one of the following factors.

$$\frac{1}{\sqrt{1 + 0.0039(t - 20)}} \quad \text{if } t > 20° \text{ C}$$

$$\text{or} \quad \sqrt{1 + 0.0039(20 - t)} \quad \text{if } t < 20° \text{ C}$$

where t°C is the temperature of measurement.

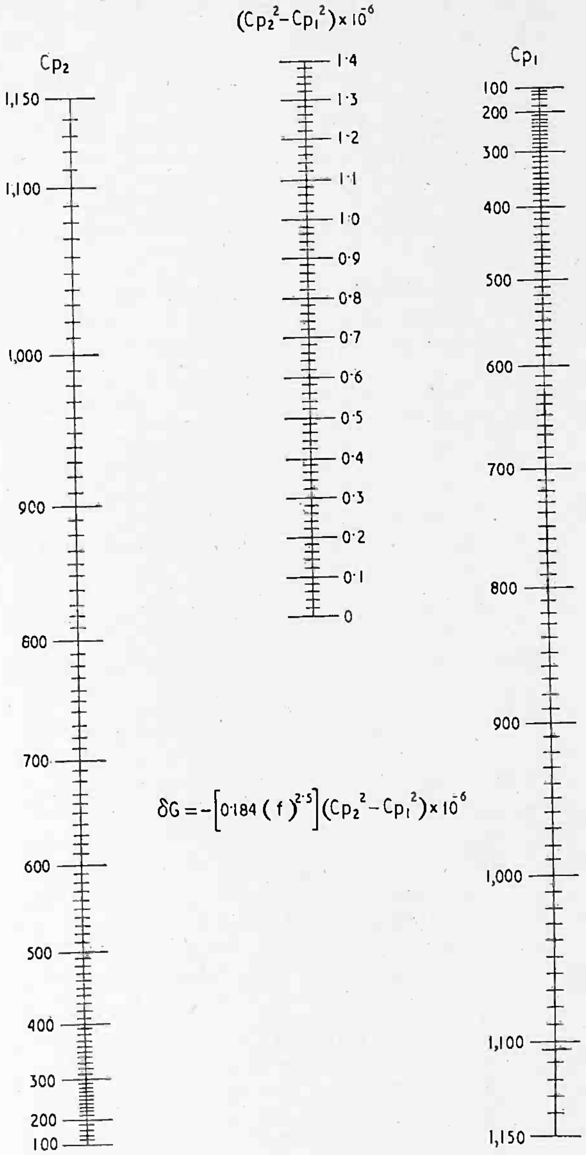

Fig. 3. *Correction for R_c (2).*

8.5 The remaining two corrections are (5), for coil self-capacitance and (6), a frequency correction to the final value of ϕ. We shall consider each of these in a separate section.

(*To be concluded*)

For references see end of article in March issue.

RECTANGULAR WAVEGUIDE SYSTEMS*

Bends, Twists, Corners and Junctions

By N. Elson, M.A., Grad.I.E.E.

SUMMARY.—The elements most commonly required in the construction of a waveguide transmission system are discussed, with particular reference to the methods which have been adopted to ensure complete transmission of the power through each element. The paper includes the main aspects of the theory, design and methods of construction of bends, twists, corners and junctions for use in rectangular waveguide systems.

LIST OF SYMBOLS.

a = width of waveguide.
b = height of waveguide.
E = electric field vector.
f = specific admittance = admittance $/(1/Z_0)$.
H = magnetic field vector.
j = $\sqrt{-1}$
l = length along the axis of the tube.
J_p = Bessel function of the first kind of order p. The addition of a prime denotes differentiation with respect to the argument.
k = π/a.
N_p = Bessel function of the second kind.
p = Angular wavelength constant.
r. exp. $(j\phi)$ = complex voltage reflection coefficient.
r, ϕ, z = cylindrical polar co-ordinates.
S = standing-wave ratio = minimum/maximum voltages.
Z = impedance.
Z_0 = characteristic impedance of line.
z = Z/Z_0 = specific impedance.
α = attenuation constant.
β = wavelength constant = $2\pi/\lambda_g$.
β_0 = wavelength constant for free space propagation = $2\pi/\lambda$.
ϵ = permittivity of the medium ($= 10^{-9}/36\pi$ farads/metre for free space).
λ = free-space wavelength.
λ_c = critical wavelength.
λ_g = guide wavelength.
λ_s = guide wavelength in a straight guide.
μ = permeability of the medium ($= 4\pi \times 10^{-7}$ henrys/metre for free space).
ω = angular frequency.

1. Introduction

THE use of centimetric waves in radar equipment has led to the replacement of the conventional coaxial or twin-line transmission line by the hollow-tube waveguide as a means of conveying the radio energy from its source to its desired destination. In most practical applications the transmission path cannot be straight, but will be constrained by other mechanical requirements as in any other plumbing† system. These requirements have opened a wide field of waveguide research, and this paper is concerned with some of its results.

It has previously been pointed out[1] that the best type of waveguide for most purposes is one of rectangular cross-section, of such a size that only the $H_{1,0}$ mode can propagate. The elements here described are therefore only of this type of cross-section. The restriction of the modes of propagation to only the one lowest mode is ensured by the use of a cross-section having an internal breadth lying between one-half and one free-space wavelength, and a height of less than one-half of a wavelength.

It is unnecessary here to recall the full field theory of such a waveguide[2], but some reference to evanescent modes is required for an adequate understanding of the effect of discontinuities in a waveguide. For each mode in a waveguide there is a characteristic field distribution across the cross-section of the tube, and this field propagates down the guide, according to the usual wave expression (in complex notation) :—

$$\exp.\ (j\omega t \pm j\beta l) \qquad \ldots \quad \ldots \quad \ldots \quad (1)$$

where l is the distance along the axis of the tube and β is the wavelength constant. β is the imaginary part of the propagation constant.

Also

$$\beta = 2\pi/\lambda_g \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where the guide wavelength λ_g is given by

$$\frac{1}{\lambda_g^2} = \frac{1}{\lambda^2} - \frac{1}{\lambda_c^2} \qquad \ldots \quad \ldots \quad \ldots \quad (3)$$

λ being the wavelength for propagation in the unbounded medium ; while λ_c is the critical wavelength dependent only on the tube size and the mode, being largest for the lowest mode, and steadily decreasing for higher modes.

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* MS. accepted by the Editor, June 1946.

† The appropriately descriptive term "Waveguide plumbing," of American origin, is now commonly used in this country.

The tube has been chosen so that the free-space wavelength λ is greater than the critical wavelengths of all modes except the first. Thus, for all these higher modes the expression (3) becomes negative, with the result that the guide wavelength, and hence the wavelength constant, become pure imaginary quantities. Writing for these cases $\beta = -j\alpha$, where α is a real quantity, the wave expression (1) becomes

$$\exp. (j\omega t \pm \alpha l) \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

This means that any such higher modes, if excited at any point in the tube, will not be propagated as waves but will appear as fields of uniform phase with amplitudes decaying exponentially along the axis of the tube. Such " static " modes are termed evanescent modes. It may be noted that the higher the mode the higher is the rate of decay.

2. Mismatch in a Waveguide

A waveguide system, which is capable of transmitting energy in only one mode, may conveniently be considered in terms of the conventional transmission line theory. It has been shown, notably by Schelkunoff[3], that the transmission-line equations are applicable to a waveguide, if voltage and current are replaced by appropriate functions of the electric and magnetic fields respectively. In this way a waveguide may be said to have a characteristic impedance which, like that of a line having two conductors, is dependent on the shape and size of its cross-section, but which is unlike in being dependent also on the ratio of its dimensions to the free-space wavelength. Similarly, discontinuities in the waveguide, such as changes in shape or constitution from the straight uniform tube, may be regarded as impedances in series or in parallel with the transmission line ; or, if their effect is distributed, as sections of line of different characteristic impedance and propagation constant ; or as combinations of both. In determining the electrical length of a portion of waveguide, the propagation constant must be taken as that appropriate to the phase velocity of the guided plane waves, as given by equation (2).

It is, however, unnecessary initially to enquire closely into such definitions of impedance from the electromagnetic field conditions, but to regard impedances only as useful expressions which are formally related to the voltage reflection coefficient. At any point in the waveguide sufficiently far from a discontinuity for any evanescent modes there excited to have decayed to negligible proportions, there can only be two waves present. One is the forward travelling wave and the other the backward travelling, or reflected, wave. The field may therefore be represented by the field distribution characteristic of the propagating mode multiplied by the wave expression :—

$$\exp. (j\omega t - j\beta l) + r. \exp. (j\omega t + j\beta l + j\theta) \quad (5)$$

where $r. \exp. (j\theta)$ is the reflection coefficient at the point $l = 0$, which may be arbitrarily chosen, giving the amplitude and phase of the backward travelling wave relative to the forward travelling wave at that point. In transmission-line theory this voltage reflection coefficient is readily related to the total impedance Z at the point relative to the characteristic impedance Z_0 of the line, by the expression

$$r. \exp. (j\theta) = \frac{Z - Z_0}{Z + Z_0} = \frac{Z/Z_0 - 1}{Z/Z_0 + 1} = \frac{z - 1}{z + 1} \quad (6)$$

Thus in waveguide applications, the specific impedance z may be regarded as an alternative parameter expressing the reflection occurring at the point considered, and without need to refer it to any other means of definition. The quantity which is directly measured is the ratio of the minimum and maximum amplitudes of the electric field along the guide and this standing-wave ratio is expressible by the equation

$$S = \frac{1 - r}{1 + r} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

(Some writers use the reciprocal of this quantity : others, mainly American, express this ratio in decibels, a convenient device if the measuring instrument is logarithmically calibrated.)

The problem of transmitting all the power through the system thus corresponds exactly to the better-known transmission-line matching problem. At a discontinuity, where the reflection coefficient is $r. \exp. (j\theta)$, the power reflected is r^2 relative to the incident power. Thus a standing wave ratio of 0.5 corresponds to $r = 1/3$, or an 11% loss of power by reflection.

In radar applications, however, two other factors are important in deciding the degree of matching that is necessary. Firstly, the presence of standing waves produces increased fields, which may cause breakdown of the air dielectric and consequent sparking across the guide. Secondly, and more important, is that pulsed-magnetron transmitters require a well-matched load if the efficiency and the pulse shape are to be maintained at their optima. It has therefore been normal practice to keep the mismatch due to a discontinuity in a waveguide down to a corresponding standing-wave ratio of 0.95 or better.

3. Discontinuities in Waveguides

The effect of a discontinuity in a waveguide is, in general, to produce a reflected wave. The mechanism of this effect can perhaps best be understood by reference to a particular and simple case. Consider a thin metal iris, of the type shown in Fig. 1(a), placed across the waveguide. Such an iris produces a reflected wave corresponding to that produced by a capacitor connected across the analogous transmission line [see Figs. 2(a) and (b)]. It is a device which has practical uses, and is commonly known as a capacitive iris or window. To consider its effect separately, assume that the terminating end is perfectly matched by an absorbing or radiating device.

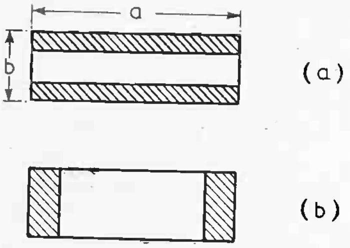


Fig. 1. *Capacitive and inductive irises are shown at (a) and (b) respectively.*

On a conducting surface the component of the electric field parallel to the surface must vanish. These conditions must be satisfied over the surfaces of the iris in addition to the surfaces of the walls of the tube. Now the latter requirement will be satisfied by any of the modes corresponding to the tube size. By suitably combining, on each side of the iris, a series of these modes with appropriately related amplitudes and phases the former requirement can also be met. Of all these modes only the one mode will propagate as a wave to or from the iris, the others will be evanescent, and quite clearly will be exponentially *decreasing* in amplitude away from the iris on both sides. The propagating mode may be regarded as three waves, one travelling forwards on both sides of the iris, and two waves each travelling outwards from the iris. The series of modes will be an infinite series, although considerations of symmetry will limit the excited modes to those of the form $H_{1,n}$. The sums of the displacements of all these modes must be identical on both sides of the iris: the series of modes on each side are therefore as represented diagrammatically in Fig. 2(c).

If these amplitudes refer to the voltage (or its waveguide analogue) it is clear that the iris may be regarded as a shunt impedance across the line. Since for good conductors there can be no appreciable power loss by absorption in the metal, this impedance must be purely reactive: the complete analysis shows it to be capacitive. Such a capacitor across a transmission line would act as a store of energy, taking in energy during one-quarter of a cycle and giving it out again in the next quarter: in the waveguide it is the evanescent modes which act in exactly similar fashion as storers of energy, the transverse electric field being in phase quadrature with the transverse magnetic field. The one major difference between the iris in the waveguide and the capacitor across the line is the different degree to which the stored energy is localized. Unless recognized this can lead to incorrectly interpreted results when discontinuities occur closely together in a waveguide. If the evanescent modes due to the one discontinuity have not decayed to negligible proportions in the vicinity of the other, the fields must undergo a modification from those which would exist if the discontinuities were widely separated in the waveguide. In the transmission line equivalent this may be interpreted as the presence of a mutual impedance effect.

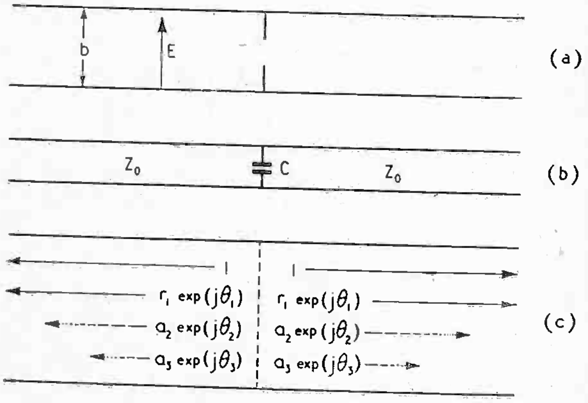


Fig. 2. *An iris across a waveguide (a) is equivalent to a capacitor across a transmission line (b). The component waves in the guide are illustrated at (c).*

In a similar manner the window of the form shown in Fig. 1(b) turns out to be representable as a shunt inductance. In both cases the reactance will depend on frequency in a more complicated manner than that of its circuit analogue. A discontinuity which is not confined to a very short length along the axis of the tube may similarly be regarded as distributed loading of the line by shunt or series impedances with appropriate mutual impedance effects. In this way a length of waveguide of different cross-sectional size interposed in the standard waveguide system may be regarded as a length of line of different characteristic impedance and propagation constant. However since the steps at the junctions between the guides of different size will be comparable with the wavelength, they must also be included in the equivalent circuit as shunt reactances at the junctions.

Any discontinuity may therefore be expressed by an equivalent transmission line circuit involving suitable combinations of lumped and distributed impedance; their values being separately expressible as functions of frequency. It is, however, often more convenient, as in circuit theory, to consider such a section of line as a general four-terminal network or quadripole. The essential linearity between the magnetic and electric fields in each mode ensures the applicability of the usual bilinear relationships. The behaviour of a four-terminal network can be expressed in general by three complex parameters. Out of the region of evanescent modes there will be four waves present in the general case, one forward- and one backward-travelling wave on each side of the quadripole. The three complex parameters used to express the behaviour of a quadripole are thus directly related to the three complex coefficients which express the amplitudes and phases of three of these waves relative to the fourth.

4. Methods of Matching

In twin-conductor transmission lines, various methods of matching-out reflections have been adopted, amongst these being the placing of a shunt reactance of correct size at the appropriate place in the line. This method is applicable to waveguides, the reactance usually taking the form of an inductive iris of the type previously mentioned, capacitive irises not being favoured for this purpose owing to their greater tendency to spark over with high powers. This method of matching suffers from the disadvantage that it is sensitive to frequency, because the electrical length of the line between the discontinuity and the matching iris changes with frequency, and there are also changes in the reactance of the iris and the reflection coefficient at the discontinuity. It rarely happens that these changes are adequately compensatory to each other; and, in general, matching over a wide frequency band can best be obtained by making modifications at and to the discontinuity itself. This may be regarded as a means of employing usefully the mutual impedance effects to obtain a greater bandwidth, in a similar manner to that in which they are used in the design of circuit band-pass filters.

This method of matching *in situ* has been applied to the design of reflectionless curved bends, twists, corners and junctions, which will now be considered in turn.

5. Curved Bends

An obvious way of turning a rectangular waveguide through an angle is by means of a curved bend. Bends in both principal planes may be required: those in which the long sides of the guide, and hence the magnetic field vector, are in the same plane are termed H-bends, while those with the electric field everywhere in the plane of the bend are termed E-bends. In both cases it may be shown that waveguide modes exist for uniformly curved bends of rectangular cross-section, having wave fronts in the radial planes and travelling round the curve with uniform angular velocity. These modes tend to the straight waveguide modes as the radius of the bend is made large (see Appendix). Thus, the curved bend may be regarded as a length of transmission line of different characteristic impedance and propagation constant, with the addition of shunt reactances at each end representing the reflections due to the junctions alone. The effect of the different characteristic impedance may be eliminated by making its length equal to an integral number of half curved-guide wavelengths. This requirement will determine the mean radius of curvature for a tube of given cross-section (see Appendix). The effect of the reflections at the junctions will be additive under these conditions, but they are generally small enough to be neglected. A partial correction may be obtained when necessary by making a small change in the mean radius, most satisfactorily determined experimentally.

Curved bends of small radius have not

been widely used in this country, owing to the development of the more compact angular bends or corners discussed later in this paper. Bends of large mean radius, greater than a free-space wavelength, give little reflection (standing-wave ratio better than 0.95) even at their worst electrical length. Where space permits they are quite convenient, and have been made on 3-cm wavelengths by bending copper rectangular waveguide tubing, the cross-section being preserved by filling with a low melting-point alloy before bending. Bends of small radius have some advantage over corners at short wavelengths since they will then be made of machined parts, and the necessary tolerances are more easily maintained than in the case of corners, which can only be made by fabrication or die-casting. If the curved bend is made in two machined parts which are to be bolted together it is advantageous to cut the curved guide into its two parts in the plane of minimum transverse current (see Appendix). If the two halves are to be soldered together the break may be made where convenient.

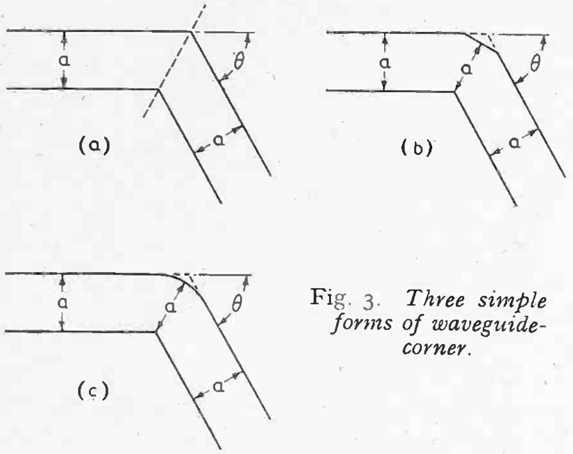


Fig. 3. *Three simple forms of waveguide-corner.*

An E-bend of 135° for use on wavelengths of about 3 cm, whose mean radius is about one-half of an inch, has been developed for use in a British radar equipment, and produces a standing-wave ratio in an otherwise matched guide no worse than 0.95 over a frequency bandwidth of ± 3%.

6. Twists

It is often convenient to be able to twist a rectangular waveguide through an angle, usually a right-angle, about its axis, so as to orientate the plane of polarization. Such a twist has the same type of equivalent transmission line circuit as the curved bend: the change in characteristic impedance and the junction effects are, in general, much smaller and the overall reflection for practical cases is negligible. This assumes that the cross-section is maintained during the twist: indeed this of itself sets a practical limitation to the rate of twist which ensures that the reflection is negligible.

7. Corners

The term corner has been used by the author to describe bends which are essentially angular rather than smoothly curved. The first type of corner to be tried was the obvious sharp angled bend of Fig. 3(a). The reflection coefficients for such bends, for the two planes of bending, and different angles of bends, are shown in the graphs of Figs. 4 and 5 with the abscissae equal to unity. The modified bends shown in Figs. 3(b) and (c) were next tried, and some improvement was obtained. Another idea tried at the same time was that of using two corners of the simplest type, each of half the angle, placed

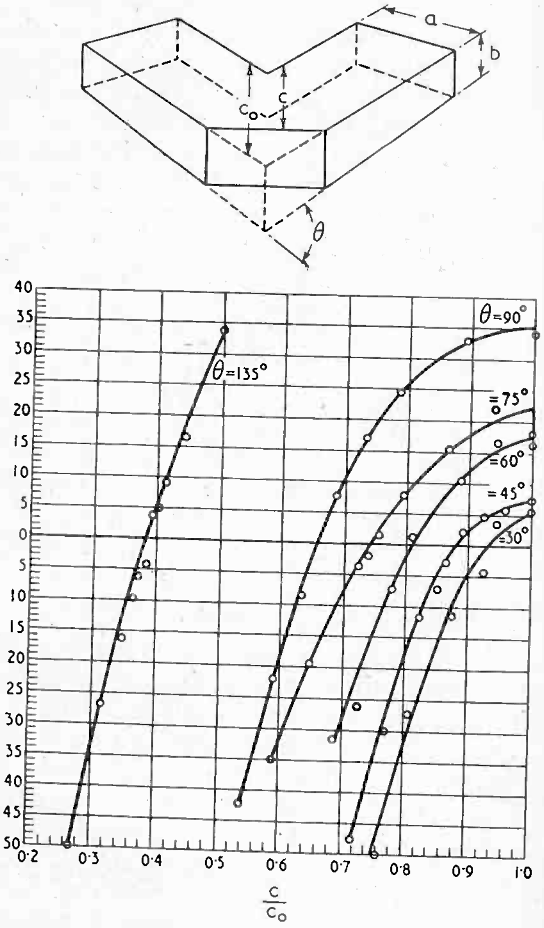


Fig. 4. *H-bend corner for a rectangular guide for $H_{1,0}$ waves. $\lambda = 10.84 \pm 0.02$ cm; $a = 7$ cm; $b = 3.25$ cm; $C_0 = a \sec \theta/2$; internal dimensions.*

an appropriate distance from each other to cause mutual cancellation of their separate reflections. It was demonstrated that this method could be satisfactorily used where space permitted, but since the spacings used in the early experiments were greater than their minimum value the conditions were not at their optimum for maximum bandwidth.

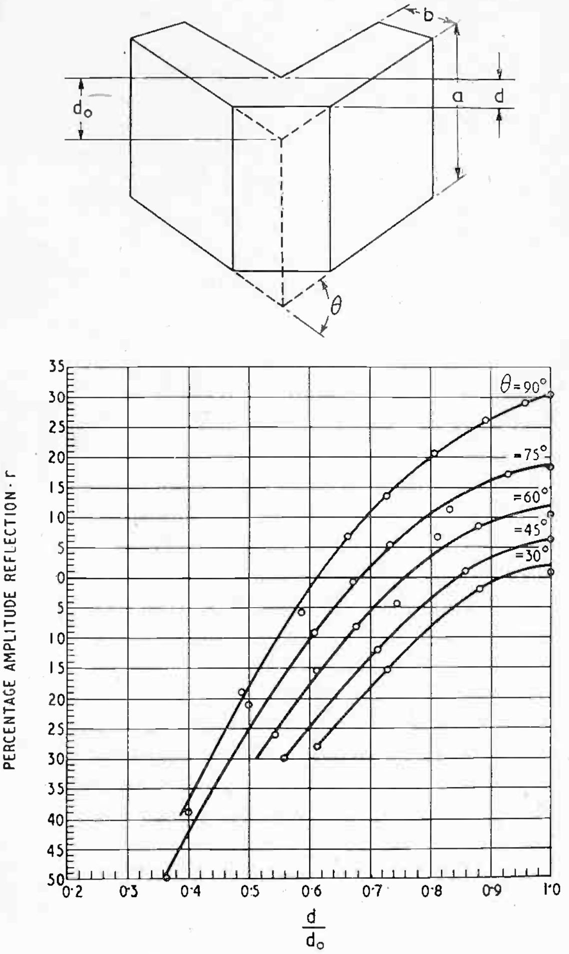


Fig. 5 (above). *E-bend corner for a rectangular guide for $H_{1,0}$ waves.* $\lambda = 10.84 \pm 0.02$ *cm*; $a = 7$ *cm*; $b = 3.25$ *cm*; $d_0 = b \sec \theta/2$; *internal dimensions.*

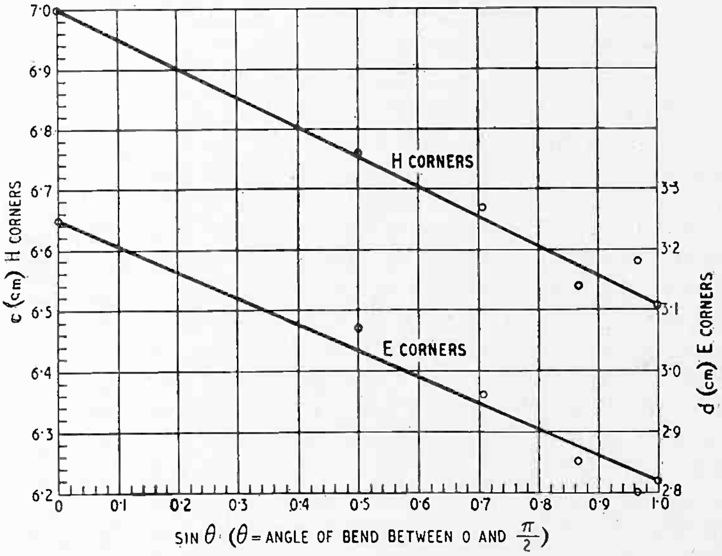


Fig. 6 (right). *Empirical relation between c and d of Figs. 4 and 5 and the angle of bend θ. For H-corners,* $c = 7 - 0.49 \sin \theta$ *and for E-corners,* $d = 3.25 - 0.43 \sin \theta$.

At this stage attention was devoted to the chopped-off corner of Figs. 4 and 5 where the dimension across the corner was to be varied experimentally in the hope of obtaining a reflectionless corner. Figs. 4 and 5 show the effect of varying the dimension across the corner for bends in both planes and of various angles. The earlier polygonal corner of Fig. 3(b) corresponds to a value of the abscissa equal to $\cos \theta/2$. Fig. 6 shows an attempt to relate empirically the optimum width across the corner to the angle of bend for the particular cross-section and wavelength used. For a waveguide whose cross-section is $a \times b$, the relations are adequately represented for angles of bend up to a right-angle by expressions of the form

$$\begin{aligned} c &= a - f \sin \theta \text{ for H corners} \\ d &= b - g \sin \theta \text{ for E corners} \end{aligned} \quad \ldots \quad (8)$$

Thus if the optimum widths are determined experimentally for the two right-angle bends, the constants f and g are known, and these expressions may then be used to interpolate for smaller angles of bend. The tolerance on the width is naturally greater for smaller angles. Typical bandwidth curves of right-angle bends are shown in Fig. 7: the bandwidth curves of bends of smaller angle are even better. For use on wavelengths of about 10 cm, reflectionless right-angle corners in both planes have been made by die-casting. Their bandwidth has been sufficient to permit a standardized compromise value of the corner-width to be adopted acceptable for the radar equipments of each of the three fighting services, operating on quite widely separated frequency bands.

For 3-cm wavelengths, the close tolerance required on the width of the E-plane corner is a serious disadvantage. For that reason the earlier suggestion of two half-bends was revived, and since the dimensions of the guide are in any case small, the increase in mechanical size is negligible. Bandwidth curves are shown in Fig. 8. The separation of the two half-bends is here so small that considerable coupling occurs between them. This mutual impedance effect doubtless contributes to the good bandwidth characteristic. Where even larger bandwidths are required the half bends may each be of the chopped-off corner type, separately matched at the mid-band frequency, and spaced to extend the bandwidth.

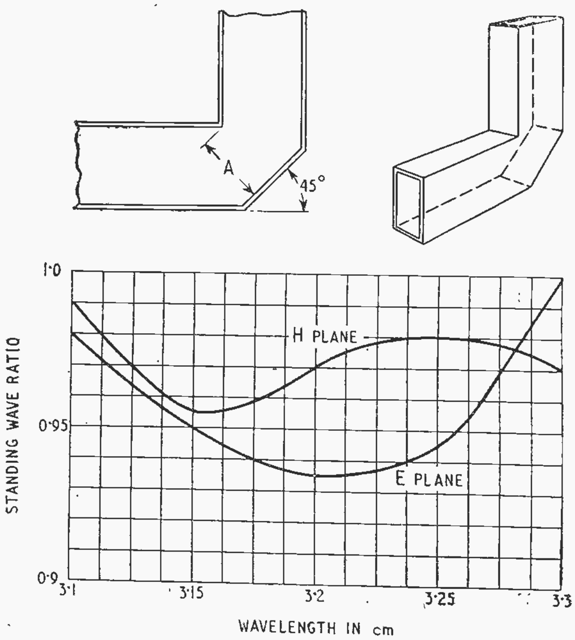


Fig. 7. *Bandwidths of right-angle corners. The optimum value of dimension A is 1.1 cm for E-plane corners and 2.5 cm for H-plane corners.*

8. T- and Y-Junctions

Waveguide T- and Y-junctions have been used for providing a continuous division of power into two arms of a waveguide system. More frequently in applications the power has been diverted into one or other of the arms alternately. This latter case constitutes a special type of bend in which the arm which is switched off has effectively a short-circuit across it, and thus acts as a reactive side stub at the corner. Junctions of this type have been matched by the arrangement of Fig. 9(a) which clearly shows the family resemblance to the chopped-off corner. The two dimensions d_1 and d_2 were determined experimentally: a typical H-plane junction of this type had a standing-wave ratio no worse than 0.90 over a ± 2% frequency band. In a similar manner a Y-junction required for a special application was constructed as in Fig. 9(b), the dimension V being taken as a variable to be determined experimentally.

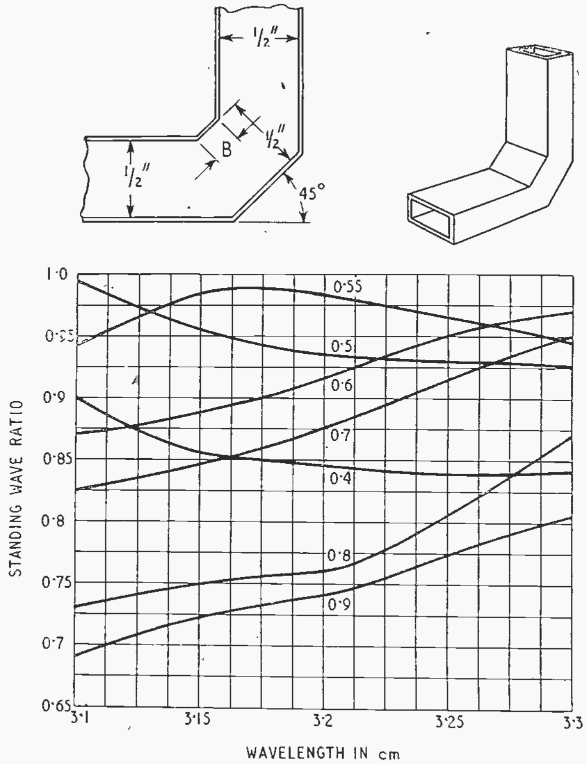


Fig. 8. *Bandwidths of right-angle corner composed of two half-bends. The figures on the curves show the dimension B in cm,—the optimum being 0.55 cm.*

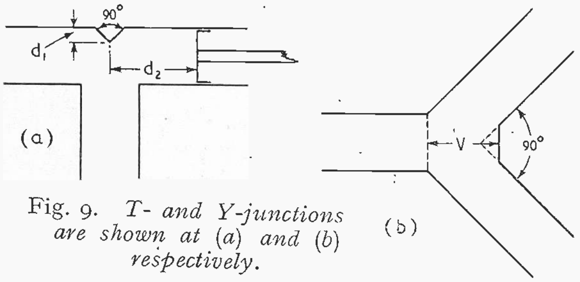


Fig. 9. *T- and Y-junctions are shown at (a) and (b) respectively.*

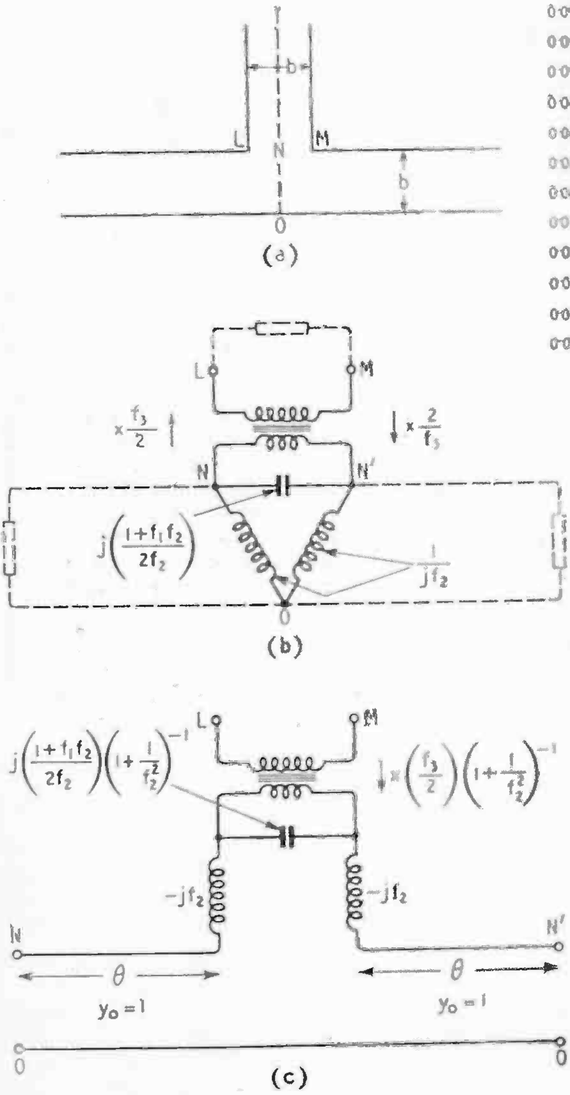
The simple unmodified T-junction of Fig. 10(a) has been analysed theoretically by Frank and Chu[4] for a junction in the E-plane, where the side arm is attached to the wider surface of the guide. The author has shown that these results may be expressed by the equivalent six-terminal network of Fig. 10(b). The impedances connected to or appearing at each pair of terminals are to be taken as the impedances at points in the corresponding waveguide arms sufficiently far from the junction to be clear of evanescent modes but referred back by the usual transmission line impedance transformation to the plane ON for the collinear arms, and to the plane LM for the side arm. For convenience, the equivalent circuit parameters are expressed as specific admittances, being the admittance relative to the characteristic admittance of the transmission line. Their magnitudes depend on the ratio of the narrow dimension of the guide to the guide wavelength, and are shown plotted in Fig. 11.

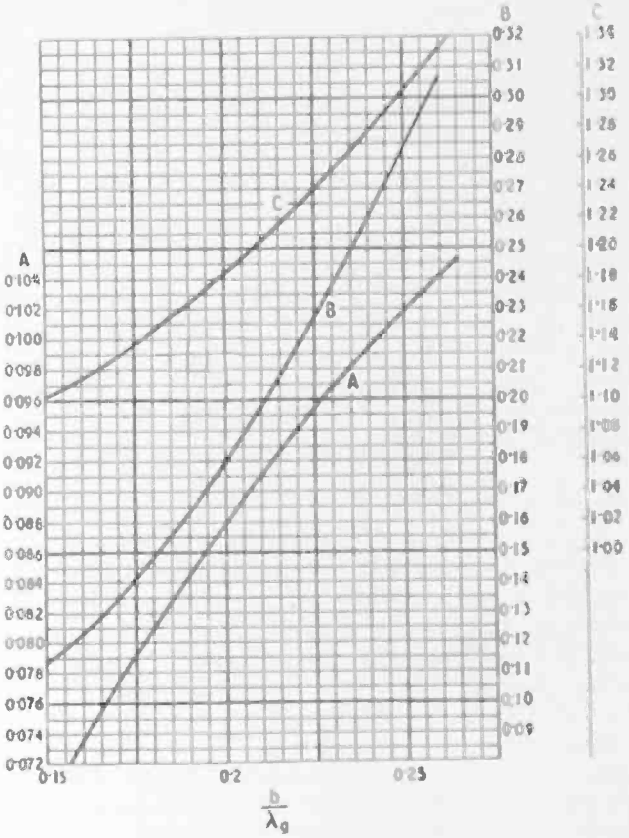
Many alternative circuits can be derived which will have identical impedance transforming relations. One of these is shown in Fig. 10(c) and is very appropriate for considering the case when the side arm is closed by a short-circuiting piston and used as a side stub in series with the line.

Some special cases are of interest. First, if the side tube is closed at such a point that it introduces a specific susceptance $+j(f_2 - f_1)/f_3$ at LM, then the junction introduces no reflection for the straight-through guide, but its electrical length is shortened by $2\tan^{-1}(1/f_2)$. Secondly, if the side stub introduces at LM a susceptance $-j(1 + f_1f_2)/f_2f_3$ then the admittance at ON presented to one limb of the straight through section is $1/jf_2$ whatever the value of the admittance on the remaining limb. Lastly, if one limb of the straight-through section is a stub presenting a susceptance $-1/jf_2$ at ON, then the admittance at ON presented to the other limb is $1/jf_2$ whatever the value of the admittance on the side tube. Similarly the admittance at LM presented to the side

Fig. 10 (below.) *The simple T-junction (a) may be represented by the equivalent six-terminal network (b). An alternative equivalent circuit is (c). The transformers are shown with typical turns ratios ($f_3 \geqslant 2$). The electrical lengths (θ) of the lines in (c) are given by tan $\theta = -1/f_2$.*

Fig. 11 (right). *The magnitude of the elements of the equivalent circuits of Fig. 10 are shown here. Scale A gives the susceptance of inductance ON ($1/f_2$), while B indicates the susceptance of capacitor NN′ $\left(\frac{1 + f_1f_2}{2f_2}\right)$; scale C is for the transformer ratio ($f_3/2$).*





tube is $+j(1+f_1f_2)/f_2f_3$ whatever the value of the admittance on the other straight-through limb.

It should also be noted that with one limb of the straight-through section forming a stub it is impossible to get transmission round the corner without reflection at the junction.

9. Conclusion

The foregoing review of waveguide components covers but a few of the elements used in waveguide systems for use in radar equipment: even these have by no means been exhaustively reviewed, but attention has been confined mainly to aspects in which the author has been in some way concerned. Among the specialized waveguide elements omitted may be mentioned rotating joints, attenuators, resistive loads and power measuring or monitoring devices, and couplings to other special devices and to waveguide radiators.

10. Acknowledgments

During the war, waveguide techniques and components for use in radar equipment were the subject of research and development by teams of workers at each of the three radar establishments. The early research work, when waveguides were still generally regarded as curiosities, was effected with the closest collaboration between these three teams. The author is aware how much this paper owes to the sum of waveguide knowledge which this collaboration produced, and wishes to acknowledge his indebtedness to these fellow workers in the teams led by Mr. E. Wild at the Admiralty Signals Establishment (A.S.E.), by Dr. W. D. Allen at the Telecommunications Research Establishment (T.R.E.), and by Dr. J. Ashmead at the Radar Research and Development Establishment (R.R.D.E.). The author would especially express his thanks to Dr. Ashmead, under whose guidance and encouragement he worked at R.R.D.E., and to Mr. L. A. Kerridge who assisted with the experimental work.

In the illustrative results quoted in the paper, use has been made of information from the following sources:—

Figs. 7 and 8 from a T.R.E. report by W. D. Allen and J. E. Williams, October 1942.

Fig. 9(a) from an A.S.E. memorandum by E. Wild, July, 1942.

Fig. 9(b) from a T.R.E. report by W. D. Allen, February, 1943.

REFERENCES

[1] Pryce, M. H. L.: "Waveguides." *J. Instn. elect. Engrs.* Vol. 93, Part IIIA, No. 1, p. 33 (1946).

[2] See, for instance, the convenient summary in:—Lamont, H. R. L.: "Wave Guides" (Methuen & Co., Ltd.).

[3] Schelkunoff, S. A.: *Bell System Technical Journal,* Vol 17, p. 17 (1938).

[4] Frank, N. H. and Chu, L. J.: Massachusetts Institute of Technology reports, 1943-6, 7.

APPENDIX

13.1 *Electric plane bend or E-bend*

For the analysis, take cylindrical polar co-ordinates as indicated in Fig. 12. Let E and H be the electric and magnetic field vectors, a subscript denoting the component parallel to the corresponding co-ordinate axis. The mode corresponding to the $H_{1,0}$ mode in a straight guide may be qualitatively derived by considering the latter's characteristic field distribution to be distorted by the bending of the guide. It is evident that E_z will be zero while the transverse E may give rise to components E_r and E_θ: similarly the transverse H will yield a component H_z, while the axial H may yield components H_r and H_θ. Also it is to be expected that the sinusoidal distribution of the amplitude of the field across the width of the guide (broad side) will be maintained, whereas the distribution across the height (narrow side) will be no longer uniform.

The waves will be plane waves, having their wavefronts in the radial planes, and propagating with a uniform angular velocity round the curve. The wave expression may therefore be written:—

$$\exp.\,(j\omega t - jp\theta) \quad \ldots \quad (9)$$

where p is the angular wavelength constant.

Applying these conditions to Maxwell's equation, the solutions for the field components, expressed in rationalized M.K.S. units, are found to be:—

$$\left.\begin{aligned}
E_r &= \left(\frac{1}{\beta r}\right)\left[A.J_p(\beta r) + B.N_p(\beta r)\right] . \sin(kz) . \exp.\,(j\omega t - jp\theta) \\
E_\theta &= \left(\frac{1}{p}\right)\left[A.J_p{}'(\beta r) + B.N_p{}'(\beta r)\right] . \sin(kz) . \exp.\left(j\omega t - jp\theta) - j\frac{\pi}{2}\right) . \\
H_\theta &= \left(\frac{k}{\omega\mu}\right)\left(\frac{1}{\beta r}\right)\left[A.J_p(\beta r) + B.N_p(\beta r)\right] \cos(kz) . \exp.\left(j\omega t - jp\theta + j\frac{\pi}{2}\right) \\
H_r &= \frac{-k}{\omega\mu p}\left[A.J_p{}'(\beta r) + B.N_p{}'(\beta r)\right] \cos(kz) . \exp.\,(j\omega t - jp\theta) \\
H_z &= \left(\frac{\beta}{\beta_0}\right)\left(\frac{1}{p}\right)\sqrt{\frac{\epsilon}{\mu}}\left[A.J_p(\beta r) + B.N_p(\beta r)\right] \sin(kz) . \exp.\,(j\omega t - jp\theta)
\end{aligned}\right\} \quad \ldots \quad (10)$$

where $J_p(\beta r)$ and $N_p(\beta r)$ are the Bessel functions of the first and second kinds, and the primes denote differentiation with respect to their argument (βr).

$k = \pi/a$ for the $H_{1,0}$ mode.

$\beta = \sqrt{\beta_0^2 - k^2} = 2\pi/\lambda_g$ = wavelength constant for a straight guide of the same cross-section.

$\beta_0 = \omega\sqrt{\mu\epsilon} = 2\pi/\lambda$ = wavelength constant for waves in free space.

μ and ϵ are the permeability and permittivity for the medium inside the tube, and have, respectively, the values $4\pi \times 10^{-7}$ henrys per metre and $10^{-9}/36\pi$ farads per metre for free space.

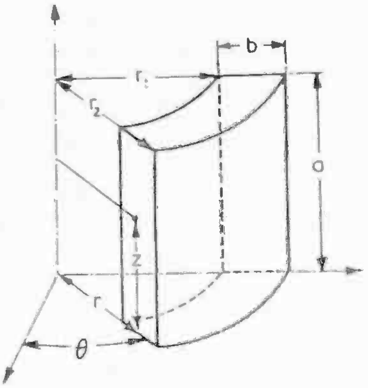


Fig. 12 (above). *Co-ordinate system for curved bends. (The dimensions a and b are shown for an E-bend; for an H-bend they should be interchanged).*

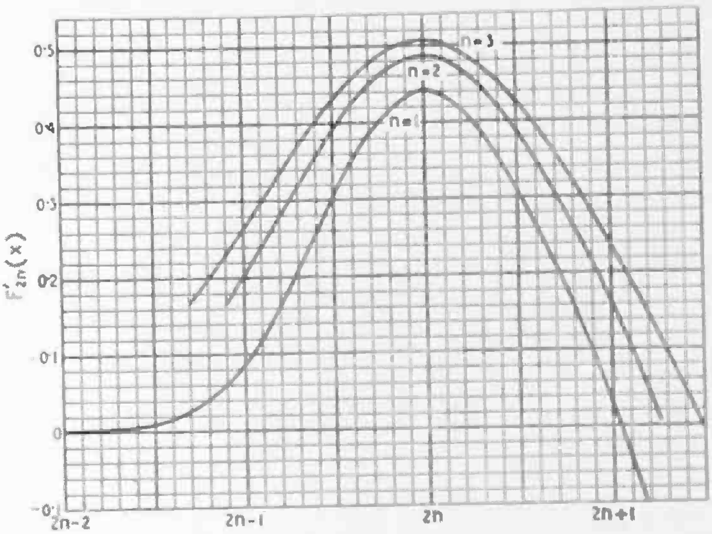


Fig. 13 (right). *Design graph for curved E-bend.*

The ratio of the constants A and B must be chosen to satisfy the boundary condition that E_θ is zero at $r = r_1$ and $r = r_2$: thus

$$-B/A = \frac{J_p'(\beta r_1)}{N_p'(\beta r_1)} = \frac{J_p'(\beta r_2)}{N_p'(\beta r_2)} \quad \ldots \quad \ldots \quad (11)$$

Hence, if the dimensions of the curved guide are given, this equation determines the angular wavelength constant p. It may be noted that the plane of zero transverse current, where E_θ is zero, is the central plane $z = b/2$.

As the mean radius becomes large E_θ and H_r become small, while the three remaining components E_r, H_θ, H_z become substantially uniform in the direction of r, thus tending to the fields for the $H_{1,0}$ mode in a straight guide.

In the design of a bend which is to produce little reflection p is fixed and equation (11) then determines the mean radius for a given height of guide $b = (r_2 - r_1)$. A reflectionless bend must be of electrical length $n\pi$, where n is an integer, and for a right-angle bend it follows that

$$n\pi = p\theta = p\pi/2.$$

Hence

$$p = 2n; \quad n = 1, 2, 3 \ldots \quad \ldots \quad (12)$$

The functions $F'_{2n}(x) = \dfrac{J'_{2n}(x)}{N'_{2n}(x)}$ are shown plotted in Fig. 13.

Equation (11) requires that $F_{2n}(\beta r_1) = F_{2n}(\beta r_1 + \beta b)$. Since for a given cross-section β is known, this equation determines the inside radius (r_1) of the bend. For most practical cases the range $r_1 < r < r_2$ is of sufficiently small size about the maximum at $x = 2n$ for this part of the graph to be regarded as symmetrical, with the result that:—

$$\beta r_1 \approx 2n - \frac{\beta b}{2}$$

$$\beta r_2 \quad 2n + \frac{\beta b}{2}$$

and hence

$$\pi/4\,(r_1 + r_2) \approx \frac{n\pi}{\beta} = n\,\frac{\lambda_g}{2}.$$

This means that as an approximate solution, the mean length of the guide round the curve may be made equal to an integral number of the straight guide half-wavelengths. The accurate solution should be found by solving equation (11) with the aid of the graphs of Fig. 13. It should be noted that the mean guide wavelength for the curve may be less than, equal to, or greater than the guide wavelength for the corresponding straight guide, depending on their common cross-section.

13.2 *Magnetic Plane Bend or H-bend.*

By applying similar qualitative arguments to those of the last section, it is to be expected that the $H_{1,0}$ mode in the H-bend curved guide will have only the field components E_z, H_θ, H_r; that the fields will be uniform in the z direction; and that the sinusoidal distribution across the width of the guide will undergo modification.

The field vectors turn out to be:—

$$E_z = \left[A.J_p(\beta_0 r) + B.N_p(\beta_0 r)\right] \exp.\,(j\omega t - jp\theta).$$

$$H_r = \sqrt{\frac{\epsilon}{\mu}}\left(\frac{p}{\beta_0 r}\right)\left[A.J_p(\beta_0 r) + B.N_p(\beta_0 r)\right] \exp.\,(j\omega t - jp\theta).$$

$$H_\theta = \sqrt{\frac{\epsilon}{\mu}}\left[A.J_p'(\beta_0 r) + B.N_p'(\beta_0 r)\right] \exp.\,(j\omega t - jp\theta - j\pi/2)$$

The boundary condition $E_z = 0$ at $r = r_1$ and $r = r_2$ determines the ratio of B to A, and the value of p when the dimensions of the curved guide are known :—

$$-B/A = \frac{J_p(\beta_0 r_1)}{N_p(\beta_0 r_1)} = \frac{J_p(\beta_0 r_2)}{N_p(\beta_0 r_2)} \quad . \ (13)$$

As before if a right-angle bend is to be of electrical length $n\pi$ to eliminate reflection, then p is equal to $2n$. The functional equation (13) has been plotted in Fig. 14 to show $\beta_0 \frac{(r_2 + r_1)}{2}$ as a function of $\beta_0 (r_2 - r_1)$.

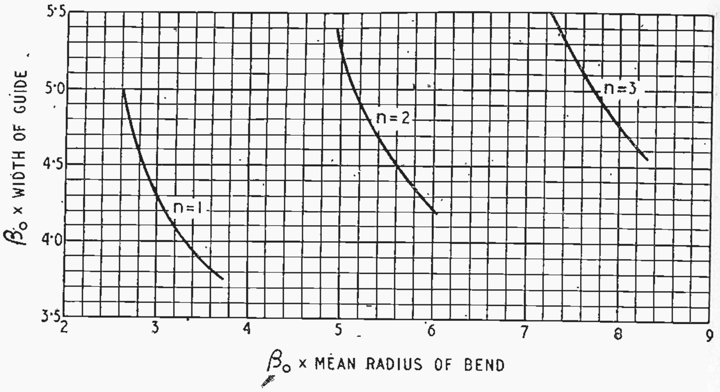


Fig. 14. *Design graph for curved H-bend.*

The position of the maximum value of transverse electric field (E_z), and of the zero transverse current is given by :—

$$-\frac{B}{A} = \frac{J_p'(\beta_0 r)}{N_p'(\beta_0 r)}$$

All the other quantities being known, this value of r, which is the correct plane in which to cut the guide if it is to be made in two parts, may readily be found for a limited but useful range of the variable, from the graphs of Fig. 13.

This circle of zero transverse current is always displaced outwards from the mean circle, and the wavelength along it is slightly longer than the wavelength in the straight guide.

DIVERSITY RECEPTION*

Statistical Evaluation of Possible Gain

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SUMMARY.—The diversity gain is defined as the reduction of transmitter power permissible on the introduction of a diversity system for the same proportion of time loss of signal.

Curves and formulae are obtained for this gain, which is shown to depend on the proportion of time loss allowed for the service, the number of received signals used, the correlation between fading in these signals and a parameter characterizing the propagation conditions. This parameter is discussed ; in order to obtain a better estimate of its value, it is suggested that more data on propagation conditions should be accumulated for links on which diversity reception is contemplated.

CONTENTS

1. Introduction

DIVERSITY reception makes use of the fact that signals do not, in general, fade simultaneously, whether received by spaced aerials, on diverse frequencies, or by any other diversity system. Usually, at any instant, the strongest signal is utilized while the others are suppressed. Two constituent signals X, Y and the resulting diversity signal Z, will first be considered and, where possible, this consideration will be extended to the case of a greater number of signals.

One method of assessing the merit of a diversity system consists of examining the records of X, Y and Z, and finding the proportion of time during which the signals are below the receiver sensitivity. On referring to Fig. 1 (a), it will be seen that for the X-signal this entails the summation of the intervals i_1, i_2, . . . and dividing the sum by the length of the record. Similarly, for the Y-signal, the summation of the

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* MS. accepted by the Editor, June, 1946.

intervals j_1, j_2, . . . is required. It will be noticed that with the diversity system the proportion of time loss could be found from the X- and Y-records by summing the intervals during which both signals are below the level of receiver sensitivity simultaneously, i.e., k_1, k_2, . . ., and dividing the sum by the length of the record. In this way an idea of the improvement in reception is obtained from the relative magnitudes of these proportions.

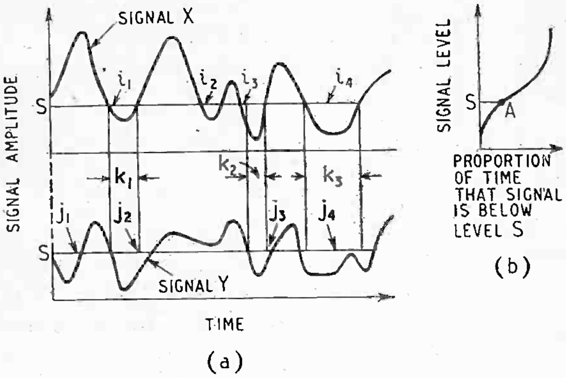


Fig. 1. *Typical curves of signal amplitude-time are shown at (a) for channels X and Y. The proportion of the time for which the X-signal is below the level S is indicated at (b).*

If the signal fluctuations are random, a probability distribution of signal strength may be considered and the probability integral curve constructed from the record. The probability integral represents the proportion of time that the signal lies below a certain level, and its value is found as explained above. The construction is illustrated in Fig. 1(*b*) where a typical form of the probability integral curve is shown; for example, the point A was obtained by summing the i's, [Fig. 1 (*a*)] and dividing by the length of the record. In some diversity systems (e.g., spaced aerials) it is reasonable to suppose that with a long enough record the X- and Y-probability integrals will not differ from each other appreciably; i.e.,

$$\Sigma i_n \approx \Sigma j_n$$

for all signal levels. These systems will be considered first. Fig. 2 gives typical curves of the probability integral as a function of the signal level s for the X-, Y- and Z-signals (the axes are here interchanged).

In practice the improvement in time loss is not the most important feature in diversity systems. If a given proportion of time loss can be tolerated in a communication service, the diversity system will allow a reduction in transmitted power, or possibly a relaxation in the requirements for receiver sensitivity. Referring to Fig. 2, it is seen that with a single receiver accepting a minimum signal level s_1, the time loss of signal would equal that for a diversity system using two receivers with a minimum signal level s_2. This means that the diversity system would allow the use of receivers of lower sensitivity. On the other hand, if the receiver sensitivity is kept constant, a reduction of transmitter power by a factor $(s_2/s_1)^2$ would be allowed. This reduction represents a merit of the diversity system and will be called "diversity gain," or simply "gain." It will be convenient to express it in decibels as

$$G = 20 \log_{10} \left[\frac{s_2}{s_1}\right] \text{db} \quad \ldots \quad \ldots \quad (1)$$

It is interesting to note that a simple extension of the procedure for finding the proportion of time loss for a given receiver sensitivity has led to the use of a probability integral. This suggests that some further conclusions may be obtained from a statistical consideration. Formulae for the diversity gain will be derived in this way.

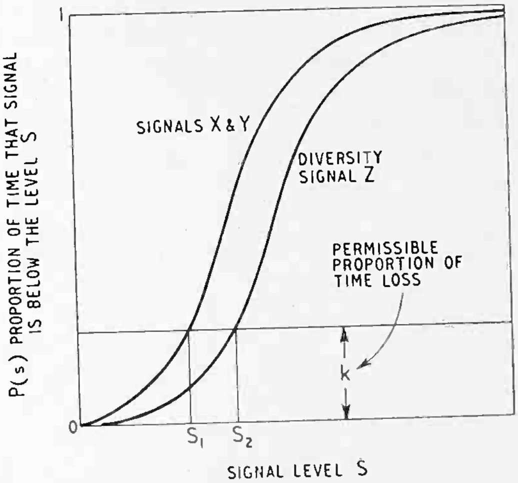


Fig. 2. *Typical probability-integral curves for the X- and Y-channels and the combined channel Z.*

2. Probability Integral of Signal Amplitude

Let the amplitudes of the signals X, Y and Z be specified at any time by the positive variates x, y and z, respectively. Denote the probability that the X- and Y-signals have amplitudes lying between x and $x + dx$, y and $y + dy$ simultaneously, by $\phi(x, y)\, dxdy$. The probability that the X-signal lies between x and $x + dx$ is denoted by

$$p_x(x)\,.\,dx = dx\int_0^\infty \phi\,(x, y)\,.\,dy \qquad .. \quad (2)$$

and the probability integral of the X-signal is denoted by

$$P_x\,(s) = \int_0^s p_x\,(x)\,.\,dx\,. \qquad .. \qquad .. \quad (3)$$

Similar expressions apply to the Y-signal.

If the stronger signal suppresses the weaker, as is usually the case, the signal Z will always be less than s, say, whenever x and y are both less than s. Consequently, the probability integral of the Z-signal is

$$P_z\,(s) = \int_0^s \int_0^s \phi(x,y)\,.\,dxdy\,. \qquad .. \quad (4)$$

When the signals fade independently, $\phi\,(x,\ y)$ is separable and is equal to $p_x\,(x)\,.\,p_y\,(y)$, and so

$$P_z\,(s) = \left\{\int_0^s p_x\,(x)\,.\,dx\right\}\left\{\int_0^s p_y\,(y)\,.\,dy\right\}$$
$$= P_x\,(s)\,.\,P_y\,(s), \qquad .. \quad (5)$$

the product of individual probability integrals. In particular, if $P_x\,(s) = P_y\,(s) = P\,(s)$, say,

$$P_z\,(s) = [P\,(s)]^2, \quad .. \qquad .. \qquad .. \quad (5a)$$

the square of non-diversity probability integrals. For an n-diversity system in which there are n independent signals, $X_1,\ X_2,\ .\ .\ .\ X_n$, this last result becomes $P_n\,(s) = [P\,(s)]^n$.

Summing up, at any signal level, the proportion of time loss in a diversity system with independent signals is the product of the proportions of time loss for the constituent signals.

3. The Evaluation of Diversity Gain

In order to evaluate the diversity gain a probability distribution must be assumed. The most typical distributions are the Gaussian, or normal, law and the Rayleigh law.

When the fading is shallow, the distribution is often approximately normal; this would also be true if the fading were produced by the combined action of a large number of small independent perturbations of the r.f. signal. If x is the deviation of the signal amplitude from its mean value, the law has the form

$$p_x\,(x)\,dx = \frac{1}{\sigma(2\pi)^{\frac{1}{2}}}\exp\left\{\frac{-x^2}{2\sigma^2}\right\}\,.\,\mathrm{dx}, \qquad (6)$$

where σ is the r.m.s. deviation of the signal from the mean.

When the fades are deep, the probability distribution often approaches the Rayleigh distribution

$$p_x\,(x)\,dx = \frac{2x}{\sigma^2}\exp\left\{\frac{-x^2}{\sigma^2}\right\}\,.\,dx, \quad x \geqslant 0, \qquad (7)$$

where σ is the r.m.s. value of the signal measured from zero. This law would also hold if the r.f. signal were the sum of a great number of components in random phase relation.[1]

3.1. *Gaussian distribution*

A disadvantage of using the Gaussian probability function is that it extends from $-\infty$ to $+\infty$, whereas the signal, being the result of detection, cannot change sign. The Gaussian law could never, therefore, represent the facts exactly, but will at least yield an approximation. On the other hand, it has the advantage that the effect of correlation between the constituent signals can be estimated comparatively simply. When the receiving aerials in a space-diversity system are closely spaced, the signals will generally fade simultaneously. By increasing the spacing, the correlation between the signals may be reduced. In some conditions it may even be possible to have negative correlation; in that case a decrease of one signal is often accompanied by an increase of the other. In general, however, one may expect at best to reach zero correlation. It will be seen later how a decrease of the correlation increases the diversity gain. Other known ways of obtaining signals with low correlation are frequency and polarization diversity, and the Musa system in which signals are isolated according to the number of ionospheric reflections suffered.

The bivariate Gaussian distribution for two variables x and y, may be written in a normalized form, where the mean values of x and y are zero and the r.m.s. values are unity:

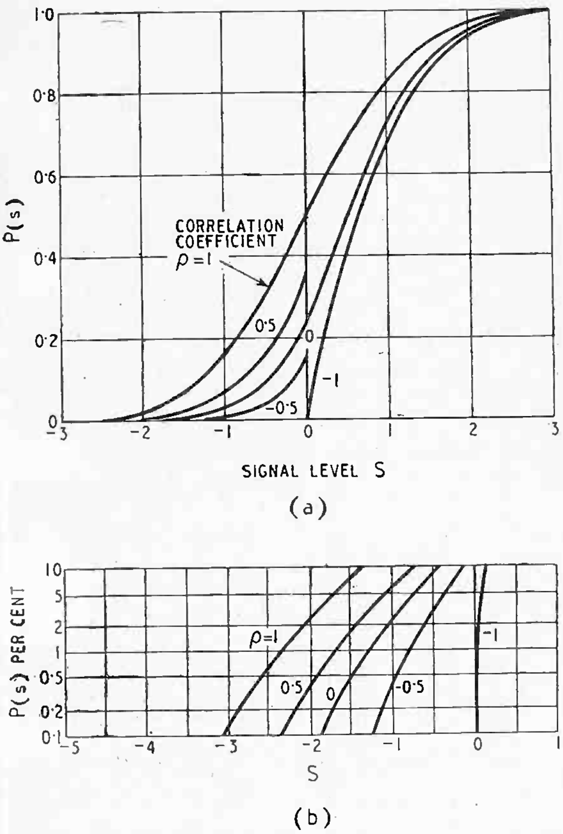
$$\phi_g\,(x, y) = \frac{1}{2\pi\,(1-\rho^2)^{\frac{1}{2}}}\exp -\left\{\frac{(x^2 - 2\rho xy + y^2)}{2(1-\rho^2)}\right\} \quad (6a)$$

where ρ is the correlation coefficient; its value has a marked effect on the gain that may be expected from a diversity system.

To determine this influence, it is necessary to find the probability integral

$$P_z(s) = \int_{-\infty}^{s}\int_{-\infty}^{s} \omega_g(x, y) \, . \, dxdy, \quad \ldots \quad (4a)$$

which will be a function of ρ; here x, y and s are measured from the mean signal level.



(a)

(b)

Fig. 3. *Normal-law probability-integral curves are shown at (a) and the lower part to an enlarged scale at (b).*

It can be shown[2] that the integral in (4*a*) is

$$P_z(s) = \frac{1}{4}\left[1 + \operatorname{erf} s/\sqrt{2}\right]^2 + \frac{1}{2\pi} e^{-s^2} \sum_{r=1}^{\infty} \left[H_{r-1}(s)\right]^2 \frac{\rho_r}{r'} \quad \ldots \quad (4b)$$

where

$$\operatorname{erf} \alpha = \frac{2}{\sqrt{\pi}} \int_0^{\alpha} e^{-2} \, dt$$

and $H_r(s)$ is the r-th Hermite polynomial. Computed results are shown in Fig. 3(*a*) for the following values of ρ:

(*a*) $\rho = 1$. Here the X- and Y-signals have identical amplitudes and no gain is obtained. The probability integral $P(s)$ reduces to the simple form $\frac{1}{2}(1 + \operatorname{erf} \frac{1}{2}s)$.

(*b*) $\rho = 0$. This corresponds to independent signals and $P(s)$ reduces to $[\frac{1}{2}(1 + \operatorname{erf}\frac{1}{2}s)]^2$.

(*c*) $\rho = -1$. In this case no losses of signal would be expected below the common mean, since one signal is the mirror image of the other. Consequently the probability integral is zero below the mean signal level.

(*d*) The intermediate cases, $\rho = 0.5$ and -0.5 are shown for negative s only.

The lower part of the curves is also shown in Fig. 3 (*b*), in which the vertical axis is marked in percentages on a logarithmic scale.

The improvement may be found directly from these curves, but the gain cannot be determined unless the mean signal value is known; this corresponds to the zero coordinate in Fig. 3 (*a*) and (*b*). In this case, the true zero of the horizontal scale can be inserted and the gain obtained from (1). Two examples have been computed and the results are shown in Fig. 4. The curves are given as functions of ρ for the permissible proportion of time loss $k = 0.5$, 1, 2 and 5 per cent, for the two cases when the ratio of the mean to the root-mean-square variation about the mean is 3 and 5.

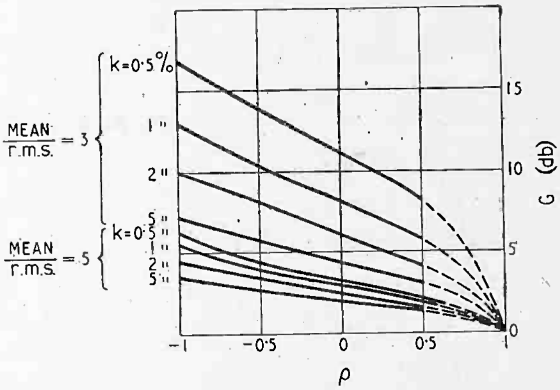


Fig. 4. *Examples of diversity gain G(p).*

3.2. *Rayleigh distribution*

Unlike the Gaussian law, the Rayleigh probability law permits only positive values of the signal. The distribution is completely described by one parameter. Its mean value is given by $x = \frac{1}{2}\sigma\sqrt{\pi}$ where σ is the root-mean-square value of the amplitude measured from zero. In the bivariate case, this law is less tractable analytically and only the case of independent signals will be considered here.

The probability integral is easily obtained; assuming that $\sigma = 1$,

$$P(s) = \int_0^s 2xe^{-x^2} \, . \, dx = \left[1 - e^{-s^2}\right]. \qquad (8)$$

For a 2-diversity system

$$P(s) = \left[1 - e^{-s^2}\right]^2, \qquad \ldots \qquad \ldots \qquad (8a)$$

and in general with an n-diversity system

$$P(s) = \left[1 - e^{-s^2}\right]^n. \qquad \ldots \qquad \ldots \qquad (8b)$$

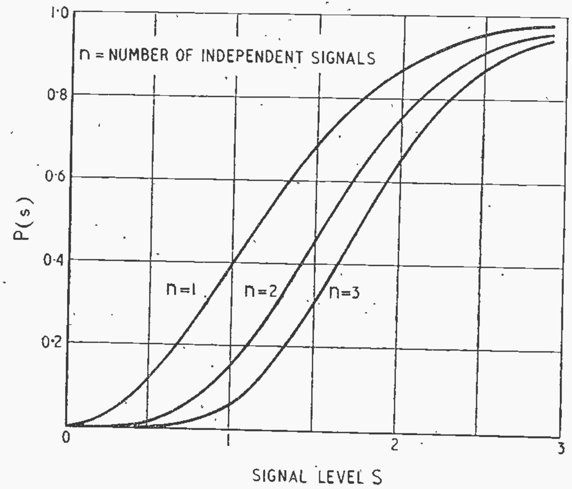


Fig. 5. *Rayleigh-law probability-integral curves.*

These functions are shown in Fig. 5 for the cases $n = 1$, 2 and 3.

The formula for diversity gain will next be derived. Suppose that for a permissible proportion of time loss k, we have signal levels s_1 on the non-diversity and s_n on the n-diversity system. Then

$$k = 1 - e^{-s_1^2} = \left[1 - e^{-s_n^2}\right]^n, \qquad \ldots \qquad (9)$$

and so

$$\frac{s_n}{s_1} = \left\{\frac{\log(1 - k^{1/n})}{\log(1 - k)}\right\}^{\frac{1}{2}}. \qquad \ldots \qquad \ldots \qquad (10)$$

Hence the gain in decibels is

$$G = 20 \log_{10} s_n/s_1 = 10 \log_{10} \left\{\frac{\log(1 - k^{1/n})}{\log(1 - k)}\right\}. \qquad \ldots \qquad \ldots \qquad (11)$$

Fig. 6 shows a graph of the gain, $G(k)$, for the cases $n = 2$ and 3.

The effect of increasing n is shown by the full lines in Fig. 7. Inspection shows that as the number of independent signals is increased, the gain is also increased but by a diminishing amount.

4. Power-Law Approximation to the Probability Integral

It has been implied in the previous section that the lower parts of the probability integral curves are of special interest since the permissible proportions of time loss are usually low.

Suppose that in this range of signal values the probability integral can be approximately represented by the power law

$$P(s) = \lambda s^m, \quad P(s) \ll 1,$$

where λ and m are constants. This leads to a simple formula for the diversity gain, easily applicable to practical cases.

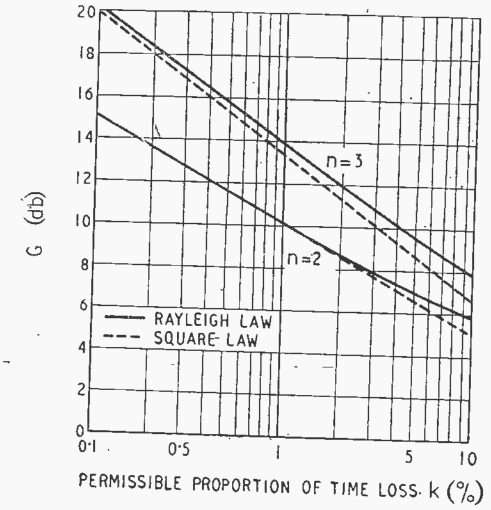


Fig. 6. *Diversity gain $G(k)$ for two- and three-signal systems.*

4.1. *The evaluation of gain.*

The equation corresponding to (9) above is in this case

$$k = \lambda s_1^m = \left[\lambda s_n^m\right]^n, \qquad \ldots \qquad \ldots \qquad (13)$$

where s_n, s_1 are the levels of the diversity and non-diversity signals respectively, corresponding to the given time loss k. Hence

$$G = 20 \log s_n/s_1 = \frac{20}{m}\left\{1 - \frac{1}{n}\right\} \log_{10} \frac{1}{k} \text{ db.} \qquad (14)$$

For example, if the power-law approximation is valid for small k, and if a 1 per cent time loss of signal is allowed, the gain for independent signals will be $\frac{20}{m}$ db in a 2-diversity system. As the number of constituent signals is increased, the gain at this level will rise asymptotically to $\frac{40}{m}$ db.

The range of validity of the power-law approximation must extend to a signal value which depends on the number of signals used, the diversity probability-integral curve and the value of k. Higher values of k and a greater number of signals require a greater range of validity. This can be seen from Fig. 8, where the Rayleigh probability integral curves (full lines) are drawn on a log-log scale on which a power law, as in (13), gives straight lines (broken lines). The range of linearity should extend at least to s_2, s_3 or s_2', s_3' if two or three signals and a level k or k' are considered. The effect of departure from linearity of the Rayleigh probability integral is illustrated in Fig. 6 and Fig. 7, where the gain is plotted for both the Rayleigh law and the square law approximation.

Up to this point the probability integrals, and therefore the mean values and standard deviations of the constituent signals, have been assumed identical at the point of the circuit where they are compared and the strongest selected. This is not always true. For instance, the receivers may have different sensitivities or the aerials different gains. However, all signals may still retain the same value of m.

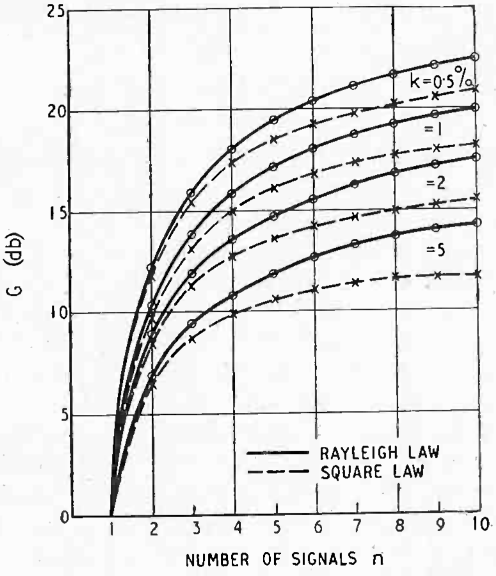


Fig. 7. *Effect on diversity gain of increasing the number of signals.*

It is shown in the Appendix that in this case (14) gives the diversity gain of the system over a single receiver which delivers a signal having a strength equal to the geometric mean of the strengths of the actual constituent signals when expressed in voltages, or alternatively, their arithmetic mean if expressed in decibels. It follows, for example, that if the sensitivity of one of the receivers changes, it will affect the reception only in so far as it alters the mean sensitivity of all receivers.

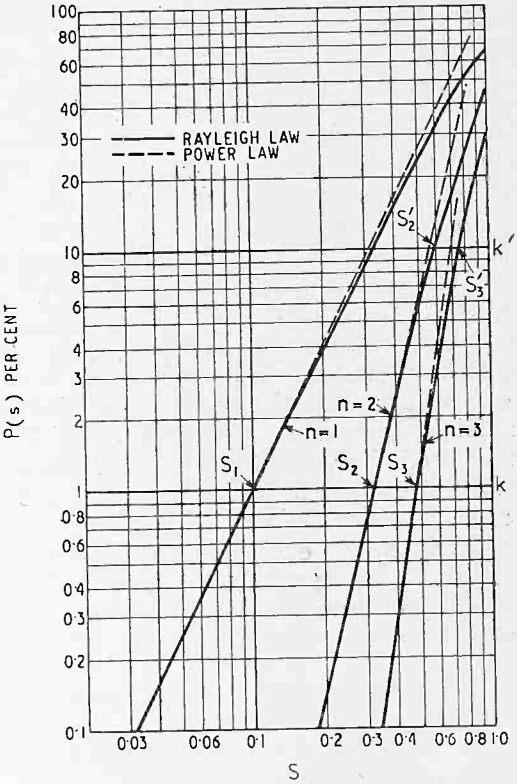


Fig. 8. *Range of linearity of Rayleigh law on log-log scale.*

It can be shown that the above conclusions only hold for a probability integral given by a power law.

A consideration of the case when the signals have neither the same mean value nor the same value of m did not yield a simple and convenient formula.

4.2. *The effect of propagation conditions on gain.*

It can be seen from (14) that the diversity gain depends on three parameters; two of them, n and k, have already been discussed; n can be determined by the designer, k is chosen by the user of the system. The remaining parameter m, however, depends on propagation conditions and is usually difficult to control. Moreover, its value varies with time.

In order to get an idea of the probable values of m, some theoretical considerations can be made, but it is more prudent to use empirical results.

If the received signal is considered as the result of the superposition of a number of signals of equal amplitudes and in random phase relation, the values of m can be derived from the formulæ and curves given by M. Slack.[3] In the case of two signals $m = 1$ and for more than two, $m = 2$.

For an infinite number of components, not necessarily equal in amplitude, the probability distribution follows the Rayleigh law in which case $m = 2$. A graph paper has been prepared in which the Rayleigh probability integral (8) appears as a straight line at 45° to the axes; the horizontal signal scale s is logarithmic.* Since the Rayleigh law is approximately linear for small s, the lower part of the vertical scale is very nearly logarithmic, so that the graph paper may be used to determine the value of m when the Rayleigh law does not apply. With the scales used the value of m is twice the slope of the lower part of the probability integral curve.

Experimental examples of probability integral curves are plotted on this graph paper in Fig. 9 for two records made at an N.P.L. station by J. H. Tait and N. Creed (S.R.D.E.).

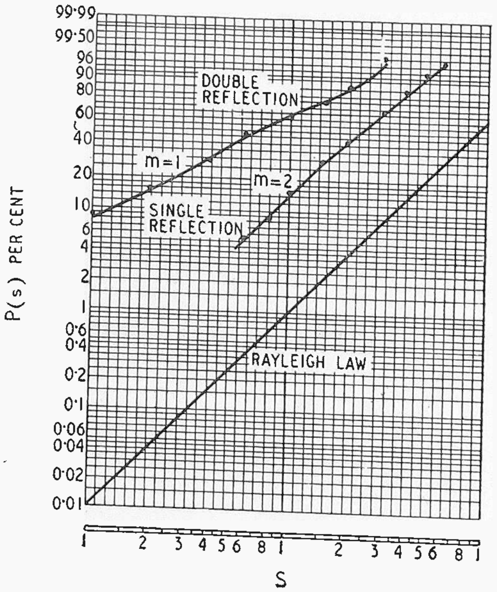


Fig. 9. *Probability integrals of single- and double-reflections of pulses from the F-layer plotted on Rayleigh probability paper.*

Pulse transmission at 1,025 kc/s was received over a distance of 116 km during the night. Two of the pulse trains received were identified as being the result of one and two reflections from the F-layer of the ionosphere respectively. Single reflection gave a probability integral which approximated closely to the Rayleigh form, thus giving $m = 2$. Double reflection, on the other hand, was far from the Rayleigh law, giving $m = 1$ in the lower part. A straight line at 45° to the axes, corresponding to the Rayleigh law, is drawn for comparison.

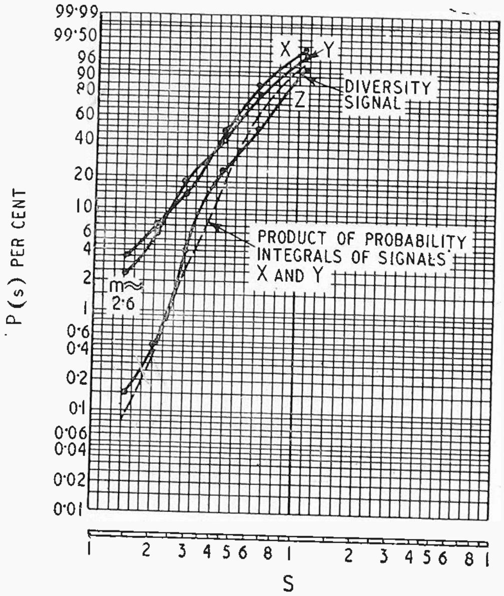


Fig. 10. *Probability integrals of signals on a 7-cm link.*

Other examples are given in Fig. 10 from records obtained by W. Childs at S.R.D.E. experimental stations in Wales, for transmission at a wavelength of about 7 cm on a 60-mile link over sea. Two receivers gave signals X and Y and these were combined to give a diversity signal Z. The probability integrals of X and Y plotted in Fig. 10 show some deviation from the Rayleigh law and have $m = 2.6$. The product of these probability integrals is plotted as a broken line; the diversity probability integral deviates little from this, indicating that the signals X and Y were substantially independent.

Similar records obtained in Wales at various times when heavy fading occurred gave several values of m. A few of them, chosen at random, are given below:—

1.9; 1.9; 1.2; 3.0; 1.4; 1.7; 5.9; 1.8; 2.5; 1.4; 1.2; 1.3; 2.2; 2.2; 2.5.

The mean value of these is about 2.1,

---

* For convenience a linear decibel scale is used.

but there is a considerable scatter ; an even greater scatter was obtained from other records of pulses reflected from E- and F-layers in the experiments at N.P.L. mentioned earlier. It may be noticed, however, that the cases in which m is large, giving a small value of G, may be discounted since then the fading is usually shallow, so that reception is satisfactory without a diversity system.

It was mentioned in Section 3 that when the fades are shallow the distribution is usually approximately normal. This is illustrated in Fig. 11 where a probability integral is plotted from a record obtained over a 10-cm link by S. Jarkowski at the stations in Wales mentioned above. It is plotted on the so-called " Arithmetic Probability " paper in which the probability integral of a Gaussian distribution would appear as a straight line.

The limited number of examples shown above gives no more than an indication of the values of m likely to be encountered. From these it appears that $m = 2$ may serve as a working value until more information is obtained. More records should be taken on links over which diversity reception may be needed, the probability integrals should be constructed as described here, plotted on log-log or Rayleigh paper and values of m accumulated for a statistical study. In practice the mean signal level varies from time to time, and diversity reception is most needed when the signal is weakest. Consequently, the periods with strong signals should be ignored.

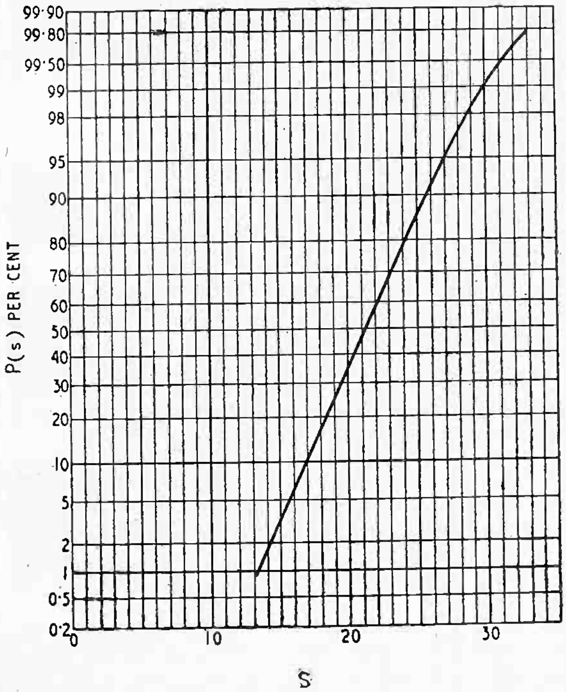


Fig. 11. *Probability integral of a 10-cm signal with shallow fading.*

5. Conclusions

If the constituent signals of a diversity system fade independently, the proportion of time in which the diversity signal falls below receiver sensitivity is the product of the corresponding proportions for the constituent signals. In a diversity system comprising n receivers of equal sensitivity, the proportion of time loss of signal will be the n-th power of the proportion for a single receiver.

If the constituent signals have the same probability integral and fade independently, the formula for diversity gain is approximately

$$G = \frac{20}{m}\left\{1 - \frac{1}{n}\right\} \log_{10} \frac{1}{k} \text{ db}$$

where k is the proportion of time loss allowed for the system, n is the number of constituent signals, and m is the slope of the lower part of the probability-integral curve of a signal when plotted on a log-log scale. It follows that, when the permissible proportion of time loss is smaller, a greater diversity gain may be expected. Also, as more signals are added, the gain is increased but each additional signal gives a reduced increase.

If there is some positive correlation between the fading of the constituent signals, the diversity gain is less than that given by the above formula ; it is greater in the case of negative correlation.

The limited experimental information available shows that the slope m assumes various values according to the propagation conditions. It appears that $m = 2$ may serve as a working value until more information is obtained.

It is suggested that data should be accumulated giving the values of m encountered on links for which diversity reception is contemplated.

If the received signals have different mean values but still the same value of m, the above formula gives the diversity gain of the system over a single receiver delivering a signal which has a mean value equal to the arithmetic mean of the actual constituent signals when expressed in decibels.

The permission of the Chief Scientist,

Ministry of Supply to publish this paper is gratefully acknowledged.

The authors wish to thank Dr. J. S. McPetrie for advice on the method of presentation of this paper. They are also indebted to their colleagues at S.R.D.E., Messrs. J. H. Tait, N. Creed, W. Childs and S. Jarkowski, whose experimental data were utilized.

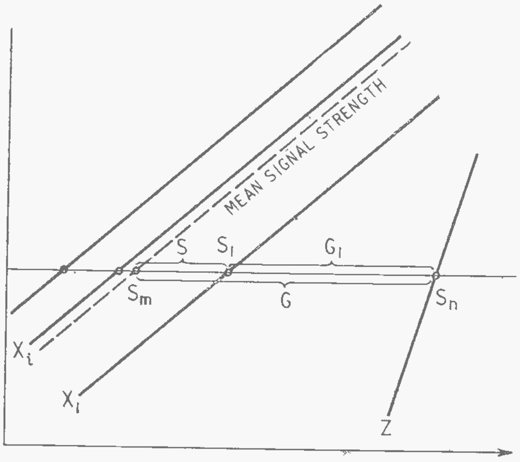


Fig. 12. *Probability integrals of signals of unequal strength.*

APPENDIX

The Effect of Unequal Strength of Signals on Diversity Gain

If the receivers of an n-diversity system deliver signals of different mean values, but with the same value of m, the corresponding power-law approximations to the probability integrals may be written

$$P_i(s) = \lambda (a_i s)^m$$

where $a_i \geqslant 1$ is the ratio of the mean values of the strongest signal and that from the i-th receiver. For the strongest signal $a_1 = 1$.

In Fig. 12 let X_1 be the probability integral of the strongest signal, plotted on log-log paper, and let the lines parallel to it correspond to the other signals. Let the line Z correspond to the diversity signal. The gain will be referred at first to the strongest signal.

If the signals fade independently, it follows, as in (13), that

$$\begin{aligned} k &= \lambda s_1{}^m = \lambda s_n{}^m \lambda (a_2 s_n)^m \ldots \lambda (a_n s_n)^m, \\ &= \lambda^n s_n{}^{mn} (a_2 a_3 \ldots a_n)^m, \end{aligned}$$

so that the gain in decibels is

$$\begin{aligned} G_1 &= 20 \log_{10} s_n/s_1, \\ &= \frac{20}{m}\left\{1 - \frac{1}{n}\right\} \log_{10} \frac{1}{k} \\ &\quad - \frac{1}{n}\left\{20 \log_{10} a_2 + \ldots + 20 \log_{10} a_n\right\}, \\ &= G - S, \end{aligned}$$

say, where G is the gain given by (14) and S is the difference between the mean value of the strongest signal and the mean strength of all signals, expressed in decibels. This is illustrated in Fig. 12.

It follows that (14) gives the gain of the diversity system over a single receiver delivering a signal with a strength which is the arithmetic mean of the strengths of the actual constituent signals if expressed in decibels, or alternatively their geometric mean if expressed in voltage.

REFERENCES

[1] Lord Rayleigh, "On the Resultant of a Large Number of Vibrations of the Same Pitch and of Arbitrary Phase." *Phil. Mag.*, 1880, Vol. 10, p. 73.

[2] Elderton, W. P.: "Frequency-Curves and Correlation." (C. & E. Layton) Appendix III.

[3] "The Probability Distribution of Sinusoidal Oscillations Combined in Random Phase." *Journ. Instn elec. Engrs.*, 1946, Vol. 93, Part III, pp. 76–86.

CORRESPONDENCE

The Equivalent Diode

To the Editor, "Wireless Engineer"

SIR,—I was much interested in the above study by G. B. Walker, with which I mainly agree. Apart from an obvious typographical error resulting in a confusion of a and α in the final equation, my only criticism is the somewhat minor one that full justice has not been done to the formula obtained, in that it would appear;

(*a*) that if $V_k = 0$, the μ used need not be the electrostatic μ but may be the true μ and thus depend on the electrode potentials. The restriction in range mentioned by Mr. Walker thus disappears; which is just as well, as the range over which the true μ and the electrostatic μ coincide is really rather small.

(*b*) that if, indeed, μ is the electrostatic μ, and independent of electrode potentials, then we are not restricted to $V_k = 0$.

In order to establish the above, all we need do is to allow for the variation of μ with V_k, so that

$$A\left(1 + \mu + V_k \frac{\partial \mu}{\partial V_k}\right) = A'$$

giving, for V_k not zero,

$$V_d = V_k + \frac{V_a - V_k + \mu(V_g - V_k)}{1 + \mu + V_k \partial\mu/\partial V_k}$$

Then if $V_k = 0$ we have, as obtained by Mr. Walker

$$V_d = \frac{V_a + \mu V_g}{1 + \mu}$$

which is seen to be true whether μ is variable or not

Alternatively, if $\partial\mu/\partial V_k = 0$, we have

$$\begin{aligned} V_d &= V_k + \frac{V_a - V_k(1 + \mu) + \mu V_g}{1 + \mu} \\ &= \frac{V_a + \mu V_g}{1 + \mu} \end{aligned}$$

—again, Mr. Walker's result, but now not restricted to $V_k = 0$.

Mr. Walker's formula differs from mine by the factor $\sqrt{1 + \frac{1}{\mu}}$. Although in practice this factor is usually very close to unity, its discovery is an important theoretical feature, and in view of the special properties of tubes having a fractional μ, immediate practical application is not lacking.

P.R.T. Laboratries Ltd., W. E. BENHAM.
High Wycombe, Bucks.

Is Rotation Absolute or Relative ?

To the Editor, "Wireless Engineer"

SIR,—Rotation about any axis may be considered as rotation about any other parallel axis together with rectilinear motion at right angles to, and in the common plane of, these axes. The rectilinear motion is not absolute, so we need only consider rotation about, say, the centre of gravity of the system under observation. To the engineer it would seem that this may be detected and measured without reference to the external world, by means of a hypothetical instrument consisting of a pair of equal masses, m, attached to the ends of a massless rod which can be rotated about a central transverse axis, at a speed, ω, measured relative to the observed system. If latter has no absolute rotation a dynamometer embodied in the rod will register a force of $rm\omega^2$, where r is half the separation of the masses ; but if the system has a component of absolute rotation about the axis of the instrument the force will be correspondingly reduced or increased. By measuring this force with the instrument set in three successive directions it should be possible to calculate the direction and magnitude of absolute rotation of the system.

P. M. C. LACEY

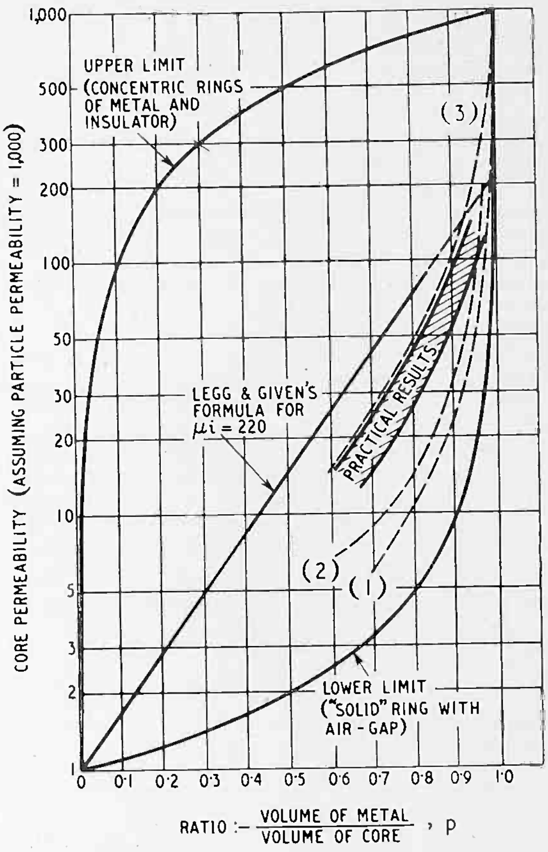
Aylesbury, Bucks.

Permeability of Dust Cores

To the Editor, "Wireless Engineer."

SIR,—The recent correspondence on the theoretical considerations of the permeability of dust cores has aroused considerable interest, but the practical aspect of the subject does not seem to have received the same attention.

Some years ago we were puzzled by the fact that the permeability of a dust core with a known percentage of filler was considerably higher than that calculated from the formula, assuming a simple air-gap or assuming the particles to be uniformly coated spheres. As Prof. Howe points out, the ultimate limit in permeability would be that of a core comprising laminations aligned in the direction of the flux. In practice we have found that over a limited range of percentage fillers the curve of core permeability against percentage filler agrees reasonably well with a formula calculated on the assumption that the particles are uniformly coated rectangular slabs (dimension ratio : 10 × 2 × 1) of 1,000 permeability material aligned with the long axis of the slab in the direction of the field (see figure). Photomicrographs of core sections have shown that under the high pressures used the particles may become flattened and tend to align themselves (in a toroid) in the required direction. The greater the flattening the higher will be the permeability. A certain amount of prominence has been given in your correspondence to Legg and Given's[1] empirical formula $\log \mu = p \log \mu_i$. The value of μ_i (intrinsic permeability) assumed by them as being 220 (for molybdenum-permalloy powder) has been considered by us to be an arbitrary value inserted in the equation so that the equation shall represent as closely as possible the practical results over a limited range of core permeability (up to about 90) and should not be associated with actual permeability of the material. The values of intrinsic permeability are certainly much higher. The published values for the permeability of Mo-permalloy in sheet form are of the order of 22,000 as compared with 9,000 for Ni-Fe alloy.[2] We have made attempts to measure the permeability of a Ni-Fe alloy as used in dust cores and have obtained values of about 1,000 (measured on d.c.) for cores pressed at the usual working pressure with no insulation.



Relation between core-permeability and metal content for different arrangements of particles. Key to theoretical curves : (1) *cubic particles ;* (2) *cubic particles (with corners cut off)—approximating to flattened spheres ;* (3) *rectangular slabs (dimension ratio* 10 : 2 : 1), *with the long axis parallel to the field.*

There are still considerable air-gaps in such a core, as is evidenced by the fact that if cores are made from the material in such a way that air-gaps are largely avoided the permeability is about 3,000.

It would appear, therefore, that it is safe to assume a figure of, say, not less than 6,000 for the intrinsic permeability of molybdenum permalloy powder, and this coupled with a certain amount of particle flattening would seem to account largely for the so-called anomalously high core-permeabilities of upwards of 150 which may be encountered in practice.

These considerations, of course, represent only a small part of the rather complex problem of such a heterogeneous body as a dust-iron core.

P. R. BARDELL.

G.E.C. Research Laboratories,
Wembley.

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[1] *Bell System Tech. Journal*, 1940, Vol. 19, p. 385.

[2] *Bell System Tech. Journal*, 1939, Vol. 18, p. 438.

NEW BOOKS

Der Frequenzstabile Schwingtopf-Generator

By Arnold Braun. Pp. 79, with 37 Figs. Published by Verlag A.G. Gebr. Leemann & Co. Zürich. Price 7.50 Francs (Swiss).

This is the author's thesis for the D.Sc. degree at Zürich Technische Hochschule. The work was carried out in the Institut für Hochfrequenztechnik under the direction of Dr. F. Tank. It deals with the use of a cavity resonator as the oscillatory circuit of a valve oscillator at frequencies of about 200 Mc/s, with special reference to the constancy of frequency and to the optimum design of the cavity resonator. The effects of temperature changes and mechanical stresses on the dimensions of the resonator and the effect of this and of air pressure and moisture on the frequency are discussed. The calculation of the losses and of the equivalent resistance and their effect on the dimensions necessary to give the optimum Q value are discussed very fully, as is also the effect of the connections between the resonator and the valve. The construction and testing of two cavity resonators, both connected to push-pull oscillators, in one case with inductive coupling and in the case with capacitive coupling, are described and discussed in detail. Figs. 4*a* and 4*b* do not agree with the text, and there seems to be something wrong with the definitions of permeability and dielectric constant on page 4. μ_0 is given as $1.256 . 10^{-8}\left[\frac{A\ \text{sec}}{V\ \text{cm}}\right]$ and ϵ_0 as $0.0886 . 10^{-12}\left[\frac{V\ \text{sec}}{A\ \text{cm}}\right]$. The quantities in brackets should be interchanged; this can be seen at once since $\mu_0 = 1.256 . 10^{-8}$ henry/cm and $\epsilon_0 = 0.0886 . 10^{-12}$ farad/cm. Instead of henrys one can put ϕ/A or $V\ \text{sec}/A^2$; similarly, instead of farads one can put Q/V or $A\ \text{sec}/V$. These are minor details, however, and the book can be recommended to anyone interested in this subject.

G. W. O. H.

"Wave Propagation in Periodic Structures"

By L. Brillouin. Pp. 247 + viii, with 137 diagrams. Published by McGraw-Hill Book Co., Ltd., Aldwych House, London, W.C.2. Price 20s.

This is an unusual book, covering as it does problems in diverse and normally unrelated fields. The author's theme is the common mathematical background linking different types of wave motion—elastic waves, electromagnetic waves, and electron waves in wave mechanics—and in particular the similarities of their interaction with periodic structures like crystal lattices and electric-wave filters; the engineer and the physicist can learn from each other in their methods of approach to these problems.

The book starts simply with the consideration of oscillations in a chain of particles and their relations to line networks. This is then extended into a general theory of one-, two- and three-dimensional lattices of particles, and proceeds to a study of the zone concept in the theory of solids, to which the author has made important contributions. This, occupying about two-thirds of the book, is largely the domain of the physicist, and the radio engineer will sometimes be hard put to it to see similarities with the properties of filter networks. In the latter third of the book is presented the engineer's approach to networks through the matrix calculus. This is finally extended to the case of continuous electric lines, which are shown to involve matrices similar to those occurring in the Pauli theory of electron spin.

The book is fairly easy to read, but the similarities of method are often masked by the differences of approach. It is a book to browse through, not to study, and as such probably one should not complain that the treatment is sometimes scrappy and the progress somewhat random. The orthodox radio engineer may make little of it, but to those whose minds are more flexible it will provide valuable new outlooks and parallel avenues of thought in other fields. In this respect a criticism might be made of the scanty references to original sources. Often a man's name is quoted but not always a reference given to the work in question. More attention is given to the atomic than to the macroscopic lattice, and the book would have benefited by a discussion, for example, of the radiation pattern of a three-dimensional array of dipoles, and its similarities with the X-ray diffraction pattern of a crystal. It seems unfortunate that the author does not mention the recent work of Kron and his collaborators in devising two- and three-dimensional networks as equivalent circuits for electromagnetic fields in bounded space. This would form a very fitting close to the book.

The volume is one of the well-known "International Series in Physics" but is smaller than normal in page size and contains only 247 pages. The typography is up to the usual high standards of McGraw Hill, but it gave the reviewer some slight comfort to find a 1946 U.S. publication which, in addition to the usual "economy of essential materials" notice on the half-title page, did show some signs of austerity in paper quality and margins.

H. R. L. L.

Broadcasting Stations of the World

Pp. 48. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 1s.

Compiled by *Wireless World* this booklet contains lists of broadcasting stations arranged both in order of frequency and by geographical location. European medium- and long-wave stations are included, and the short-wave lists cover the whole world and give call-signs as well as the power of stations.

THE PHYSICAL SOCIETY

A meeting of those interested in the formation of an acoustical group will be held in the Jarvis Hall of the Royal Institute of British Architects, 66, Portland Place, London, W.1, on 19th February, 1947, at 3 p.m. There will be a paper by Dr. Alex Wood on "The Contribution of Acoustical Science to Allied Studies," and a general discussion of the proposal to form an acoustical group.

Those interested are asked to send their names to the acting secretaries, A. T. Pickles and W. A. Allen, at 1, Lowther Gardens, Prince Consort Road, London, S.W.7.

ABSTRACTS AND REFERENCES

Compiled by the Radio Research Board and published by arrangement with the Department of Scientific and Industrial Research

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

ACOUSTICS AND AUDIO FREQUENCIES

4 **327**

Problems of Modern Acoustics: Noise and bration.—P. Chavasse. (*Onde élect.*, July 1946, l. 26, No. 232, pp. 274–287.) A review of the oject covering architectural, physiological and isical acoustics, electroacoustics and supersonics. e definition of intensity in accordance with the eber-Fechner law leads to the units decibel, phon, n, pal and vibro based on the frequency curves equal aural or tactile sensation. Apparatus which es an objective indication of sound level has been nstructed using microphones and an amplifier h a frequency weighting circuit corresponding to response of the ear.

.212 : 534.321.9 **328**

he Directional Characteristics [for supersonic iation] **of a Free-Edge Disk mounted in a Flat fle or in a Parabolic Horn.**—F. H. Slaymaker, F. Meeker & L. L. Merrill. (*J. acoust. Soc. er.*, Oct. 1946, Vol. 18, No. 2, pp. 355–370.) l paper, summary of which was noted in 3512 1946.

.231 **329**

ay Computation for Non-Uniform Fields.—S. Saby & W. L. Nyborg. (*J. acoust. Soc. er.*, Oct. 1946, Vol. 18, No. 2, pp. 316–322.) A formula is derived which simplifies computation and ray tracing. The method is particularly useful in the study of the propagation of supersonic waves in the atmosphere.

534.24 : 551.510.52 **330**

Reflection of Sound Signals in the Troposphere.—G. W. Gilman, H. B. Coxhead & F. H. Willis. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 274–283.) Attempts have been made to detect non-homogeneities in the first few hundred feet of the atmosphere by vertical propagation of sound waves with a low-power set which has been named the sodar. Periods of strong temperature inversion, strong sodar displays and strong microwave fading tended to coincide, but it is significant that sound echoes were often very strong when there was no meteorological reason to expect them. The sodar seems to have confirmed the existence of non-homogeneities which it would be difficult or impossible to observe by conventional methods.

534.321.9 : 621.395.613.5 **331**

An Ultrasonic Condenser Microphone.—T. H. Bonn. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 496–502.) The microphone has overall diameter 0.875 inch, special electrode design, and essentially constant free field calibration of 51 db below 1 V per dyne per sq. cm up to 32 kc/s.

534.322.1 **332**

Analyses of the Tones of a Few Wind Instruments.—F. A. Saunders. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 395–401.) Charts are given for clarinet, oboe, English horn, French horn, and flute, covering the whole range of each instrument.

534.612 : 621.396.611.21 **333**

A New Sound Measurement System.—F. Massa. (*Communications*, Oct. 1946, Vol. 26, No. 10, pp. 16–17..50.) Determines the absolute magnitude of sound pressures with a minimum of disturbance to free-field conditions or conditions inside small enclosures, by means of a new design of calibrated piezoelectric sub-standard microphone.

534.612.4 + 621.395.613.5] : 551.547 **334**

On the Absolute Pressure Calibration of Condenser Microphones by the Reciprocity Method.—A. L. DiMattia & F. M. Wiener. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 341–344.) Calibration details are given for temperatures from −25°C to +40°C and pressures corresponding to altitudes up to 40 000 ft. The estimated accuracy is ± 0.2 db.

534.78 335

On the Intelligibility of Bands of Speech in Noise.—J. P. Egan & F. M. Wiener. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 435–441.) Tests were conducted with several communication systems of different bandwidth, under different conditions of masking noise, and the acoustic gain of the system expressed relative to the transmission of speech through 1 m of air. For each system a relation between syllable articulation and level of received speech was obtained.

534.78 336

Speech Clippers for More Effective Modulation.—J. W. Smith & N. H. Hale. (*Communications*, Oct. 1946, Vol. 26, No. 10, pp. 20–22 . . 25.) Peak-limiting methods in transmitters give high average modulation, and improve intelligibility when static interferes with reception or frequency channels are congested. The advantages rise in proportion to the interference. The method also prevents over-modulation and, with a filter, provides a clean, sharp signal with no splatter. The carrier is fully used.

534.78 337

The Masking of Speech by Sine Waves, Square Waves, and Regular and Modulated Pulses.—S. S. Stevens, J. Miller & I. Truscott. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 418–424.) Optimum masking is produced when the fundamental frequency of the interfering signal lies in the range 100–500 c/s, the exact position depending on its other characteristics.

Full paper, summary of which was noted in 3527 of 1946.

534.78 : 621.396.813 338

Effects of Amplitude Distortion upon the Intelligibility of Speech.—J. C. R. Licklider. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 429–434.) The reduction in intelligibility depends on the type of distortion, but with peak clipping (symmetrical and asymmetrical) the reduction is almost zero. Appreciable centre clipping or linear rectification has a serious effect. Tests under aircraft noise conditions are described, and the improvement in radio communication provided by the noise limiting action of an audio clipping circuit is discussed. Full paper, summary of which was noted in 3524 of 1946.

534.781 : 371.3 339

Training for Voice Communication.—J. W. Black & H. M. Mason. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 441–445.) Speech training programme for telephone or radio communication in the U.S. Army Air Force.

534.833.082.4 340

The Measurement of Acoustic Absorption by the Stationary Wave Method.—G. Sacerdote. (*Alta Frequenza*, June 1946, Vol. 15, No. 2, pp. 68–76. With English, French and German summaries.) A theoretical analysis.

534.833.1 341

Absorption of Sound by Coated Porous Rubber Wallcovering Layers.—C. W. Kosten. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 457–471.)

534.843 342

The Effect of Non-Uniform Wall Distributions of Absorbing Material on the Acoustics of Rooms.—H. Feshbach & C. M. Harris. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 472–487.)

534.846.3 343

Acoustical Correction by Sound Diffusion.—F. L. Bishop. (*Communications*, Oct. 1946, Vol. 26, No. 10, pp. 36–37.) Hemispherical sound diffusers 12 inches to 36 inches in diameter were arranged in random pattern on one wall of a studio to improve its acoustical properties.

534.862 344

A Simplified Recording Transmission System [to operate from a microphone and into a sound recording modulator].—F. L. Hopper & R. C. Moody. (*J. Soc. Mot. Pict. Engrs*, Aug. 1946, Vol. 47, No. 2, pp. 132–141.) Requirements were: light weight, parts easily accessible, high reliability, and low power consumption. The instrument described has a transmission system (whose output is limited by a discharge tube), an amplifier and a noise reduction system. Several components are marked with normal operating voltages for ease in detecting faults. Circuit diagrams are given of the amplifier and power supply unit, together with noise reduction performance graphs.

621.395.61 : 621.385.82.029.3 345

[The development of] **a High Power Thermionic Cell using Positive Ion Emission and operating in a Gaseous Medium.**—Klein. (*See* 593.)

621.395.613 : 621.385 346

“Vibrotron” Tube.—R.C.A. (*See* 584.)

621.395.623.6 347

Development of Midget Earphones for Military Use.—H. A. Pearson, A. B. Mundel, R. W. Carlisle, W. F. Knauert & M. E. Zaret. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 348–354.) Full paper, summary of which was noted in 3534 of 1946.

621.395.625.2 348

Lateral Disc Recording at the Naval Research Laboratory.—A. T. Campbell. (*Communications*, Sept. 1946, Vol. 26, No. 9, pp. 11–15 . . 50.) Description of N.R.L. sound recording system facilities, of the types of record produced, and of modifications to commercial equipment used in the system. Response curves over the frequency range 50–10 000 c/s illustrate the performance of different types of pickup. Further improvements are expected from the use of a newly designed moving-coil pickup of which brief details are given.

621.396.33.029.3.083.7 : 656.2 349

Train Position Indicator.—Dahl. (*See* 535.)

621.396.645.029.3 350

Modern Studio and Portable Speech Input Equipment.—L. G. Killian, P. L. Tourney & J. W. Hooper. (*Radio, N.Y.*, Sept. 1946, Vol. 30, No. 9, pp. 14–17 . . 31.) Technical details for a studio console and a three-channel remote amplifier.

AERIALS AND TRANSMISSION LINES

621.315.211.2 : 679.5 351

Developments in Solid Dielectric R.F. Transmission Lines.—R. C. Graham. (*Radio News*, Oct. 1946, Vol. 36, No. 4, pp. 46–48 . . 157.) A brief account of the use of polythene in various types of h.f. cable.

21.315.211.9.052.63 : 621.396.44 **352**

Carrier-Current Communication on Air and Paper Insulated Cables.—F. Lucantonio. (*Alta Frequenza*, June 1946, Vol. 15, No. 2, pp. 77–110. With English, French, and German summaries.) An ppreciation of the future importance of this ystem, using pair and quad lines, for long distance ommunication, and a discussion of the primary and erived characteristics — impedance, attenuation, ross-talk, and distortion, with numerical data.

21.392 **353**

Wave Guides.—M. H. L. Pryce. (*J. Instn elect. Engrs*, Part I, Oct. 1946, Vol. 93, No. 70, pp. 59–460 [summary] & Part IIIA, 1946, Vol. 93, No. 1, pp. 33–39 [full version].) The early development of waveguides is surveyed. Only when 10-cm vaves were developed was the size of waveguides ufficiently convenient to encourage their development. Early guides had high losses. Waveguides ecame more important when 100-kW magnetrons vere developed, as they have low attenuation and re less liable to breakdown by sparking than oncentric feeders. It is undesirable that a waveuide should propagate more than one mode, so hat a rectangular guide with one side above the ritical dimension for the H_{10} mode ($\lambda_0/2$) but less han the critical dimension for the H_{20} mode (λ_0), nd the other side below the critical dimension for he H_{01} mode ($\lambda_0/2$) is preferred. The waveguide ust be matched to the media or units which recede and follow it. The use of waveguides volves a number of auxiliary components such as uplings, bends, corners, branches, switches, tating joints, etc., whose design involves specialed techniques.

1.392 : 621.396.11 **354**

Some Questions connected with the Excitation d Propagation of Electromagnetic Waves in ubes.—Mandelstam. (*See* 506.)

1.392 : 621.396.67 **355**

Dielectric [rod and tubular] **Aerials.**—(*Onde ect.*, Oct. 1946, Vol. 26, No. 235, pp. 387–390.) review of unpublished German work mainly of an pirical nature by Zinke and Mallach. The lar diagrams of both rod and tubular type aerials e considered in relation to the aerial dimensions d permittivity of the material concerned. For bes maximum values of 6λ and 0.8λ are suggested the length and diameter respectively; the per limit to the wall thickness is set by the need adequate side- and back-lobe suppression. nilar considerations result in an optimum range the diameter of a rod aerial. An example of a ered rod aerial is briefly discussed. Finally it uggested that a given dielectric aerial will behave tisfactorily over a frequency range of approxitely 2 : 1.

1.396.67 : 537.122 : 538.3 **356**

Complete Calculation of the Radiation of a Linear usoidal Oscillator.—É. Durand. (*C. R. Acad.* ., *Paris*, 2nd Jan. 1946, Vol. 222, No. 1, pp. -70.) From formulae developed previously (see & 393 below) it is shown that in the radiation d of an electric charge oscillating sinusoidally ng a straight line, all the harmonics of the damental frequency are present, the amplitudes olving Bessel functions. Potential formulae derived from which the fields can be easily deduced. With two oscillating charges of opposite sign always occupying symmetrical positions with respect to the origin, only the odd harmonics are found.

621.396.67 : 621.315.62 **357**

Dipole Reflector Insulation.—J. A. Saxton & L. H. Ford. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 325–327.) "The effects of various insulators, used to support the ends of the parasitic aerial, were determined by measurements of the front-to-back signal ratio of a receiving-aerial system consisting of a half-wavelength dipole and a single parasitic reflector, at a wavelength of six metres. The particular insulators used in this investigation resulted in the effective length of the reflector being increased by about 20 per cent."

621.396.67 : 621.396.9 **358**

Aerials for Radar Equipment.—J. A. Ratcliffe. (*J. Instn elect. Engrs*, Part I, Oct. 1946, Vol. 93, No. 70, pp. 458–459 [summary] and Part IIIA, 1946, Vol. 93, No. 1, pp. 22–33 [full version].) For flood-lighting at wavelengths greater than about 3 m, an elevated horizontal dipole was usually used as a transmitter, and an elevated crossed pair of dipoles as receiver. Bearing was obtained by comparing the e.m.fs in the two receiving dipoles with a rotating goniometer coil. Elevation was determined by comparing signals in aerials at different heights. Broadside arrays with arrangements for swinging the beam rapidly by electrical means from side to side were also used to determine bearing. The satisfactory use of a common aerial for transmission and reception was one of the major achievements in radar development. An important and fundamental theorem shows that the space distribution diagram of an aerial is given by the Fourier analysis of the distribution of radiating sources over the aerial. At centimetre wavelengths, pencil beams narrow in elevation and azimuth, or fan beams narrow in one plane only (usually azimuth) become possible. Fan beams rotated about a vertical axis were extensively used for searching.

Pencil beams have usually been produced by a small radiating source situated near the focus of a parabolic mirror, with reflector and/or director elements to ensure that radiation from the source is predominantly towards the mirror.

Fan-shaped beams were produced by distorting a parabolic mirror in one section; a method originated by Chu is available for calculating the mirror shape for any required secondary-radiation pattern. Fan-shaped beams could also be produced by combining a long linear array with a specially shaped cylindrical mirror. The linear array provided a broadside of aerials which must be fed in phase. For this purpose they were coupled to a waveguide and spaced one guide-wavelength apart. A second set of aerials was placed at points midway between the first set and fed in the opposite phase to strengthen the required beam at the expense of an unwanted side-beam. A slight adjustment of position is also required to avoid a highly frequency-sensitive effect due to reflections at coupling points.

621.392 **359**

Wave Guides. [Book Review]—H. R. L. Lamont. Methuen, London, 2nd edn 1946, 96 pp., 6s. 3d (in Australia). (*Proc. Instn Radio Engrs, Aust.*, Oct. 1946, Vol. 7, No. 10, p. 31.)

CIRCUITS AND CIRCUIT ELEMENTS

621.314.6 **360**

Nonlinear Commutating Reactors for Rectifiers.—A. Schmidt, Jr. (*Trans. Amer. Inst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, pp. 654–656.) A commutating reactor is used to 'drag out' the anode current, *i.e.* to maintain it at a low value for a sufficient period just before the end of commutation, in order substantially to reduce residual ionization and the probability of arc-back.

621.314.671 **361**

Circuit Cushioning of Gas-Filled Grid-Controlled Rectifiers.—D. V. Edwards & E. K. Smith. (*Trans. Amer. Inst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, pp. 640–643.) A small resistance and capacitance connected in series between the cathode and anode delays the rise of initial inverse voltage by a few microseconds, and therefore increases the life of the rectifier.

621.316.313.025 **362**

A New Design for the A.C. Network Analyzer.—J. D. Ryder & W. B. Boast. (*Trans. Amer. Inst. elect. Engrs.*, Oct. 1946, Vol. 65, No. 10, pp. 674–680.) A general description is given of the analyser, which operates at 10 000 c/s using standard radio components. The cost is therefore much less than for previous types operating at 400–500 c/s. See also 31 of January (Meyers & Schultz).

621.316.726.078.3 : 531.3 **363**

On the Theory of Frequency Stabilization.—S. M. Rytoff, A. M. Prokhoroff & M. E. Zhabotinski. (*Zh. eksp. teor. Fiz.*, 1945, Vol. 15, No. 10, pp. 557–571. In Russian.) In all investigations so far published on the operation of a valve oscillator containing a stabilizing element, simplifying assumptions are made regarding the linearity of the system under consideration. There are strong reasons to believe that good results can be obtained by using rigorous methods based on the Poincaré–Lyapunoff theory, although this is only applicable to slightly nonlinear systems, *i.e.* to systems with a small parameter μ determining the deviation of the system from linearity.

Accordingly, the operation of a pull-in system consisting of a valve oscillator inductively coupled to an LCR circuit (Fig. 1) is discussed from the standpoint of the theory. The properties of the LCR circuit necessary for it to act as a 'quartz' stabilizer are determined and a definition of stability is given.

The operation of pull-in crystal controlled oscillators with a capacitive coupling (Fig. 3, bottom) and of Pierce's oscillator (Fig. 3, top) is then considered, and equations (11) and (17) are derived for the two systems respectively; an analysis of the first system only is given. A periodic solution of equations (17) is found and its stability investigated. Formulae (24) and (26) determining the variation of the amplitude and of the frequency respectively are derived and it is shown that in the absence of anode reaction and grid current, the stabilization makes the frequency of oscillations independent of the valve parameters apart from second order effects. A numerical example of the calculation of the oscillation frequency is added. See also 377 below.

621.317.373 **364**

Phase Detectors : Some Theoretical and Practical Aspects.—Farren. (*See* 474.)

621.318.3/.4] .042 : 621.396 **365**

Coils, Cores, and Magnets : Part 1— Magnetic Design Factors of Modern Radio Components.—H. W. Schendel. (*Radio Craft*, Oct. 1946, Vol. 18, No. 1, pp. 30–31 . . 47.)

621.318.4 : 538.12 **366**

Effective Impedance of a Sphere in a Magnetic Field.—T. S. E. Thomas. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 322–324.) "A conducting sphere in a uniform magnetic field may be regarded as being equivalent to a single-turn coil of the same diameter. Formulae are given for (*a*) the equivalent resistance and inductance of the coil, (*b*) the change in inductance and resistance of a solenoid when a sphere is placed at its centre, (*c*) the heat dissipated in a sphere in a uniform alternating magnetic field."

621.318.4.011.3 **367**

Calculating the Inductance of Universal-Wound Coils.—A. W. Simon. (*Radio, N.Y.*, Sept. 1946, Vol. 30, No. 9, pp. 18 . . 31.) It is required to find the number of turns to produce a given inductance. For universal-wound coils this can be done by a method based on 1464 of 1945 (Simon).

621.392 : 621.396.645.029.64 **368**

Circuits for Use with Triode Amplifiers and Oscillators operating at U.H.F.—G. Lehmann. (*Onde élect.*, Oct. 1946, Vol. 26, No. 235, pp. 357–366.) A general paper in which the desirable electrical features of cavities and coaxial line derivatives are analysed. The design principles for the triode valve itself were discussed in an earlier paper (3821 of 1946). In the amplifier application the effects of the Q and impedance of the cavities on operation are considered, neglecting the effect of inter-cavity coupling *via* the grid screen. It is concluded that these circuit parameters should be high in the case of the anode (output) circuit, and low for the cathode (input) circuit. Possible ways of neutralizing the valve are considered in relation to the design of power amplifiers; experimental arrangements are outlined for achieving neutralization empirically. The circuit conditions necessary to ensure satisfactory operation of u.h.f. triode oscillators are considered. It is established that, for maximum energy dissipation at a fixed frequency in a given load, four independent adjustments are necessary and sufficient. One of these determines the operating frequency, the second, the impedance match of the load; the third and fourth fix the real and imaginary components of the transfer impedance from the anode to the cathode cavity. Means of making these adjustments in practice are discussed; the common use of an internal capacitive-type coupling between the cavities is criticized. Finally, the power output possibilities of triodes in the wavelength range 10–300 cm are summarized.

621.392.051 **369**

Conditions for Transfer of Maximum Power.—H. E. Ellithorn. (*Communications*, Oct. 1946, Vol. 26, No. 10, pp. 26–28 . . 35.)

621.392.51 : 534.1 **370**

Violation of the Reciprocity Theorem in Linear Passive Electromechanical Systems.—E. M. McMillan. (*J. acoust. Soc. Amer.*, Oct. 1946, Vol. 18, No. 2, pp. 344–347.) It is shown by an energy argument that the theorem of reciprocity is satisfied by crystal or electrostatic transducers in both magnitude and sign, but in the case of magnetic or electrodynamic transducers it is satisfied only in magnitude. By combining these two types, systems can be constructed that violate reciprocity in magnitude.

621.394/.397].645.34 **371**

Radio Design Worksheet No. 53 : Graphics of Negative Feedback in Cascade.—(*Radio, N.Y.*, Oct. 1946, Vol. 30, No. 10, pp. 17–18.)

621.394/.397].645.34 **372**

How Negative Feedback Operates.—C. A. A. Wass. (*P.O. elect. Engrs' J.*, Oct. 1946, Vol. 39, Part 3, pp. 114–116.) Demonstration by numerical and pictorial examples of the way in which negative feedback improves amplifier performance.

21.395.645 **373**

Three-Channel Amplifier : a 15-W Unit with Individual Control of Each Channel.—M. Contassot. (*Toute la Radio*, Jan. 1946, Vol. 13, No. 102, pp. 36–37.) A French version of 2845 of 1946.

21.395.661 **374**

Mica Capacitors for Carrier Telephone Systems.—. J. Christopher & J. A. Kater. (*Trans. Amer. nst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, p. 670–674.) Silvered mica capacitors are superior the previous dry stack type, because of their latively simple unit construction and ease of djustment to the very close capacitance tolerance quired. Construction details and performance aracteristics are given.

21.396.61 : 538.56 : 535.23 **375**

The Radiation through an Aperture in a Resonator.—L. Mandelstam. (*Zh. eksp. teor. Fiz.*, 1945, Vol. 5, No. 9, pp. 471–473. In Russian.) An electroagnetic field is set up inside an ideal hollow conuctor with infinitely thin walls and a circular perture whose diameter is small compared to the avelength. The radiation through the aperture determined by a method similar to that used by ayleigh for diffraction at a small aperture.

The following two auxiliary problems are solved st : (*a*) Given a flat capacitor with two infinite ates A and B at an infinite distance apart, and at plate B is infinitely thin and has a circular erture in it, determine the additional field due this aperture ; (*b*) Given two ideally conducting finitely thin plates A and B at an infinite distance part, such that a current flows in plate A and, in e opposite direction, in plate B, and that a cular aperture is made in plate B, determine the stribution of the magnetic field

For the main problem, it is assumed that the ngential component of the field at the point here the aperture is to be made is H_0. It is shown at the field set up by the aperture at a great stance is that of a magnetic dipole with a moment $^3H_0/3\pi$ where a is the radius of the aperture. milarly, if E_0 is the normal component of the ctric field at the point where the aperture is to made, the field due to the aperture is that of an ctric dipole with a moment $a^3E_0/3\pi$.

1.396.611 **376**

Electromagnetic Cavities.—J. Bernier. (*Onde ct.*, Aug./Sept. 1946, Vol. 26, Nos. 233/234, 305–317.) A mathematical paper. The tural modes of oscillation of cavities having infinitely conducting walls are first considered, particular attention being paid to resonators having mathematically convenient forms. An expression for the perturbation of the natural frequency of the resonator due to a small change in its shape is derived by two methods. The damping and frequency shift introduced by assigning a finite conductivity to the walls are determined. The fact that practical resonators have Q values lower than the theoretical is attributed either to oxidation or to the nature of the top few microns of the cavity walls. Finally the behaviour of cavities under conditions of forced oscillation is examined, and the nature of 'lumped value' equivalent circuits discussed.

621.396.611 : 531.3 **377**

On a Special Case of Systems with Two Degrees of Freedom.—M. E. Zhabotinski. (*Zh. eksp. teor. Fiz.*, 1945, Vol. 15, No. 10, pp. 573–585. In Russian.) If approximate methods are used for examining systems with two degrees of freedom, system equations are derived with small terms of the same (first) order of smallness as the small parameter μ. If however exact methods based on the Poincaré–Lyapunoff theory are applied, terms of higher orders of smallness may appear in the equations. In the present paper an analysis is made of the case when terms of any arbitrary orders may appear together with terms of the first order. Methods are indicated for finding a periodic solution of the system equations (1) for different cases, for example, when the system is operated with or without a stabilizing element, and conditions of stability are derived. It is shown that the calculations involved in the use of the exact methods are no more complicated than in the case of an equation with terms of the first order of smallness only. See also 363 above.

621.396.611 : 621.317.79.029.64 **378**

High Q Resonant Cavities for Microwave Testing.—I. G. Wilson, C. W. Schramm & J. P. Kinzer. (*Bell Syst. tech. J.*, July 1946, Vol. 25, No. 3, pp. 408–434.) An engineering approach to the design of tunable cylindrical cavities resonant in the TE_{01n} mode which gives the maximum Q in a given volume. The dimensions to give as few unwanted modes as possible may be determined from charts. The suppression of the unwanted modes, particularly the TM_{11n} mode which has the same frequency as the required mode, is discussed. Methods of coupling a TE_{10} waveguide to the cavity are given in tabular form. As a practical example an outline electrocoil design for an echo box is described and the mechanical requirements outlined. The uses of such a box for radar testing are indicated.

621.396.611.018.41 **379**

Theory and Measurements of the Natural Frequencies of Various Kinds of Resonant Cavities. [Thesis]—J. J. Verschuur. Drukkerij Waltman (A. J. Mulder), Delft, 1946. A mathematical and experimental investigation of the natural frequencies of symmetrical and asymmetrical cavity resonators, with particular reference to symmetrical 're-entrant' types (*i.e.* the space between two concentric cylinders). A method of analysis in terms of an equivalent LC circuit has proved to be much simpler than previous analyses, and has given theoretical values of resonant frequency within 5% of measured values. The measurements were made over the range 35–200 cm. A long summary in English is given (pp. 114–115) and a bibliography of 58 items is appended.

621.396.611.1 **380**

Mathematical Treatment of *n* Directly Coupled H.F. Oscillatory Circuits.—H. Behling. (*Funktech. Mh.*, May 1940, No. 5, pp. 75–80.) A general method is developed for obtaining the selectivity curve of any number n of directly coupled circuits and this is applied specially to the case of $n = 4$. Selectivity and amplification formulae are then given for $n = 2, 3, 6$. The selectivity curves for $n = 2, 4, 6$ present marked similarities, as also do those for $n = 3$ and 5. Numerical calculations are given for a 4-circuit filter.

621.396.611.21 : 537.228.1 : 534.13 **381**

General Dynamical Considerations applied to Piezoelectric Oscillations of a Crystal in an Electrical Circuit.—W. F. G. Swann. (*J. Franklin Inst.*, Sept. 1946, Vol. 242, No. 3, pp. 167–195.) A mathematical paper dealing with forced and free oscillations in an X-cut crystal. Electrical and mechanical damping effects are taken into account, but for certain solutions of practical interest, internal mechanical damping is neglected. An expression is developed for the mechanical displacement at the two ends of the crystal under resonant conditions. When the frequency of the applied e.m.f. is equal to the lowest natural frequency of the crystal (or to an odd harmonic thereof) the displacements at the two ends are equal, even when the media surrounding the two ends of the crystal are different. See also 3244 of 1946 (Ekstein).

621.396.615.1 **382**

Response of Oscillator to External E.M.F.—D. G. Tucker: R. E. Burgess. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 341–342.) Correspondence on 3216 of 1946. Tucker suggests that "it is not possible to consider the effective 'half-power' bandwidth of the system, nor to express it in terms of a linear tuned circuit." Burgess in reply amplifies his treatment and reasserts its validity for the conditions he specified.

621.396.62 **383**

Design and Application of Squelch Circuits.—Delanoy. (*See* 519).

621.396.62 **384**

Notes on the Design of Squelch Circuits.—Delanoy. (*See* 520.)

621.396.645.014.332 **385**

Class-B Amplifiers.—A. S. G. Gladwin. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, p. 343.) Extension of the method of 3563 of 1946 (Sturley) to the case when the grid excitation is of arbitrary waveform.

621.396.645.211 **386**

Improved Analysis of the RC Amplifier.—J. Roorda, Jr. (*Radio, N.Y.*, Oct. 1946, Vol. 30, No. 10, pp. 15–16.) New design formulae are developed rigorously, whereby analysis of resistance-coupled amplifier performance is simplified, and an equivalent circuit holding at all frequencies of the amplifier is obtained. A numerical example is given.

621.397.621 **387**

Deflector Coil Coupling.—Cocking. (*See* 558.)

GENERAL PHYSICS

530.13 : 530.12 **388**

A Relativistic Misconception.—C. R. Eddy. (*Science*, 27th Sept. 1946, Vol. 104, No. 2700, pp. 303–304.) "The idea that matter and energy are interconvertible is due to a misunderstanding of Einstein's equation $E = mc^2$ . . . In calculating the kinetic energy released or consumed by nuclear reactions from the formula $E = (\Delta m)c^2$, the rest masses and not the actual masses must be used in computing Δm." The total actual mass of the system is invariant.

530.145.63 **389**

On Dirac's Theory of Quantum Electrodynamics: the Interaction of an Electron and a Radiation Field.—C. J. Eliezer. (*Proc. roy. Soc. A*, 22nd Oct. 1946, Vol. 187, No. 1009, pp. 197–219.)

531.18 : 531.15 **390**

Is Rotation Relative, or Absolute?—B. A. Hunn: D. A. Bell (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 342–343.) Correspondence on 3564 of 1946 (C.W.O.H.).

532.13 : 537.29 **391**

The Effect of an Electric Field on the Viscosity of Liquids.—E. N. da C. Andrade & C. Dodd. (*Proc. roy. Soc. A*, 5th Nov. 1946, Vol. 187, No. 1010, pp. 296–337.) A description of apparatus for measuring this effect, in which the liquid runs in a narrow channel between plane metal boundaries which can be used as electrodes.

Measurements on polar and non-polar liquids are described and the observations are explained theoretically.

537.122 : 538.3 **392**

Calculation of the Field due to a Moving Electric Charge.—É. Durand. (*C. R. Acad. Sci., Paris*, 20th Nov. 1944, Vol. 219, No. 20, pp. 510–513.) It is shown that the method of calculation given by R. Reulos (4374 of 1937: *Cah. Phys., Paris*, 1941, No. 3, pp. 1–14.), which seems to differ essentially from the classical treatment, is in reality completely equivalent to it. See also 393 below and 356 above.

537.122 : 538.3 **393**

Calculation of the Field due to a Moving Electric Charge.—É. Durand. (*C. R. Acad. Sci., Paris*, 4th Dec. 1944, Vol. 219, No. 22, pp. 584–587.) The potential formulae previously given (see 392 above) are applied to the case where the trajectory remains within a spatially limited domain, the potentials being calculated outside this domain. A formula is derived for the radiation of the particle. Simplified potential formulae are given for small distances from the domain. For two charges symmetrical with respect to the origin the formulae yield the classical results for the dipolar oscillator.

537.291 **394**

Volt-Ampere Characteristics for the Flow of Ions or Electrons between Concentric Cylinders in Gases at Atmospheric Pressure.—C. W. Rice. (*Phys. Rev.*, 1st/15th Aug. 1946, Vol. 70, Nos. 3/4, pp. 228–229.)

537.533.73 395

Refraction Effects in Electron Diffraction.—J. M. Cowley & A. L. G. Rees. (*Nature, Lond.*, 19th Oct. 1946, Vol. 158, No. 4016, pp. 550–551.) Study of diffraction patterns of magnesium and cadmium oxide smokes with the R.C.A. type electron microscope. Results are explained in terms of variations of inner potential. See also 3697 of 1945 (Sturkey & Frevel).

538.3 — 396

Stresses in Magnetic and Electric Fields.—G. W. O. H. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 319–321.) A critical theoretical discussion setting forth the discrepancies between the results arrived at by various workers.

538.566 397

The Group Velocity in a Crystal Lattice.—L. Mandelstam. (*Zh. eksp. teor. Fiz.*, 1945, Vol. 15, No. 9, pp. 475–478. In Russian.) The group and phase velocities of waves propagated in a continuous medium have the same direction, and the group velocity is in this case said to be positive. There are, however, real media in which the velocities have opposite directions, *i.e.* the group velocity is negative. An analysis is made of the propagation of waves in a crystal lattice and it is shown that the group velocity $\frac{d\omega}{dk}$ is in this case negative (ω is the frequency and k the wave number). It is also shown that the velocity W of the propagation of energy, as defined by Rayleigh, is in this case equal to the group velocity. It is pointed out that the crystal lattice is a limiting case of a continuous medium with a periodically variable parameter, such as density, dielectric constant, etc. As an example the propagation of waves in the direction x in a medium the properties of which vary only with x is briefly considered.

539.185 398

Two Kinds of Neutrons ?—J. De Ment. (*Science*, 27th Sept. 1946, Vol. 104, No. 2700, p. 303.) The usual neutron breaks down into a proton with the emission of a β-particle. Theory appears to require a second kind which would break down into a negative proton with the emission of a positive electron.

548.0 : 546.74 : 538 399

Magnetic Studies on Nickel Ions in Crystals.—A. Mookherji. (*Indian J. Phys.*, Feb. 1946, Vol. 20, No. 1, pp. 9–20.)

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

522.23 : 523.755 400

Scientists explore Sun.—M. G. Morrow. (*Sci. News Lett., Wash.*, 14th Sept. 1946, Vol. 50, No. 11, pp. 170–171.) Describes the use of a coronagraph at the High Altitude Observatory at Climax to observe continuously the solar corona.

523.165 401

An Observed Abnormal Increase in Cosmic-Ray Intensity at Lahore.—H. R. Sarna & O. P. Sharma. (*Nature, Lond.*, 19th Oct. 1946, Vol. 158, No. 4016, p. 550.) A threefold increase in directional total intensity of cosmic radiation was observed during the period 31st July–3rd Aug. 1946.

523.7 + 523.854] : 621.396.11 402

Extra-Tropospheric Influences on Ultra-Short-Wave Propagation.—E. V. Appleton. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 110–113.) The effect of the ionosphere and of radio noise of extraterrestrial origin is considered. Transient echoes from temporarily ionized scattering centres at about the level of the E layer are probably due to the ionization trails of meteorites. The scattering coefficient L (defined in Scott's paper 510 below) is about 100 m at 9 Mc/s, and very roughly L varies as $1/f^n$ where f is the frequency and n is about 2. Early experimental evidence of long-distance scatter with a delay time of 15 to 25 ms is now believed to be caused by waves which have been reflected by the F layer, scattered back, and then reflected again by the F layer. The limiting frequency for such scattering may be taken as 3.5 times the vertical-incidence F_2-layer critical frequency for the mid-point of the trajectory. Account must be taken of the general world morphology of F_2-layer ionization.

Galactic radio noise has been studied among others by Hey, Parsons & Phillips (see 3599 of 1946 and back reference) while L. A. Moxon and J. M. C. Scott have found that galactic noise power varies roughly as the square of the wavelength for frequencies above about 20 Mc/s.

Solar radio noise in excess of the expected black-body intensity by a factor as great as 10^5 or 10^6 on metre wavelengths, and connected with sunspot activity, has frequently been reported recently, as in 403 below. Such noise is not appreciable at centimetre wavelengths. It is sometimes convenient to express results in terms of the 'equivalent black-body temperature' of the noise source. The pioneer work in this field was done by Burgess (see 438 of 1942 and back references).

523.72 : 621.396.822 403

Noise during Radio Fade-Outs.—O. P. Ferrell. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, p. 449.) A survey of observations of solar noise discussed more fully in 402 above.

523.72 : 621.396.822.029.62 404

Conditions of Escape of Radio-Frequency Energy from the Sun and the Stars.—M. N. Saha. (*Nature, Lond.*, 19th Oct. 1946, Vol. 158, No. 4016, p. 549.) The minimum frequency of electromagnetic waves that can escape from various layers of the sun, and from sunspots, is calculated from Appleton's magneto-ionic theory. It is concluded that the ordinary wave cannot escape, and that the larger sunspots are most favourable for the escape of extraordinary waves in the frequency range 10–200 Mc/s ; therefore radio waves reaching the earth should be circularly polarized.

523.72 : 621.396.822.029.62 405

Abnormal Solar Radiation on 75 Megacycles.—S. E. Williams & P. Hands. (*Nature, Lond.*, 12th Oct. 1946, Vol. 158, No. 4015, p. 511.) Observations on the nature of solar radiation on 75 Mc/s were made during periods of sunspot activity in July and August 1946. The radiation can be roughly divided into two components, one slowly variable, and the other abruptly variable, and showing correlation with visual solar observations. Correlation between solar noise and prominence activity seems probable. Short abstract only. See also 406.

523.72 : 621.396.822.029.62 **406**

Abnormal Solar Radiation on 72 Megacycles.—A. C. B. Lovell & C. J. Banwell. (*Nature, Lond.*, 12th Oct. 1946; Vol. 158, No. 4015, pp. 517–518.) Experimental data on a frequency of 72.6 Mc/s obtained during July and August 1946 confirm that solar radiation on radio frequencies can be as much as 10^8 times the black body value; this appears to be associated with solar flares. See also 405 above, 86 of January and back references.

523.78 : 551.510.535 **407**

Effects on the Ionosphere at Huancayo, Peru, of the Solar Eclipse, January 25, 1944.—Ledig, Jones, Giesecke & Chernosky. (*See* 503.)

523.78 : 551.510.535 **408**

Eclipse-Effects in F_2-Layer of the Ionosphere.—Wells & Shapley. (*See* 502.)

538.566.3 + 621.396.812 **409**

Observations on the Interaction of Waves in the Ionosphere, in relation to the Gyrofrequency.—Cutolo, Carlevaro & Gherghi. (*See* 513.)

538.71 **410**

The Development and Applications of Airborne Magnetometers in the U.S.S.R.—A. A. Logachev. (*Geophys.*, April 1946, Vol. 11, No. 2, pp. 135–147.) Translation of three papers describing the pioneer work by the Russians in magnetic exploration with airborne equipment.

550.38(091) **411**

Chapters in the History of Terrestrial Magnetism.—A. C. Mitchell. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 323–351.)

550.385 : 525.241 **412**

The Mean Field of Disturbance of Polar Geomagnetic Storms.—L. Harang. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 353–380.)

551.501.7 **413**

Measurements of Refractive Index Gradient.—F. L. Westwater. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 100–101.) Three yachts were equipped to take temperature and humidity observations in the first 200 ft in connexion with the Cardigan Bay experiments described in 518 below. Pairs of dry and wet copper-constantan thermocouples fitted in double radiation shields were mounted on the masts at heights of 25 ft, 40 ft and 50 ft, and on 10-ft booms projecting over the ship's side at heights of 5 ft, 10 ft, and 15 ft respectively. For temperature readings, each dry thermocouple was compared electrically with a standard thermocouple; for humidity readings, with its corresponding wet thermocouple. Readings were taken at half-hourly intervals. Sea temperature was also measured by means of a thermocouple, and checked by direct reading from sea water in a bucket. Similar thermocouples were also fitted to a barrage balloon, readings being taken at 50-ft intervals up to 200 ft. The measurements reveal very complex conditions. Sharp discontinuities are common. Similar measurements on a barrage balloon at Cardington revealed a very sharp temperature discontinuity occurring across a subsidence inversion.

551.510.53 **414**

The Basic Reactions in the Upper Atmosphere: Part 1.—D. R. Bates & H. S. W. Massey. (*Proc. roy. Soc. A*, 5th Nov. 1946, Vol. 187, No. 1010, pp. 261–296.) "The properties of the upper atmosphere and in particular of the ionosphere and of the night-sky emission are outlined. The fundamental processes that might be involved are discussed. Various suggestions regarding the production of the layers are considered in detail and the main difficulties indicated. The theory of the equilibrium of the layers is built up and the outstanding problem of explaining the rate of disappearance of electrons is emphasized. Current views on the origin of the night-sky light are studied critically and serious discrepancies are shown to exist. Other possibilities are examined." An extensive bibliography is appended.

551.510.535 **415**

On Diffusion in the Ionosphere.—V. C. A. Ferraro. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 427–431.) "It is shown that Jaeger's discussion of diffusion in the ionosphere [598 of 1946] is applicable only to regions of the F_2 layer 100 km or more above the level of maximum ion-production. Further reasons are given for the conclusion reached in an earlier paper [3785 of 1945] that, though diffusion in the F_2 layer may not be negligible (as in the case of the E and F_1 regions), its effect is likely to be small. The air-density in the F_2 layer at the level of maximum electron-density is then unlikely to be much less than 10^{10} mol per cc."

551.510.535 **416**

The Mechanism of Ionospheric Ionization.—R. v. d. R. Woolley. (*Proc. roy. Soc. A*, 8th Oct. 1946, Vol. 187, No. 1008, pp. 102–114.) "The available mechanisms for the production of electrons in the three regions of the ionosphere are discussed with special reference to the question whether it is possible to account for the observed electron densities without supposing that the sun emits far more energy in the remote ultra-violet spectrum than would be emitted by a black body at 6 000°. The contributions to electron densities made by metastable states of atoms and molecules are examined. It is concluded that the observed electron densities may be accounted for without requiring high solar energy in the ultra-violet if the effective recombination coefficient in the F_2 region is 10^{-11}. The F_2 region is attributed to the ionization of atomic oxygen, and the E region to the ionization of molecular oxygen. The electrons forming the F_1 region are supposed to be provided by metastable N_2 or by NO."

551.594.51 **417**

The Auroral Luminosity-Curve.—L. Harang. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 381–400.) The auroral luminosity curve is calculated theoretically as a function of height for cathode rays penetrating the ionosphere rectilinearly. Estimates are made of cathode-ray velocities for observed aurorae, and the heights of abnormal-E reflections and of the absorbing layer are discussed.

621.396.812.029.64 **418**

Elements of Radio Meteorology: How Weather and Climate cause Unorthodox Radar Vision beyond the Geometrical Horizon.—Booker. (*See* 516.)

621.396.812.029.64 **419**

The Attenuation of Centimetre Radio Waves and the Echo Intensities resulting from Atmospheric Phenomena.—Ryde. (*See* 515.)

551.510.535 (02) **420**

Contribution à l'Étude de la Structure de l'Ionosphère. (Mémoires de l'Institut Royal Météoroogique de Belgique, Vol. 19.) [Book Review]—I. Nicolet. Institut Royal Météorologique de Belgique, Brussels, 1945, 162 pp. (*Observatory*, Oct. 1946, Vol. 66, No. 834, pp. 345–346.)

LOCATION AND AIDS TO NAVIGATION

21.396 : 629.13 **421**

Aviation Radio Equipment.—(*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 366–368.) The ain types of radio equipment shown at the exhibiion of the Society of British Aircraft Constructors ere: general purpose communication sets, v.h.f. pparatus, radio aids to navigation, airborne power upply units, and electronic equipment for balancing yroscope rotors and for flaw detection.

21.396.9 **422**

I.E.E. Radiolocation Convention, March 1946.—*See* 603.)

21.396.9 : 623.451 : 551.46 **423**

Properties of Radar Echoes from Shell Splashes.—. Goldstein. (*Phys. Rev.*, 1st/15th Aug. 1946, ol. 70, Nos. 3/4, pp. 232–233.) Scattering from pray drops has been suggested as the explanation sea echo on microwave radar. Experiments on choes from shell splashes are described which rovide further evidence that this is not the case. Wavelengths of 9.2, 3.2 and 1.25 cm were used nd a high speed photographic technique employed compare the echo intensities; simultaneous otion pictures of the splashes were also taken ith a cine-theodolite.

The effective cross-section of the splash at any stant could be calculated, and a detailed comarison of the results on 9.2 and 1.25 cm was made. he cross-section was initially greater on 9.2 cm, ut as the splash changed to spray this condition as reversed, and the 1.25 cm echo was still ppreciable after the other had disappeared. The tio of the cross-sections for very fine drops is ven by the Rayleigh λ^{-4} law as +35 db, whereas e maximum value measured was about +20 db. his is still much greater than the +8 db observed sea echo, which therefore cannot arise from all drops of spray.

1.396.9 (52) **424**

Short Survey of Japanese Radar: Parts 1 & 2.—I. Wilkinson. (*Elect. Engng, N.Y.*, Aug./Sept. & t. 1946, Vol. 65, Nos. 8/9 & 10, pp. 370–377 & 5–463.) A report based on a study made immediely after the fall of Japan by the U.S. Army, which s particularly useful because of the obvious lingness of the Japanese to volunteer technical ormation. Army and navy radar are discussed, ether with general problems concerning the nufacture and operation of radar equipment.

621.396.932 **425**

The SL Radar.—N. I. Hall. (*Bell Lab. Rec.*, Oct. 1946, Vol. 24, No. 10, pp. 353–357.) A brief descriptive account of a shipborne 10 cm radar system with p.p.i. display, designed in 1942 for submarine detection.

621.396.933 **426**

Air Navigation: Survey of Radio Aids to Civil Aviation.—M. G. Scroggie. (*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 352–356.) The principal types of navigational aid at present available are briefly discussed. The main immediate need is for world-wide standardization and coordination of these equipments to reduce the number that aircraft must carry. Attempts are also being made to replace cathode-ray tube displays developed during the war by meters which give the pilot a direct reading of the information he requires.

621.396.933.4 **427**

Anti-Collision Radio.—H. W. Secor & E. Leslie. (*Radio Craft*, Oct. 1946, Vol. 18, No. 1, pp. 17..75.)

621.396.933(02) **428**

Demonstrations of Radio Aids to Civil Aviation. [Book Review]—H.M. Stationery Office, London, 80 pp., 5s. (*Wireless Engr*, Nov. 1946, Vol. 23, No. 278, p. 298.) Descriptions of equipments shown to delegates of the Provisional International Civil Airways Organization.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.275.083 **429**

Measuring Humidity in Air and Gases by the Dew-Point Method.—R. Czepek. (*Arch. tech. Messen*, Aug. 1940, No. 108, pp. T85–86.) A review of the principles and brief description of seven practical methods.

533.5 : 621.3.032.53 **430**

Stresses in Cylindrical Glass-Metal Seals with Glass Inside.—A. W. Hull. (*J. appl. Phys.*, Aug. 1946, Vol. 17, No. 8, pp. 685–687.) The stresses in the glass are shown to be all of the same sign and thus a moderate mismatch is allowable when the thermal expansion of the metal is greater than that of the glass. The theory is given in an earlier article: Glass to Metal Seals, by A. W. Hull & E. E. Burger (*Physics*, 1934, Vol. 5, pp. 387 ff). See also 431 below.

533.5 : 621.3.032.53 **431**

Theory and Practice of Glass-Metal Seals: Part 4.—J. A. Monack. (*Glass Ind.*, Nov. 1946, Vol. 27, No. 11, pp. 556–559..582.) For previous parts see 119 of January. See also 430 above.

535.37 **432**

Fluorescence Fatigue.—T. Alper. (*Nature, Lond.*, 28th Sept. 1946, Vol. 158, No. 4013, p. 451.)

537.533.8 **433**

The Change in Conductivity of Aluminium Oxide when it is bombarded by Electrons.—I. F. Kvartskhava. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, p. 373. In Russian.) Summary of a report. In studying secondary electron emission it is important to observe the excitation of electrons in the emitter by primary electrons. Certain experimental difficulties are obviated by the use of aluminium oxide emitters. In experimenting with these it was found that with gradients of the order of 10^6 V/cm a process takes place in the emitter causing an increase in the dark conductivity and a decrease in the excitation of the electrons.

539.23 : 669 **434**

Identification of Electroplated Coatings.—(*Materials & Methods*, Sept. 1946, Vol. 24, No. 3, p. 673.) Table of simple identification tests involving scratching, spot tests with concentrated HNO_3 and HCl, and other chemical tests.

539.234 **435**

Structure of Catalytic Metal Films.—D. D. Eley. (*Nature, Lond.*, 28th Sept. 1946, Vol. 158, No. 4013, p. 449.) When certain metals evaporate on to the walls of a glass tube, films are formed whose actual area is several times their apparent area. This is best explained by assuming such films to be microcrystalline.

546.287 **436**

Silicones: Food for Imagination.—R. R. McGregor. (*J. Franklin Inst.*, Aug. 1946, Vol. 242, No. 2, pp. 93–102.) Address to a joint meeting of the Franklin Institute and the Philadelphia Science Teachers' Association.

620.191.33 : 669.3 **437**

Microfissures.—"Recorder II". (*Metal Ind., Lond.*, 25th Oct. 1946, Vol. 69, No. 17, p. 347.) Fine cracks otherwise invisible in impure copper or copper alloy specimens can be detected microscopically if the specimens are electrolytically polished and immersed in a special ammonium sulphide reagent.

620.193.8(213) **438**

The Deterioration of Materiel in the Tropics.—W. G. Hutchinson. (*Sci. Mon., N.Y.*, Sept. 1946, Vol. 63, No. 3, pp. 165–177.) A brief résumé of the ways in which different classes of materiel are affected. Some possible measures of control are indicated.

621.315.211.2 : 679.5 **439**

Developments in Solid Dielectric R.F. Transmission Lines.—Graham. (*See* 351.)

621.315.6 : 621.39 **440**

Dielectrics for Telecommunication Purposes.—W. Jackson. (*Engineering, Lond.*, 1st Nov. 1946, Vol. 162, No. 4216, pp. 427–428.) Another account of part 2 of 314 of January.

621.315.61.015.5 : 547 **441**

Determination of the Flashpoint of Organic Insulating Materials.—M. Zürcher. (*Schweiz. Arch. angew. Wiss. Tech.*, March 1945, Vol. 11, No. 3, pp. 94–96.) Powdered materials in tubular containers are inserted in holes in a copper block pre-heated to a known temperature Any gases given off are collected and tested for combustibility. The sensitivity of the apparatus and the effect of grain size are discussed and results given graphically for certain materials.

621.315.612.2 : 551.547 **442**

Investigation of Porcelain Insulators at High Altitudes.—C. V. Fields & C. L. Cadwell. (*Trans. Amer. Inst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, pp. 656–660.) Flashover voltages are given for a.c. and d.c. for porcelain bushings. Tests were made at both normal and reduced pressure. Solid insulation should be used to obtain the benefit of its puncture strength rather than its flashover under extreme conditions.

621.315.615.2 **443**

The Influence of the Concentration and Mobility of Ions on Dielectric Loss of Insulating Oils.—B. P. Kang. (*Trans. Amer. Inst. elect. Engrs*, July 1946, Vol. 65, No. 7, pp. 403–407.) The relationships between the amount of impurities, the viscosity, and the dielectric loss in insulating oils are investigated.

621.315.617.3 **444**

Insulating Varnishes and Compounds.—N. Bromberger. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1946, Vol. 7, No. 10, pp. 4–12. Discussion, pp. 12–14.) The selection and characteristics of both natural and synthetic materials are outlined, and details are given of the processes involved in the manufacture of varnishes and compounds. Their application and methods of production control are also discussed.

621.318.22/.23 **445**

Modern Hard Magnetic Materials.—K. Hoselitz. (*Metal Treatm.*, Autumn 1946, Vol. 13, No. 47, pp. 213–222.) Reprint of 2607 of 1946.

621.319.7 : 621.385 **446**

Plotting Electrostatic Fields.—G. Silva (*Alta Frequenza*, June 1946, Vol. 15, No. 2, pp. 117–118.) Comment on 3322 of 1946 (Pinciroli & Panetti).

621.357.1 : 666.1 : 621.314.67 **447**

Electrolysis Phenomena in Soft-Glass Stems of Rectifier Tubes.—J. Gallup. (*J. Amer. ceram. Soc.*, 1st Oct. 1946, Vol. 29, No. 10, pp. 277–281.) The longitudinal cracks and black deposits which form along the leads during the life of rectifier tubes were found to be due to electrolysis in the soft glass stems. Rupture was caused by glass bombardment by reverse emission from the rectifier anode. This theory is supported by mass spectrometer analysis of the gas produced. Associated electrolysis phenomena are also described.

621.357.7 : 669.3 **448**

Copper Plating.—C. Struyk & A. E. Carlson. (*Metal Ind., Lond.*, 25th Oct. 1946, Vol. 69, No. 17, pp. 348–352.) Description of the advantages of using copper fluoborate solutions with high limiting current densities for the electrodeposition of copper, instead of the ordinary copper sulphate solutions.

621.791.353 **449**

Soft Soldering.—"Recorder II". (*Metal Ind., Lond.*, 6th Dec. 1946, Vol. 69, No. 23, p. 476.) Survey of progress of investigations into the problem of 'solderability.'

666.1 : 62 **450**

Modern Developments in Glasses for Technical Purposes.—W. E. S. Turner. (*Endeavour*, Jan. 1945, Vol. 4, No. 13, pp. 3–16.) Recent discoveries of chemical, thermal and mechanical properties are described and the use of glass in combination with metals and as fibre is discussed.

666.1.032 **451**

Scientific Glass Blowing and Laboratory Techniques.—W. E. Barr & V. J. Anhorn. (*Instruments*, Jan. 1946, Vol. 19, No. 1, pp. 14–32.) To be continued.

666.11 **452**

Dielectric Properties of Glasses at Ultra-High Frequencies and Their Relation to Composition.—L. Navias & R. L. Green. (*J. Amer. ceram. Soc.*, 1st Oct. 1946, Vol. 29, No. 10, pp. 267-276.) The dielectric constants and dielectric losses of 104 kinds of glass were measured at 3 000 and 10 000 Mc/s by the resonant cavity method. SiO_2 and B_2O_3 glasses are relatively transparent at these frequencies. Alkali ions in glasses give high losses increasing with the number of ions. Glasses containing a combination of alkalis show lower losses than the equivalent compositions with only one alkali. Divalent ions contribute less to losses than alkalis.

566.3 : 539.4 **453**

Stress-Strain Relations in Ceramic Materials.—M. Lassettre & J. O. Everhart. (*J. Amer. ceram. Soc.*, 1st Sept. 1946, Vol. 29, No. 9, pp. 261–266.)

578.77 **454**

Some Recent Contributions to Synthetic Rubber Research.—C. S. Fuller. (*Bell Syst. tech. J.*, July 946, Vol. 25, No. 3, pp. 351–384.)

79.5 **455**

Annealing of Styrene and Related Resins.—. Bailey. (*Mod. Plast.*, Oct. 1946, Vol. 24, No. 2, p. 127–131.) Failure of parts caused by thermal nd mechanical strains can be overcome by the se of appropriate annealing processes.

79.5 **456**

Manufacture of Laminates in Germany.—(*Mod. Plast.*, Oct. 1946, Vol. 24, No. 2, pp. 147–149..210.) ranslation based on a production manual of ynamit A.-G., Troisdorf, a subsidiary firm of G. Farbenindustrie A.-G.

79.5 : 62 **457**

Plastic Laminates — as Engineering Materials.—. Rose. (*Materials & Methods*, Sept. 1946, ol. 24, No. 3, pp. 653-664.) Comprehensive article ealing with the industrial aspect of these materials, ith their light weight, high dielectric strength, low ater absorption and resistance to attack by hemicals. They can be supplied in sheets, rods nd tubes, and other forms. The production of gh-pressure, low-pressure and composite laminates described, with their particular industrial uses, nd details concerning the machining of these aterials.

79.5 : 669 **458**

Metal Test Specimens mounted in Urea.—(*Mod. last.*, Oct. 1946, Vol. 24, No. 2, p. 121.) Metal pecimens must be mounted for certain microscope sts. Moulded Plaskon is an economical mounting aterial which is easy to use, and can be coloured.

78.534.8 **459**

A System for Rapid Production of Photographic ecords.—F. M. Brown, L. L. Blackmer & C. J. unz. (*J. Franklin Inst.*, Sept. 1946, Vol. 242, . 3, pp. 203–212.) Equipment for automatic posure, processing, and projection of 16 mm film described. The final image is completely prossed in 15 sec on Eastman Fine Grain Release ositive Film Type 5302.

MATHEMATICS

7.942 **460**

Mathieu Functions and Their Classification.— W. McLachlan. (*J. Math. Phys.*, Oct. 1946, ol. 25, No. 3, pp. 209–240.)

518.5 **461**

The Automatic Sequence Controlled Calculator: Parts 1 & 2.—H. H. Aiken & G. M. Hopper. (*Elect. Engng, N.Y.*, Aug./Sept. & Oct. 1946, Vol. 65, Nos. 8/9 & 10, pp. 384–391 & 449–454.) See also 468 below.

518.5 **462**

The ENIAC, an Electronic Computing Machine.—D. R. Hartree. (*Nature, Lond.*, 12th Oct. 1946, Vol. 158, No. 4015, pp. 500–506.) General description with examples of operations.

518.61 **463**

An Escalator Process for the Solution of Linear Simultaneous Equations.—J. Morris. (*Phil. Mag.*, Feb. 1946, Vol. 37, No. 265, pp. 106–120.) The Escalator process, originally devised for the solution of Lagrangian frequency equations in connection with aircraft vibration problems (see 1636 of 1945) is adapted to the solution of linear simultaneous equations, particularly those which are 'ill-conditioned' and difficult to solve by other methods. Each of the variables involved is introduced in turn by definite self-contained stages, at each of which powerful checks are available to assess, and if necessary to adjust, accuracy. A numerical example is fully explained.

The Escalator method has a very wide application to vibration problems because it enables the various parts of a complicated system to be considered separately. It has also an application to networks and transients, but further work is necessary to make this fully effective. A comprehensive account of the method will be published in book form shortly.

519.2 : 518.4 **464**

Graphical Solutions of Statistical Problems.—F. Levi. (*Engineer, Lond.*, 18th & 25th Oct. 1946, Vol. 182, Nos. 4736 & 4737, pp. 338–340 & 362–364.) Discusses the applications of 'probability graph paper'.

519.28 : 621.3 **465**

A New Approach to Probability Problems in Electrical Engineering.—H. A. Adler & K. W. Miller. (*Trans. Amer. Inst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, pp. 630–632.)

531.3 : 621.396.611 **466**

On a Special Case of Systems with Two Degrees of Freedom.—Zhabotinski. (*See* 377.)

51(02) **467**

The Common Sense of the Exact Sciences. [Book Review]—W. K. Clifford. A. A. Knopf, New York, 249 pp., $4.00. (*Sci. Mon., N.Y.*, Sept. 1946, Vol. 63, No. 3, p. 242.) "Mathematics made easy."

518.5 **468**

A Manual of Operation for the Automatic Sequence Controlled Calculator. (Annals of the Computation Laboratory of Harvard University, Vol. 1.) [Book Review]—Staff of the Computation Laboratory. Harvard Univ. Press, Cambridge, Mass.; Oxford Univ. Press, London, 561 pp., $10. (*Nature, Lond.*, 26th Oct. 1946, Vol. 158, No. 4017, pp. 567–568.) The machine described can be regarded as a modern version of Babbage's difference engine, and "is largely composed of standard Hollerith counters, but with a superimposed and specially designed tape sequence control for directing the operations of the machine". See also 461 above.

518.61 469

Relaxation Methods in Theoretical Physics. [Book Review]—R. V. Southwell. Clarendon Press, Oxford, 248 pp., 20s. (*Electrician*, 25th Oct. 1946, Vol. 137, No. 3569, p. 1137.) It is claimed that any problem that can be formulated can be solved arithmetically. See also 463 above.

MEASUREMENTS AND TEST GEAR

621.317.2 : 656.2 470

Mobile Electrical Measurements Laboratories for the German State Railways.—E. W. Curtius. (*Arch. tech. Messen*, Aug. 1940, No. 108, pp. T93–94.) Choice of test gear and of methods of measurement is limited mainly by the essential requirement of robust equipment that can withstand the severe vibrations encountered in railway rolling-stock.

621.317.32 : 537.221 471

Measurement of Surface Potential or Contact Potential Differences.—A. A. Frost. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, pp. 266–268.) The term surface potential is preferable when surface effects are being studied. Such potentials may conveniently be measured by forming the two surfaces into a capacitor whose charge is neutralized by an opposing potential supplied by a *p*H meter. See also 1282 of 1946 (Meyerhof & Miller).

621.317.32.027.3 472

High-Voltage Measurement.—F. M. Bruce. (*Elect. Rev., Lond.*, 22nd Nov. 1946, Vol. 139, No. 3600, p. 838.) Summary of two I.E.E. papers, one discussing factors in the design of an ellipsoid voltmeter, and the other describing spark gap calibration.

621.317.35 : 621.396.611.1.015.3 473

Evaluation of Circuit Constants from Oscillograms.—L. S. Foltz. (*Elect. Engng, N.Y.*, Oct. 1946, Vol. 65, No. 10, pp. 490–492.) Formulae are derived and applied to typical oscillograms of transients in series circuits, and it is shown that the results (values of the resistance, capacitance, and inductance present) have an accuracy which makes the formulae and the method useful.

621.317.373 474

Phase Detectors : Some Theoretical and Practical Aspects.—L. I. Farren. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 330–340.) Fundamental methods were described by Levy (2323 of 1940). In the present paper, a detailed analysis shows that simple push-pull detectors are more efficient than the balanced type. Simple push-pull detectors with sinusoidal input voltages have good sensitivity, but a sinusoidal relationship between the output and the phase-difference of the input voltages ; this relationship is more nearly linear in the square-wave case, but sensitivity is less.

621.317.39.029.6 : 536.33 475

The Measurement of Thermal Radiation at Microwave Frequencies.—R. H. Dicke. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, pp. 268–275.) The connection between ' Johnson noise ' and black-body radiation is discussed, using a simple thermodynamic model. A suitable microwave receiver assembly with a wide-band i.f. amplifier is described in which the effect of radio noise generated in the apparatus is eliminated.

The experimentally measured r.m.s. fluctuation of the output meter of such a microwave radiometer is 0.4°C, compared with a theoretical value of 0.46°C.

The method of calibrating, using a variable temperature resistive load, is described. See also 219 of January (Kyhl, Dicke & Beringer).

621.317.728 476

Measurement of R.M.S. Voltage using a Sphere Gap.—W. Raske. (*Arch. tech. Messen*, April 1940, No. 106, p. T42.) Methods of adapting a sphere gap, used for peak voltage measurement, to find the r.m.s. value. Calibration and errors are discussed.

621.317.75 477

Frequency Spectrum Analysis : Principles and Applications.—E. Aisberg. (*Toute la Radio*, Dec. 1945, Vol. 12, No. 101, pp. 9–12.) An account of the construction and operation of an analyser suitable for studying the frequency characteristics of the various circuits in radio receivers.

621.317.79.029.64 478

Techniques and Facilities for Microwave Radar Testing.—E. I. Green, H. J. Fisher & J. G. Ferguson. (*Bell. Syst. tech. J.*, July 1946, Vol. 25, No. 3, pp. 435–482.) Reprint of 2645 of 1946.

621.317.79.029.64 : 621.396.611 479

High Q Resonant Cavities for Microwave Testing.—Wilson, Schramm & Kinzer. (*See* 378.)

621.318.572 480

Counting Rate and Frequency Meter.—E. Lorenz, J. Weikel & S. G. Norton. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, pp. 276–279.) A counting rate and frequency meter consists essentially of an apparatus for bringing signals of different amplitudes and waveforms to a uniform unidirectional size and measuring their rate of arrival. The instrument described has a resolving power of 10^{-5} sec for evenly spaced pulses and consists of a thyratron whose rate of striking is controlled by the input pulses, while the duration of the arc at each discharge is fixed by an RC circuit. The resulting anode current is thus proportional to the frequency of the input pulses.

621.319.4 : 621.317 481

The Characteristics and Errors of Capacitors used for Measurement Purposes.—C. G. Garton. (*J. Instn elect. Engrs*, Part II, Oct. 1946, Vol. 93, No. 35, pp. 398–408. Discussion, pp. 408–414.) Causes of variation of capacitance and loss angle are discussed with relation to time, humidity, temperature, frequency, voltage, screening, and the properties of materials used in capacitor construction. When a guard ring is used to measure the capacitance and loss angle of a plane sample of dielectric, errors in loss angle due to surface conductivity are small only if $g \ll t$, $g \ll R$, or $r > 10^{17}/Rf$ where $2g$ is the guard ring gap, t is the thickness of the sample, R is the radius of the main electrode, and f is the frequency. These conditions are difficult to realize in practice, and if none of them is satisfied, spurious loss angles up to 10^{-2} may occur in specially unfavourable cases.

621.396.611.21.012.8 : 537.228.1 482

Methods of Measuring the Constants of the Equivalent Network of a Piezoelectric Crystal : Quartz Meter.—Jacquinot, Dumesnil & Boughon. (*Onde élect.*, July 1946, Vol. 26, No. 232, pp. 259–273.) The equivalent circuit has components L, C and R in series with C_p in shunt. The natural frequency and bandwidth give the magnification Q. The time constant $\tau = 2L/R$ is determined by observing the decay of free oscillations in the crystal when the excitation is removed and a fluxmeter integrator gives direct indication of τ. The bandwidth is measured as the difference of the 'quadrantal' frequencies at which phase displacements of ±45° are obtained relative to the resonant frequency and c.r.o. indication is used. The dynamic resistance is determined by comparison with a known resistance (using c.r.o. indication). The various methods of measurement are combined n a single instrument (a universal Quartz meter) or use between 50 kc/s and 10 Mc/s.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

536.48 **483**

On the Possible Use of Brownian Motion for Low Temperature Thermometry.—A. W. Lawson & E. A. Long. (*Phys. Rev.*, 1st/15th Aug. 1946, Vol. 70, Nos. 3 4, pp. 220–221.) Thermal noise in a high esistance is only suitable for measuring temperaures down to about 0.01°K and requires an amplifier of very narrow pass band; the resistance, ecessarily of a semiconductor, will have an exonential temperature coefficient which introduces ifficulties.

Alternatively by measuring the thermal noise oltage of a quartz resonator (after calibration at he boiling point of helium) temperatures as low as .000 1°K should be measurable. The main xperimental difficulty is to establish thermal conact between the resonator and its surroundings ithout reducing its Q.

39.16.08 **484**

Design of Beta-Ray and Gamma-Ray Geiger-üller Counters.—W. Good, A. Kip & S. Brown. *Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, pp. 62–265.)

39.16.08 : 57 **485**

An Electronic Method of Tracing the Movements f Beetles in the Field.—G. A. R. Tomes & M. V. rian. (*Nature, Lond.*, 19th Oct. 1946, Vol. 158, o. 4016, p. 551.) A beetle is made to carry 5 μgm radium sulphate; its position is then detected ith a special form of Geiger-Müller tube.

15.84 **486**

Crystal-Controlled Diathermy.—R. L. Norton. *Electronics*, Oct. 1946, Vol. 19, No. 10, pp. 113–115.) escription of a 500-W unit operating at about Mc/s, crystal frequency being a quarter of rrier frequency. An air-cooled tetrode is used in e output stage to which the load is connected means of leads 4 ft in length. Provision is made r tuning the load: a lamp, loosely coupled to the tput leads, is used as an indicator.

1.316.9 : 621.38 **487**

Electronic Devices in Power Supply.—"Kilovar". *verseas Engr*, Dec. 1946, Vol. 20, No. 231, pp. 5–157.) A general account of the protection of rge high voltage power supply networks by elecnic devices, and their use in telemetering, ult location, and so on.

1.318.572 **488**

Electronic Relay.—G.G.C. Development Co. (*J. . Instrum.*, Oct. 1946, Vol. 23, No. 10, p. 247.) When the control contact is open the anode and grid of a valve are fed with a.c. in antiphase. Closure of this contact earths the grid and causes anode-current to flow thus operating the relay. The maximum current through this contact is 15 μA.

621.318.572 : 623.451 **489**

A Paper Screen signaling Missile Passage in Ballistics.—H. Lamport & M. G. Schorr. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, p. 280.)

621.365.036.65 **490**

A Simple Automatic Furnace Temperature Control.—E. L. Yates. (*J. sci. Instrum.*, Oct. 1946, Vol. 23, No. 10, pp. 229–231.) By using a platinum resistance thermometer in an a.c. bridge, furnace temperature can be automatically controlled to within ±0.5°C at all temperatures between 0°C and 1 000°C.

621.365.92 : 677 **491**

Radio Heating in Textile Industry.—C. N. Batsel. (*Radio News*, Oct. 1946, Vol. 36, No. 4, pp. 44–45 . . 82.) High frequency heating is used for processing cotton, rayon, nylon and wool, mainly for drying and setting the twist. A method has also been developed for curing the resin in impregnated fabrics.

621.38 : 62 **492**

Electronics: Their Scope in Heavy Engineering.—W. G. Thompson. (*G.E.C.J.*, Aug. 1946, Vol. 14, No. 2, pp. 59–72.) A survey of various types of electronic equipment, and their application to research, testing, manufacture, power control, and safety in heavy engineering.

621.38.001.8 : 621.9 **493**

Electronics and Precision Grinding Machines.—(*Engineer, Lond.*, 4th Oct. 1946, Vol. 182, No. 4734, pp. 300–301.)

621.384 : 538.691 **494**

The Stability of Electron Orbits in the Synchrotron.—N. H. Frank. (*Phys. Rev.*, 1st/15th Aug. 1946, Vol 70, Nos. 3/4, pp. 177–183.) The motion of an electron in an axially symmetric magnetic field under the action of an external torque due to an r.f. field is analysed, and the oscillations about the equilibrium orbit investigated. The transition from betatron to synchrotron motion is examined and the condition established for the 'locking in' of the electrons to synchronous driving by the r.f. field. Stable synchrotron operation is shown to be quite practicable. See also 3440 of 1946 (Dennison & Berlin).

621.384.032.21 **495**

R.F. Heating Cyclotron Filaments.—A. E. Hayes, Jr. (*Phys. Rev.*, 1st/15th Aug. 1946, Vol. 70, Nos. 3/4, p. 220.) The r.f. generator which feeds the filament of a cyclotron is usually remote (for ease of adjustment), and so requires a long transmission line between the oscillator and the ion source. The advantages of using a mean oscillator frequency which makes the line one quarter wavelength long are explained.

621.385.833 + 537.533.72 **496**

The Electron Microscope.—G. Dupouy. (*Metal Treatm.*, Autumn 1946, Vol. 13, No. 47, pp. 153–168, 205.) Description of its theory, construction, and operation, and some of the results obtained by its application to the study of metals.

621.396.998 : 629.135 **497**

Drones — Prelude to "Push-Button" Warfare ?—O. Read. (*Radio News*, Oct. 1946, Vol. 36, No. 4, pp. 25–29..104.) A brief account of the use of automatically controlled aircraft for taking observations during atom-bomb tests. The aircraft were controlled by radio from piloted aircraft.

621.397.26 : 343.977.33 **498**

Transmission of Finger-Prints by Radio.—(*Nature, Lond.*, 12th Oct. 1946, Vol. 158, No. 4015, pp. 525–526.) Note of some recent applications of facsimile to police work described in pamphlet by F. R. Cherrill.

771.448.1 **499**

Photographic Use of Electrical Discharge Flashtubes.—H. E. Edgerton. (*J. opt. Soc. Amer.*, July 1946, Vol. 36, No. 7, pp. 390–399.)

PROPAGATION OF WAVES

538.566 **500**

The Group Velocity in a Crystal Lattice. — Mandelstam. (*See* 397.)

551.501.7 **501**

Measurements of Refractive Index Gradient.—Westwater. (*See* 413.)

551.510.535 : 523.78 **502**

Eclipse-Effects in F_2-Layer of the Ionosphere.—H. W. Wells & A. H. Shapley. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 401–409.) A study of ionospheric observations at College, Watheroo and Huancayo during the partial solar eclipses of February and August 1943 and January 1944. F_2-layer ionization was in all cases subnormal before and after the eclipse, indicating that radiations from beyond the limb of the sun may contribute to the ionization of the region. Estimated values of the recombination coefficient for the F_2 layer for these eclipses lie between 10^{-9} and 2×10^{-10}. At Huancayo during the 1944 eclipse the F_2 layer rose to great heights at a rate of about 200 km per hour, and a new F-region stratification developed at normal heights. See also 503 below.

551.510.535 : 523.78 **503**

Effects on the Ionosphere at Huancayo, Peru, of the Solar Eclipse, January 25, 1944.—P. G. Ledig, M. W. Jones, A. A. Giesecke & E. J. Chernosky. (*Terr. Magn. atmos. Elect.*, Sept. 1946, Vol. 51, No. 3, pp. 411–418.) A detailed account of the results for the E, F_1 and F_2 layers is given, together with simultaneous signal intensities observed on a 15-Mc/s transmission over a distance of 3 500 miles. Minima in ion density were recorded for the E and F_1 layers near the time of maximum eclipse, with a delayed effect in the case of the F_2 layer. An effect on F_2-layer ion-density, possibly due to a corpuscular eclipse, is also described. See also 502 above.

551.594.51 **504**

The Auroral Luminosity-Curve.—Harang. (*See* 417.)

621.396.11 : 523 [.7 + .854 **505**

Extra-Tropospheric Influences on Ultra-Short-Wave Propagation.—Appleton. (*See* 402.)

621.396.11 : 621.392 **506**

Some Questions connected with the Excitation and Propagation of Electromagnetic Waves in Tubes.—L. Mandelstam. (*Zh. eksp. teor. Fiz.*, 1945, Vol. 15, No. 9, pp. 461–470. In Russian.) A new analytical method is proposed. The excitation of electromagnetic waves in free space is considered first. It is assumed that in the plane $z = 0$ there is a double layer of electric charges, *i.e.* a plane layer of dipoles with their axes parallel to the z-axis. A formula (1) is quoted determining the z-component Π of the Hertz vector, and is transformed into formula (4). The latter formula is applied to the case of a linear belt of dipoles of radius r and constant linear dipole density m. A formula (5) determining Π for this case is derived. If the belt is reduced to a point the well-known Sommerfeld integral is obtained.

A circular tube of infinite length and with ideally conducting walls is then considered. The exciter is assumed to be a plane double electric layer, *i.e.* a layer of electric moments lying in the plane $z = 0$ and directed along the z-axis of the tube. A formula (11) determining Π for this case is derived together with formula (15) for the case of a point dipole on the axis of the tube. Methods for determining E and H from these formulae are indicated. Formula (15) is analysed, and various peculiarities are pointed out. The excitation by a point dipole displaced from the z-axis is also considered.

The case of 'magnetic' excitation of waves in tubes is discussed next. This type of excitation can be achieved by introducing into the tube in the plane $z = 0$ a loop carrying current and having a figure-of-eight or more complicated shape. Methods for determining the 'magnetic' Hertz vector Π^* for this case, as well as E and H, are suggested.

The attenuation of the waves in tubes due to losses in the walls is considered and relationships between the various quantities involved are established.

Finally, it is shown that the problem considered can be reduced to the same boundary conditions as those of a vibrating diaphragm. It is therefore possible to make use of Courant's theorems for obtaining additional information such as the effect of varying the shape of the tube cross-section or introducing a conductor along the axis of the tube.

621.396.11.029.64 **507**

Perturbation Theory of the Normal Modes for an Exponential M-Curve in Non-Standard Propagation of Microwaves.—C. L. Pekeris. (*J. appl. Phys.*, Aug. 1946, Vol. 17, No. 8, pp. 678–684.) The region beyond the horizon is mainly considered, for cases in which the deviation of the M-curve from the standard is an exponential function of the height expressed in natural units (M denotes modified refractive index). Within its region of convergence the theory is applicable to the most general type of M-curve, including elevated ducts. "The region of practical convergence ranges from highly substandard conditions down to cases where the decrement is a fraction of the standard value." The procedure is to express the height gain function of any mode in the non-standard case as a linear combination of the height gain functions of all the modes in the standard case. The success of this depends on being able to evaluate quantities $\beta_{nm}(\lambda)$ which can be expressed as infinite integrals involving products of the height gain functions of the standard case.

621.396.65 **508**

Hertzian Cable [radio links in multichannel telephony circuits].—Clavier & Phélizon. (*See* 540.)

521.396.81.029.6 : 551.43 **509**

An Experimental Investigation on the Propaga- ion of Radio Waves over Bare Ridges in the Wave- .ength Range 10 cm to 10 m (Frequencies 30 to 3 000 Mc/s).—J. S. McPetrie & L. H. Ford. (*J. Instn lect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 108– 109.) For horizontally-polarized transmission over an approximately cylindrical hill of radius 11 000 ft. xperimental results are in good agreement with the rate of attenuation calculated by Domb and Pryce assuming a ground reflection coefficient of −1) at vavelengths 9.2 cm, 25 cm, and 50 cm.

For a cylindrical ridge of radius 1 250 ft, wave- ength 2.25 m, horizontal polarization gives results greeing with the calculations of Domb and Pryce or a sphere of 1 250 ft radius, but vertical polariza- ion shows a lower rate of attenuation, and signal trength less out of the shadow and greater in the hadow. Experiments were also made at 9.2, 5, 50 cm and 11.15 m; at 11.15 m attenuation was ess with vertical than with horizontal polarization, therwise results were the same on the two polariza- ions. Summary of an I.E.E. Radiolocation Con- ention paper.

21.396.81.029.63/.64 **510**

Theoretical Estimation of Field Strength. . M. C. Scott. (*J. Instn elect. Engrs*, Part IIIA, 946, Vol. 93, No. 1, pp. 104–105.) The reflecting ower of a target for decimetre or centimetre waves an be satisfactorily expressed in terms of a 'linear cattering constant' L which is roughly 2 m to m for the head-on aspect and 1 m for other spects; received power is proportional to trans- itted power × $L^2\lambda^{-2}$

Ray-theory interference patterns obtained by eometrical optics are satisfactory at short ranges r great heights. For long ranges and low heights, ave theory must be used, especially when some of e power emitted by the transmitter becomes apped in an atmospheric layer. This effect can t in below a certain wavelength depending on the eteorological situation. According to the wave eory there is an infinite series of characteristic aves (or 'normal modes') of which, for any articular meteorological situation, some may avel horizontally with little attenuation while e rest are rapidly attenuated. The attenuation onstants and height gains can be calculated umerically from the wave equation; tables for arious types of atmospheric model are available.

If the wavelength is small compared to that for ergy trapping, ray-tracing methods can be used. e rays in a heterogeneous atmosphere with a onlinear structure form a series of envelopes or ustic curves. Calculations are laborious.

Calculations have also recently been made of the flection coefficient of an elevated inversion layer oblique incidence.

1.396.81.029.64 : 551.43 **511**

Some Experiments on the Propagation over Land Radiation of 9.2 cm Wavelength, especially on e Effect of Obstacles.—J. S. McPetrie & L. H. ord. (*J. Instn elect. Engrs*, Part IIIA, 1946, ol. 93, No. 1, pp. 107–108.) A signal of known wer was transmitted, and the received signal rength measured with a calibrated receiver. ort range results on a level site (up to 1 km) reed with the inverse square law and a ground flection coefficient of −1, but this was not true for an undulating site. It was found that a large tree should be regarded as an opaque body. A dense screen of leafless trees was comparable to a solid obstacle over which Fresnel diffraction took place. Screens of trees in full leaf, even only two or three trees thick, formed an opaque obstacle. Most buildings must be regarded as opaque, diffracting objects. Summary of an I.E.E. Radiolocation Convention paper.

621.396.81.029.64 **512**

A Study of Some of the Factors influencing Microwave Propagation. B. J. Starnecki. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 106–107.) An analysis of the experimental results described in Megaw's paper (518 below). For a slightly non-optical link propagation can be regarded as normal. On the other hand, for a 60-mile link 2.3 times optical range, signal levels are mainly much higher than can be expected from refraction-diffraction formulae. Only in about 15% of the cases was there clear meteorological evidence of the formation of a radio duct of width greater than 50 ft, but comparison of simultaneous signal levels on 3 cm and 9 cm suggested that between 50% and 70% of the results on this link were due to ducts with heights between 20 ft and 40 ft, the remainder being due to normal propagation. The signal level was above 'free space' level for about 20% of the whole 5-month period. When the receiver was replaced by one at 20 ft, the results still agreed well with those expected for duct widths between 20 and 40 ft. For the 200-mile link, 70% of the observed signal levels can only be explained by the presence of ducts.

Summary of an I.E.E. Radiolocation Convention paper.

621.396.812 : 538.566.3 **513**

Observations on the Interaction of Waves in the Ionosphere, in relation to the Gyrofrequency.—M. Cutolo, M. Carlevaro & M. Gherghi. (*Alta Frequenza*, June 1946, Vol. 15, No. 2, pp. 111–117.) A description of experiments carried out in Italy in 1946 on the Luxemburg (cross-modulation) effect. Observations on a number of stations, one of which was varied in frequency, confirmed V. A. Bailey's theoretical prediction that the degree of cross-modulation is greatly increased if the frequency of the disturbing station is in the neighbourhood of the gyrofrequency. See 2437 of 1937 and back references.

621.396.812 : 621.396.11 **514**

The Importance of Theory in the Development and Understanding of Radar Propagation. T. L. Eckersley. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 103–104.) The phase integral theory was originally applied to the problem of diffraction round an imperfectly conducting earth, and was later extended to include the effect of atmospheric refraction in a particularly easy and significant way. Ray methods are essentially inaccurate and must be replaced by correct wave theory. To use refraction in radar work a more thoroughly satisfactory meteorological theory is required than yet exists. Sudden discontinuities of refractive index at considerable heights due for example to subsidence inversions, could cause long distance propagation by the internal reflection of characteristic waves. The radio problem is perfectly definite if the radio refractive index is known everywhere as a function of height, though the solution may be difficult in practice.

Carefully controlled experiment could help to decide the physical basis of theories for problems as yet imperfectly understood, such as turbulence and attenuation due to scattering.

621.396.812.029.64 **515**

The Attenuation of Centimetre Radio Waves and the Echo Intensities resulting from Atmospheric Phenomena.—J. W. Ryde. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 101–103.) The effects to be considered are quite negligible for wavelengths above the centimetre band, but in general increase rapidly as wavelength decreases. Of atmospheric gases, oxygen produces an attenuation between 0.01 and 0.02 db/km throughout the centimetre band, while water produces a very small attenuation at 10 cm rising to about 0.2 db/km near 1 cm ; other gases can be neglected.

For fogs and fine droplet clouds, attenuation depends only on the total mass of liquid per unit volume ; a table gives attenuation approximately in terms of visual range in such clouds.

For rain, average attenuation in db/km is approximately proportional to precipitation rate in the centimetre band ; the constant of proportionality depends upon temperature and wavelength.

The attenuation produced by hail is small compared to that for rain except for wavelengths near 1 cm.

Echo intensities from atmospheric fogs and fine droplet clouds are very weak : even moderate rain, however, can produce an echo intensity (for which a formula is given) comparable with that from an aircraft.

621.396.812.029.64 **516**

Elements of Radio Meteorology : How Weather and Climate cause Unorthodox Radar Vision beyond the Geometrical Horizon.—H. G. Booker. (*J. Instn elect. Engrs*, Part I, Oct. 1946, Vol. 93, No. 70, pp. 460–462 [summary] and Part IIIA, 1946, Vol 93, No. 1, pp. 69–78 [full version].) Radar receivers are frequently able to 'see' round the curved surface of the earth owing to radio refraction in the lower atmosphere. The phenomenon is most marked when both radar equipment and target are close to the earth. In its simplest form it involves an atmospheric waveguide, or radio duct, close to the earth's surface ; within the duct the curvature of a radio ray emanating horizontally from a transmitter would exceed that of the earth. The longer the wavelength, the greater must be the width of this radio duct for efficient guiding to take place. In the British Isles, a typical duct involving important conditions of superrefraction would be one extending from the earth's surface up to 100 ft. This can be an efficient waveguide for centimetre wavelengths, but at metre wavelengths it would merely produce an abnormal reduction of horizontal attenuation beyond the horizon. In other parts of the world, such as India during the hot season, duct widths of 1 000 ft or more can occur ; a case is cited of a 1½-metre radar near Bombay which had at various times 'seen' different points on the Arabian coastline up to 1 500 miles away.

The most important meteorological conditions for superrefraction are that the upper air, at a height of a few thousand feet, should be exceptionally warm and dry in comparison with the earth's surface ; the associated unusual gradients of temperature and humidity are the cause of downward superrefraction. In order to allow for the normal drop of temperature and humidity with height in a well-mixed air mass, it is advisable to use 'potential temperature' and 'specific humidity' as the fundamental parameters. Stormy and turbulent conditions, and bad weather in general, produce a well-mixed air mass near the ground with little vertical change of potential temperature or specific humidity and therefore with orthodox propagation. Superrefraction occurs when upper-air potential temperature exceeds appreciably that at the surface, while upper-air specific humidity falls short of that of the surface. This is essentially a fine-weather phenomenon, and therefore tends to be most intense in tropical (but not equatorial) climates, inland at night in fine, warm weather, and when warm, dry air over land drifts out over relatively cool sea. At present, only qualitative forecasting of superrefraction is possible.

621.396.812.029.64 **517**

A Preliminary Investigation of Radio Transmission Conditions over Land and on Centimetre Wavelengths.—R. L. Smith-Rose. (*J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, No. 1, pp. 98–100.) A study of the radio-meteorological aspects of the experiments described in Megaw's paper (518 below). In overland transmission along a 38-mile path, mean hourly intensity was sometimes steady to within 1 or 2 db all day, while on other occasions there was a marked diurnal variation from a minimum in the early morning to a peak near midnight, associated with fine, clear nights. If fog occurred, the signal strength would drop to a well-marked minimum, and rise to the normal daily value when the fog cleared. For radio communication links at centimetre wavelengths on an oversea non-optical path, it is advantageous to place the stations as high as practicable if the maximum reliability of service is required.

During good weather, signal level is usually high and somewhat variable ; low signal corresponds to poor visibility ; a decrease followed by an increase is associated with the passage of a front. Special meteorological observations by aircraft between 50 ft and 1 500 ft were made from which could be calculated the radio signal strength to be expected ; the agreement with the observed values is very good (Fig. 3).

621.396.812.029.64 **518**

Experimental Studies of the Propagation of Very Short Radio Waves.—E. C. S. Megaw. (*J. Instn elect. Engrs*, Part I, Oct. 1946, Vol. 93, No. 70, pp. 462–463 [summary] and Part IIIA, 1946, Vol. 93, No. 1, pp. 79–97 [full version].) "The main experimental programme described consisted of measurements of 3-cm, 9-cm, and 3½-m waves over sea paths 57 and 200 miles long ; and of 9-cm waves over a single 38-mile land path. The measurements were continuous over some of these paths for periods between two and three years ; and, particularly as regards detailed correlation with meteorological measurements, the work is still in progress."

From preliminary studies it is concluded that for optical paths (up to about 20 miles) over sea the observed field differs little from that calculated from a standard atmosphere ; over longer paths with correspondingly greater heights, variability increases ; over very long optical paths variability increases still further; fades of 30 db lasting a few minutes are not uncommon while fades of 10 db lasting an hour may occur in fine weather. Atmospheric absorption is unimportant at 9 cm over a path of 100 miles. Short-period fading on 9.2 cm is quite different from that on 10.0 cm though general trends are similar.

For optical paths over land up to 50 miles results are similar to those for sea except for unexpectedly low, steady levels over some short paths, possibly due to interference. Variations are greatest at night. For non-optical paths over sea, the minimum signal level (when measurable) was usually close to that calculated for a standard atmosphere; the maximum approaches but rarely exceeds the level corresponding to free-space propagation. In anticyclonic weather with the wind mainly off-shore, there tends to be a diurnal maximum in the afternoon and evening, and a minimum in the early morning. For non-optical paths over land results are similar to those for sea but less definite owing to geometrical uncertainties concerning the path. High diurnal levels occur during radiation-inversion nights, but overcast skies or wind suppress this variation.

Change of polarization had little effect; changes in bearing exceeding the measurement accuracy of about 1° were hardly ever observed.

See also 517 above.

RECEPTION

621.396.62 **519**

Design and Application of Squelch Circuits.—F. Delanoy. (*Radio, N.Y.*, Sept. 1946, Vol. 30, No. 9, pp. 11–13..30.) Two main classes of squelch circuits are considered, namely, that in which a control voltage related to the amplitude of the input carrier immobilizes the receiver *via* an electromagnetic relay, and that in which the action is fully electronic. Examples from each class are briefly described. See also 520 below.

621.396.62 **520**

Notes on the Design of Squelch Circuits.—F. Delanoy. (*Radio, N.Y.*, Oct. 1946, Vol. 30, No. 10, pp. 12–14.) Descriptions of various interchannel noise-suppression circuits for f.m. receivers, including blocked audio-frequency circuits, reflected impedance squelch circuits, and squelch oscillators. The severe distortion due to signal levels which partially operate the squelch tube but do not suppress reception completely can be overcome by using an adjustable threshold control, or a squelch disabling switch. See also 519 above.

621.396.62 : 621.317.755 **521**

Panadaptor.—Panoramic Radio Corporation. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, p. 285.) An instrument for panoramic reception, which may be attached to communications receivers with i.f. of 450–470 kc/s. The bandwidth is adjustable from 200 kc/s down to zero. Many applications are indicated, including three-station communication, air traffic control when an aircraft transmitter is off frequency, detection of frequency shift, and study of signal characteristics.

621.396.621 **522**

Designing the Postwar Receiver.—B. Halligan & C. Read. (*Radio News*, Oct. 1946, Vol. 36, No. 4, pp. 50–51..110.) The receiver described provides a.m. or c.w. reception from 540 kc/s to 110 Mc/s and f.m. reception from 27 Mc/s to 110 Mc/s. This wide coverage is obtained by the use of a new r.f. 'split-stator' circuit. Other features of the receiver are described briefly.

621.396.621.029.62 **523**

Super-Regenerative 2 Meter Receiver.—J. A. Kirk. (*Radio News*, Oct. 1946, Vol. 36, No. 4, pp. 30–31..108.) General remarks on the performance of superregenerative receivers and details of a suitable circuit for such a receiver operating at v.h.f.

621.396.621.54 **524**

Zero Tracking Error in Superheterodynes.—A. Bloch. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, pp. 328–329.) Describes a pair of LC circuits which give zero tracking error over the entire tuning range. This is obtained by simultaneous variation of L and C such that the ratio L/C remains constant. A first-order deviation from this constant ratio leads only to second-order tracking errors. The treatment is theoretical, but the principle has been successfully applied in a practical case.

621.396.813 : 534.78 **525**

Effects of Amplitude Distortion upon the Intelligibility of Speech.—Licklider. (*See* 338.)

621.396.822 : 621.385.032.21 **526**

Radio Design Worksheet No. 52: A.C. Filament Noise.—(*Radio, N.Y.*, Sept. 1946, Vol. 30, No. 9, p. 20.) The nature of the interfering voltages introduced into the anode current of a directly heated valve operated with an a.c. filament supply is considered.

STATIONS AND COMMUNICATION SYSTEMS

621.394/.396].7.029.58 **527**

Radio Stations near Toulouse.—C. Cardot & M. Bergeron. (*Onde élect.*, Aug./Sept. 1946, Vol. 26, Nos. 233/234, pp. 318–330.) Describes a system of radio stations planned as a Government communication headquarters and partially constructed despite the German occupation, operating in the wavelength range 13–60 m.

621.394.441 **528**

Performance Characteristics of Various Carrier Telegraph Methods.—T. A. Jones & K. W. Pfleger. (*Bell Syst. tech. J.*, July 1946, Vol. 25, No. 3, pp. 483–531.) On-off, single sideband, and one- and two-source frequency shift methods were considered, to determine their relative advantages from the standpoints of signal speed, sensitivity to level change, carrier frequency drift, interchannel interference, and line noise. For stable, quiet circuits the on-off system is the most suitable, but the other systems may result in improvement under certain adverse conditions. Numerous graphical results are summarized in tabular form.

621.395/.396].7 **529**

R.M.S. Queen Elizabeth.—(*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 357–358.) A general description of equipment carried, which includes: a ship-to-shore radio-telephone system; lifeboat radio equipment; a low power system for communication between pilot and tugs when docking; Gee, Loran and other navigational aids; and a public address system.

621.395(7) **530**

Telecommunications Developments.—(*Electrician*, 4th Oct. 1946, Vol. 137, No. 3566, pp. 935–936.) Summary of a report on the visit of British Post Office officials to North America. Recent developments there include a new automatic telephone system using the ' cross bar ' switch ; equipment for use on coaxial cables ; mobile telephones for motor cars ; temporary splitting of trunk circuits ; and an automatic (trunk-call) ticketing system. Experiments were in progress to develop telephones for communication between train driver and guard, and for shunting.

621.395.44 **531**

New Single Channel Carrier Frequency Telephone System for Open-Wire Lines.—E. Eklund. (*Ericsson Rev.*, 1946, Vol. 23, No. 3, pp. 259–266.) A new system ZAF11 has been developed replacing the older ZL400 (described in *Ericsson Rev.*, 1936, No. 2). The dimensions and weight of the new system are considerably reduced. The range is 700 km without intermediate repeaters when using an open-wire circuit of copper wires 3 mm in diameter.

621.396 : 629.13 **532**

Aviation Radio Equipment.—(*See* 421.)

621.396.004.67 : 629.135 **533**

Airline Radio Service.—E. D. Padgett. (*Radio Craft*, Oct. 1946, Vol. 18, No. 1, pp. 20–21 . . 53.) A table of common faults, probable causes and remedies is given, together with miscellaneous suggestions for preventive maintenance.

621.396.1 : 621.396.933.1/.4 **534**

International Conference on Air Routes over Europe and the Mediterranean (Paris, April/May 1946).—Dalle. (*Onde élect.*, July 1946, Vol. 26, No. 232, pp. 299–300.) Among the subjects discussed were the provision of various aerodrome and ground facilities, and the allocation of frequencies for telecommunications, navigation systems and distress signals.

621.396.33.029.3.083.7 : 656.2 **535**

Train Position Indicator.—E. A. Dahl. (*Electronics*, Oct. 1946, Vol. 19, No. 10, pp. 122–124.) Outline description of an audio-frequency system in which the times of arrival of trains at chosen points and departures therefrom are recorded on paper in a remote signal-box.

621.396.4 : 551.509 **536**

AACS Radioteletype Weather Transmission System.—F. V. Long. (*Communications*, Sept. 1946, Vol. 26, No. 9, pp. 16 . . 55.) The frequency-shift system as used by the U.S.A.A.F. for transmission of weather reports is illustrated with the aid of block diagrams. Methods used during the first weather broadcasts by radioteletype, with intercept receiving installations at smaller airfields and the operational difficulties of simplex systems are described. An analysis is made of improved results obtained from full duplex operation.

621.396.41 : 621.398 **537**

Test shows how Wire-Carrier and Beamed Radio direct Signals and Train Operation.—(*Telegr. Teleph. Age*, Oct. 1946, Vol. 64, No. 10, pp. 5–6 . . 30.) Demonstration of the application of existing wire-carrier and centimetre-wave multiplex communication circuits to the operation of signals and points of a railway system at very long ranges from a control signal box. Signals from the control box were sent by a roundabout route about 900 miles long to operate signals and points some 60 miles distant. The significance of the tests is briefly discussed.

621.396.44 : 621.315.211.9.052.63 **538**

Carrier-Current Communication on Air and Paper Insulated Cables.—Lucantonio. (*See* 352.)

621.396.619 **539**

High Efficiency Modulating Method.—J. Beckwith. (*Radio, N.Y.*, Oct. 1946, Vol. 30, No. 10, pp. 9–11 . . 32.) Amplitude modulation is achieved by shifting the phase of the carrier frequency at an audio-frequency rate and combining the phase-shifted carrier with the unmodulated carrier, producing a resultant varying in amplitude as the phase is shifted. The magnitude and spread of the phase-modulation side-bands (which accompany the amplitude-modulation side-bands in the radiated signal) are not excessive by F.C.C. regulations. Circuit diagrams are given for a 4.5-kW transmitter.

621.396.65 **540**

Hertzian Cable [radio links in multichannel telephony circuits].—A. G. Clavier & G. Phélizon. (*Onde élect.*, Aug./Sept. 1946, Vol. 26, Nos. 233/234, pp. 331–344.) Discussion of the application of frequency-modulated centimetre wave radio links to multichannel telephony circuits, followed by a general description of a twelve-channel link about 10 miles long between Paris and Montmorency (See also 3743 of 1946). In this circuit, transmission in one direction is horizontally polarized on a wavelength of 9 cm, with vertical polarization on 10 cm in the reverse sense. Separate horns having beam widths of the order of 10° are used for transmission and reception. The radio link is designed for direct insertion in a carrier telephony circuit, the twelve speech channels occupying the frequency band 12–60 kc/s. At the transmitter a velocity-modulated oscillator developing about 30 W of r.f. power is used. The speech-modulated carriers are used for frequency modulation of the oscillator which has a sensibly uniform characteristic for a frequency range of about 1 Mc/s. Superheterodyne receivers having positive grid oscillators and diode mixers are used. Extensive application is made of negative feedback technique in transmitters and receivers to maintain linearity and stability of operation ; the principles involved are discussed in some detail. The possible future development of radio links for transmission of wide-band intelligence is outlined ; the attenuating effects of constituents of the atmosphere at centimetre wavelengths are briefly mentioned.

621.396.712.004.5 **541**

Preventive Maintenance for Broadcast Stations : Part 4.—C. H. Singer. (*Communications*, Sept. 1946, Vol. 26, No. 9, pp. 36 . . 38.) A discussion of " seven basic preventive maintenance procedures . . . feel, inspect, tighten, clean, adjust, lubricate and measure ". For part 3 see 3423 of 1946.

621.396.712 **542**

Radio Stations. [Book Notice]—Federal Communications Commission, 26 pp., 10c. (*U.S. Govt. Publ.*, July 1946, No. 618, p. 777.) Standards of good engineering practice concerning f.m. broadcast stations, revised to 9th Jan. 1946.

SUBSIDIARY APPARATUS

621–526 **543**

Dimensionless Analysis of Servomechanisms by Electrical Analogy.—S. W. Herwald & G. D. McCann. (*Trans. Amer. Inst. elect. Engrs*, Oct. 946, Vol. 65, No. 10, pp. 636–639.)

621.314.6+621.319.4+621.383] : 669.018 **544**

Light Alloys in Metal Rectifiers, Photocells and ondensers.—Continuing the series in various ssues of *Light Metals*. For previous parts see 3768 f 1946.

(vi) Dec. 1944, Vol 7, No. 83, pp. 565–566. egins a detailed consideration of the theory and ractice of electrolytic capacitors.

(vii) Jan. 1945, Vol. 8, No. 84, pp. 25–41. An xhaustive discussion on the theory, practice nd operation of the electrolytic capacitor. In articular the properties of the aluminium-oxide lm are considered.

(viii) Feb. 1945, Vol. 8, No. 85, pp. 87–100. onsideration is given to the theory and ractice of the formation of electrolytes for electroly- c capacitors, and to their design and production, ith typical examples.

(ix) April 1945, Vol. 8, No. 87, pp. 193–202. iscussion on the theory and practice of electroly- c capacitors.

(x) May 1945, Vol. 8, No. 88, pp. 246–254. ncludes (ix) and considers in detail fixed paper pacitors.

(xi) June 1945, Vol. 8, No. 89, pp. 292–304. xed paper capacitors, and the use of tin and uminium foils, are discussed.

To be continued.

1.317.755.087.5 **545**

Recording of Transients.—W. Nethercot. (*Elect. mes*, 14th Nov. 1946, Vol. 110, No. 2873, pp. 648– 1.) For all except the highest writing speeds a aled-off cathode-ray oscillograph with an accelera- g voltage not less than 5 kV and a blue-violet een may be used. A camera with an F 1.0, nch focus lens operating with an object/image io of 4 or 5 to 1 and using a high speed ortho- omatic film is recommended. Thirteen prints h writing speeds up to 20 000 km/sec are shown.

.318.42 **546**

aturable Choke Controlled Rectifiers.—H. S. uble. (*P.O. elect. Engrs' J.*, Oct. 1946, Vol. 39, rt 3, pp. 110–113.) Notes on the basic principles l capabilities of this form of control for d.c. ver supplies.

.352.7 **547**

Iiniature Dry Cell.—(*Rev. sci. Instrum.*, July 1946, l. 17, No. 7, pp. 286–287.) A dry cell having a h ratio of capacity to volume with long life been developed for tropical use by P. R. Mallory Co. Within its rating the cell has an ampere- r capacity substantially independent of rate of harge. Dimensions of the cell are 1 inch in dia- er and $\frac{5}{8}$ inch high.

.383 **548**

arious Papers on Electron Multipliers.—(*See* /578.)

.384 **549**

arious Papers on Electron Accelerators.—(*See* 495.)

621.395.631.4 **550**

Recent Design of a Small Telephone Magneto.—D. S. Smith. (*Canad. J. Res.*, Sept. 1946, Vol. 24, Sec. F, No. 5, pp. 406–408.) " An example is given of the product obtained by applying modern methods in permanent magnet design to the problem of constructing a hand driven magneto of about flashlight battery size."

621.791.76 **551**

Miniature Spot-Welding Tools.—R. W. Hallows. (*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 373–374.) The tool, which is made by Siemens-Halske A.-G., is 10 inches long and 1 inch in diameter: the smaller model can be used for wire up to 0.8 mm diameter while the larger is for any joint whose surface area does not greatly exceed 10 sq. mm. Mains supply at 110 V or 250 V (50 c/s) can be used: the welding voltage does not exceed 35 V.

TELEVISION AND PHOTOTELEGRAPHY

621.396.8 : 621.397.26 **552**

Television Link Tests in Southern California.—P. B. Wright. (*Communications*, Oct. 1946, Vol. 26, No. 10, pp. 15, 55.) Report of experimental f.m. television transmission and reception over 17.2-mile line-of-sight paths between Mt Wilson (5 700 ft) and Hollywood. In one case metallic lenses 5½ ft by 7½ ft with a power gain of about 35 db per lens were used, in the other, 57-inch parabolic reflector-type radiators, with gain 3 to 4 db less. Each lens gave an effective directed power of 1 200 W over that of an omnidirectional point source. This gives a sufficient margin even under severe fading conditions. The frequency bands were 4 416–4 420 Mc/s (reflectors) and 4 376–4 380 Mc/s (lenses).

621.397.262 **553**

Approximate Method of Calculating Reflections in Television Transmission.—D. A. Bell. (*J. Instn elect. Engrs*, Part III, Sept. 1946, Vol. 93, No. 25, pp. 352–354.) An examination of the effects of " carrier frequency, size of reflecting obstacle, distance of reflecting obstacle from transmitter and from receiver, and degree of definition of the television picture, on the incidence of reflection troubles in television reception. The diffraction problem is treated by a simple mathematical approximation which has been previously used in optics."

621.397.5 : 532.62 **554**

Oil-Film Television.—(*Radio Craft*, Oct. 1946, Vol. 18, No. 1, pp. 22–23.) An electron gun, modulated by incoming signals, scans 50 times a second the surface of a film of special liquid about 0.1 mm thick and deforms it in such a way that light from an arc lamp is allowed to pass on to a projection screen. The film rests on a glass plate, which is illuminated from below by focusing the arc lamp beam with mirrors and a lens. The deformation is increased by placing a charged electrode near the film and by charging the film uniformly with a second electron gun. The glass plate rotates uniformly, carrying the film, and provision is made for the film to be smoothed ready for further use.

621.397.6 **555**

U.S. Television Gear.—(*Wireless World*, Nov. 1946, Vol. 52, No. 11, p. 380.) Description of an image orthicon camera developed by R. C. A. with a revolving lens turret, a device for rapid changing of lenses and a wide-band microwave relay link.

621.397.6 **556**

Surveying Recent Television Advances.—R. R. Batcher. (*Electronic Industr.*, Oct. 1946, Vol. 5, No. 10, pp. 46–48..106.) New cameras include the image-orthicon with a telephoto lens system while the iconoscope and the orthicon tubes have been improved. New valves are now used in transmitters and receivers and relay systems involving airborne apparatus are being investigated. Mirror and lens systems are being used for large-screen projection and experiments with skiatrons are in progress. American television-frequency data are tabulated.

621.397.62 **557**

Rebuilding a Televiser.—N. Chalfin. (*Radio Craft*, Sept. 1946, Vol. 17, No. 12, pp. 832..881.) Describes methods of modernizing pre-war television receivers; a circuit diagram indicates the changes necessary.

621.397.621 **558**

Deflector Coil Coupling.—W. T. Cocking. (*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 360–363.) A straightforward semi-graphical method is described whereby curvature of valve characteristics may be used to compensate the nonlinear characteristics of the deflector coil to produce a linear saw-tooth output. A numerical example is fully discussed. See also 272 of January (Cocking).

621.397.74 **559**

Multi-Outlet T-V [television].—(*Electronic Industr.*, Oct. 1946, Vol. 5, No. 10, p. 57.) Describes a system for providing a large number of television receivers with choice of programme. The programmes are received by suitable aerial systems and passed through single-valve amplifiers into a common concentric line. Attenuating pads at each receiver prevent mutual interference.

TRANSMISSION

621.396.61 : 621.396.619.018.41 **560**

Direct F.M. Transmitters : Part 9.—N. Marchand. (*Communications*, Sept. 1946, Vol 26, No. 9, pp. 26–29..35.) Design principles are considered with the aid of block and circuit diagrams. Input capacitance, phase discriminator exciter and pulse control exciter units are discussed. For part 8 see 3452 of 1946.

621.396.61 : 621.396.619.018.41 **561**

Mobile F.M. Transmitters : Part 10.—N. Marchand. (*Communications*, Oct. 1946, Vol. 26, No. 10, p. 30.) The advantages of f.m. are briefly stated and a 25–50-W mobile transmitter on 30–44 Mc/s is described. For earlier parts see 560 above and back references.

621.396.61 : 621.396.721 **562**

An Auxiliary Radio Transmitter for Broadcast Service.—C. A. Cullinan. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1946, Vol. 7, No. 9, pp. 4–11. Discussion, pp. 11–12.) Designed and constructed with available war-time material, the circuit consists of a crystal-controlled oscillator, a single r.f. buffer stage, and a class-C amplifier with a class-B modulator (anode modulation). The carrier power was 125–150 W, capable of 100% modulation. The audio-frequency response was "within 0.5 db from 40–10 000 c/s and within 2 db down to 30 c/s ". Distortion and noise were virtually non-existent. A 56-ft vertical radiator was used, and the transmitter could be in operation in less than a minute.

621.396.61 : 621.396.97 **563**

Experimental 88 to 108-Mc/s 250-Watt F. M. Broadcast Transmitter.—J. H. Martin. (*Communications*, Sept. 1946, Vol. 26, No. 9, pp. 22–24..45.) Main features include the Armstrong phase-shift system modulator, with the centre carrier frequency directly controlled by crystal for stability reasons. The complicated modulator system is explained fully. The power amplifier comprises 4-125A type tetrodes, neutralized by tuning the screen inductance to earth by means of a split-stator capacitor.

621.396.61 [(43) + (44) + (73)] " 1939/45 " **564**

Transmitting Equipment of the French, German and American Armies.—R. Besson. (*Toute la Radio*, Jan. 1946, Vol. 13, No. 102, pp. 31–35.) An account of the special features of various types of equipment handled by a French technician between 1939 and 1945. The great tactical superiority of the f.m. apparatus used by the Americans is stressed.

621.396.61.029.56/.58 **565**

Top-Band Two Transmitter.—J. N. Walker. (*R.S.G.B. Bull.*, Nov. 1946, Vol 22, No. 5, pp. 66–69, 75.) Description of a self-contained low power transmitter for use on 1.8 Mc/s, 3.5 Mc/s and also on 7.5 Mc/s at somewhat reduced efficiency. Constructional details, a circuit diagram, and a list of components are given.

621.396.61.029.62 **566**

A 100-kW Portable Radar Transmitter.—H. L. Lawrence. (*Communications*, Sept. 1946, Vol. 26, No. 9, pp. 30..33.) The unit contains the r.f. power-oscillator modulator, high voltage power supply, and a wavemeter for frequency measurement. Frequency range is 225 to 250 Mc/s ; mean power output, 40 W ; pulse shape, half sine wave ; pulse length, 1.6 μs and recurrence frequency, 600 c/s. Primary power is obtained from a petrol-driven generator. Special air-cooled oscillator valves 4C27, are used in a grounded plate circuit, and the frequency is controlled by a variable inductance in the grid circuit. The cathode is tuned by a parallel wire transmission line, to which the antenna is directly coupled. " The r.f. oscillator is plate-modulated by a gas-discharge tube pulse-forming circuit."

621.396.619.018.41.029.6 **567**

Über Frequenzmodulatoren für Ultrahochfrequenz. [Book Review]—G. Weber. Gebr. Leemann, Zürich, 95 pp., Swiss Fr. 9. (*Wireless Engr*, Dec. 1946, Vol. 23, No. 279, p. 340.) Deals with the difficulties of applying frequency modulation to transmitters working at frequencies of 100 to 600 Mc/s.

VALVES AND THERMIONICS.

537.533.7 **568**

Electron-Optical Properties of Emission Systems.—L. A. Artsimovich. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 313–329. In

Russian.) Apparatus in which an electron-optical image of an object emitting slow electrons is obtained can be divided into three classes according o whether the image is (*a*) greatly magnified, *e.g.* n emission electron microscopes used for studying hermo- and photo-cathodes, (*b*) of approximately he same dimensions as the object, *e.g.* in devices used in television, or (*c*) reduced to a point, *e.g.* in he electron gun. A brief survey of each class is given. This is followed by a detailed mathematical analysis of the formation and focusing of electron beams by electrostatic methods. Equations are derived determining the trajectories of the electrons and approximate solutions indicated. Chromatic aberration, transverse as well as longitudinal, is calculated and the plane of the optimum image found. The depth of focus, determining the accuracy of focusing, is examined. Further possible defects of electron-optical systems, such as spherical aberration, curvature of the image, and astigmatism, are also discussed. A technically ideal system would use purely electrostatic focusing, with two electrodes only. An analysis of its operation is given and possible applications are discussed.

537·533·7 : 621.383 **569**

The Electron-Optical Properties of the Magnetic ube (Electron Multiplier) of Kubetski.—G. R. Rik. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, o. 6, pp. 366–369. In Russian.) A detailed investigation of the tube was carried out and in this paper brief summary of the results obtained is given. he equipotential lines of the electric field and the ectron trajectories in the region of the cathode are plotted. The absence of an accelerating field near he cathode and the lack of co-ordination between he fields result in a useless dispersion of a large umber of photo-electrons. The curves of focusing in he longitudinal direction are shown. The variation the size of the emitting rings (they become wider eginning from No. 12 ring) is not adjusted to the ongitudinal gradient of the magnetic field with the esult that further dispersion of electrons occurs. he electron trajectories near the anode are shown Fig. 3. The diffusion of the magnetic field in this egion obstructs the collection of electrons at the node. The general conclusion reached is that ectron-optical properties of the tube are rather oor, but that they could be improved by modifying he operating conditions and altering certain onstructional details. *See* also 577 below Kubetski).

37·533·8 **570**

On the Secondary Electron Emission from Solid odies.—S. Y. Luk'yanoff. (*Bull. Acad. Sci. .R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 330–339. n Russian.) A general theory of the phenomenon ased on modern conceptions and experimental ata is presented. The penetration of a primary ectron into a solid body is discussed and prosses determining the appearance and intensity of condary emission are examined in detail. It is own that the shape of the (σ, E_ρ) curve is determined mainly by the ionizing effect of the primary ectron (proportional to the total loss of energy er unit length) in the layer from which secondary ectrons are emitted. The possibility of an experiental verification of this statement is indicated and sults obtained by other investigators are quoted. table of the latest reliable data on secondary emission for various metals is given, whence it appears that $\sigma_{\max}$ is low for all metals and that there is no direct relationship between it and the work function. It is suggested that the variation of $\sigma_{\max}$ for various metals is determined by the effect of bound electrons in the metal, and by the number of atoms per unit volume. Finally, the secondary emission from semiconductors and dielectrics is examined. Although not every semiconductor or dielectric has a $\sigma_{\max}$ exceeding those for pure metals, materials with very high values of $\sigma_{\max}$ must necessarily be semiconductors or dielectrics. The reasons for this are suggested and experimental data for some of the materials are quoted. Reference is made to the possibility of increasing the secondary emission of a material with high resistance by electron bombardment which causes the appearance of surface charges on the material. This effect is utilized in various devices, such as electron multipliers, but the author is not inclined to regard it as important.

An abstract in English was noted in 2074 of 1946.

537·533·8 **571**

The Effect of Strong Electric Fields on the Secondary Electron Emission from Thin Dielectric Films.—D. V. Zernoff. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 352–356. In Russian.) As a result of the action of an electron beam on a thin film of dielectric deposited on a metallic base, a strong field is built up in the film affecting in a number of ways the characteristics of the emitter. The effects of the field are enumerated and, in order to clarify the processes taking place in the film, a mathematical analysis is presented of the energy spectrum of the system metal-dielectric-vacuum (Fig. 1). Experiments carried out with the MgO and Al_2O_3–Cs_2O emitters are described, and the possibility of obtaining large secondary currents, especially in the form of short impulses, is indicated.

An abstract in English was noted in 2075 of 1946.

537·533·8 : 621.385 **572**

Electronic Apparatus with Effective Emitters of Secondary Electrons.—R. M. Aranovich. (*Bull. Acad. Sci. U R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 346–351. In Russian.) Emitters prepared by evaporating magnesium and other metals in dry oxygen are briefly discussed. The effects of various gases, of materials used for bases, of the velocity of primary electrons, of the conditions under which the evaporation of the metal is carried out, and of the manner in which the secondary voltage gradient is built up were investigated and experimental curves were plotted. Emitters with $\sigma = 80$ were produced and even with $\sigma = 100$–$10\,000$, although in the last case inertia of secondary emission was observed. The breakdown of the emitters is discussed and microphotographs showing their structure are included. An interpretation of the experimental results is offered. The operating data of a photocell and a valve with one stage of amplification are given.

An abstract in English was noted in 2390 of 1946.

537·533·8 : 621.385.1.032.216 **573**

The Emission from an Oxide Cathode under the Application of an Impulse Voltage.—A. M. Andrianoff. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 5, p. 290. In Russian.) A preliminary note on an experimental investigation in which it was found that if an impulse voltage at a frequency of 50 p.p.s. is applied to the anode of a diode with an oxide cathode, the emission from the latter at the normal temperature of 850–900°C is enormously increased and reaches the value of 30 A/sq. cm.

An abstract in English was noted in 2076 of 1946.

621.314.653 **574**

Excitation, Control, and Cooling of Ignitron Tubes.—C. C. Herskind & E. J. Remscheid. **Rectifier Capacity.**—C. C. Herskind & H. C. Steiner. (*Trans. Amer. Inst. elect. Engrs*, Oct. 1946, Vol. 65, No. 10, pp. 632–635 & 667–670.) The first paper describes the control, limitations, and operating requirements of mercury-arc tubes of the ignitron type, while the second paper deals with the load-time and volt-ampere characteristics of these tubes, the relations between these characteristics and the factors affecting them.

621.314.67 : 621.357.1 : 666.1 **575**

Electrolysis Phenomena in Soft-Glass Stems of Rectifier Tubes.—Gallup. (*See* 447.)

621.319.7 : 621.385 **576**

Plotting Electrostatic Fields.—Silva. (*See* 446.)

621.383 **577**

Some Conclusions reached from the Use of Secondary Electron Multipliers.—L. A. Kubetski. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 357–365. In Russian.) Since the first attempts by the author in 1934 to use secondary emission for the amplification of the primary electron current, a large amount of work both experimental and theoretical has been carried out. In the present paper the results achieved are systematized and further lines of development indicated. The specific requirements for electron multipliers are enumerated and reference is made to the type evolved by the author to meet these requirements. A logical basis for further search of suitable emitters is elaborated; those of the Cu–S–Cs type developed by the author are described. Criteria determining the quality of electron multipliers are established. The maximum amplification and the threshold of sensitivity of multipliers are also discussed.

An abstract in English was noted in 2029 of 1946.

621.383 **578**

Electron Multipliers.—E. G. Kormakova. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 370–372. In Russian.) Since systems with a magnetic field are not convenient in use, only systems with an electrostatic field were considered. It was found that focusing was best achieved by means of grids. Accordingly a multiplier with a cylindrical grid and using caesium oxide cathode and emitters was developed. Equipotential lines and lines of force are plotted by a graphical method of successive approximation. Various characteristics of the multiplier are shown and operating data given.

An abstract in English was noted in 2028 of 1946.

621.385 **579**

On the Flow of High-Frequency Currents through Electronic Apparatus.—S. D. Gvozdover. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 5, pp. 267–274. In Russian.) It is not always possible, in designing high frequency apparatus, to regard $\theta = \omega T_0$ as a small quantity where ω is the frequency and T_0 the travelling time determined by the constant voltages. Solutions for any value of θ can be obtained in all cases without much difficulty if the approximate solutions derived by expansion in series are modified in accordance with Laplace's transformation. It is assumed that the electron stream passes between flat electrodes, and that the electron velocity is a single-valued function of the coordinates, *i.e.* that the electrons cannot overtake one another.

Equations (1–4) determining the movement of the electrons between the electrodes are given, and an approximate solution (14) is derived by expansion. Laplace's transformation is applied to this solution, and a modified formula (15) is derived which is more suitable for calculations. The results obtained are used in a discussion divided into the following sections: (*a*) the determination of the current in the external circuit, and of the power consumed; (*b*) the determination of the self-excitation regions in the case of a single-circuit klystron ('monotron'); (*c*) the determination of the dielectric constant of an electron gas; (*d*) an analysis of the rectification of h.f. currents in a diode; (*e*) the calculation of the amplitude of stationary oscillations in a monotron.

An abstract in English was noted in 2389 of 1946.

621.385 **580**

The Role of Surface Charges in Electronic Apparatus.—P. V. Timofeeff. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 340–342. In Russian.) While the effects of space charges are widely used in electronic apparatus, little attention has been paid to the possibility of utilizing charges appearing on the surface of insulators inside the apparatus. Normally these charges are formed as a result of secondary emission from the insulators, caused by electron bombardment. An insulator can thus be charged to a high positive potential and the following three possible applications of this effect are indicated: (*a*) an insulator mounted near the cathode and acquiring a high positive charge may produce a potential gradient sufficient for cold emission of electrons from the cathode; (*b*) the high secondary emission from caesium-oxide cathodes is probably due to the presence of dielectric particles in the cathodes, which may acquire positive charges (Fig. 1); this opens a possibility for a further increase in the secondary emission; (*c*) positive charges also would assist photo-emission from caesium-oxide cathodes which may be achieved by making this effect more pronounced.

An abstract in English was noted in 2388 of 1946.

621.385 **581**

The Mechanism of the Operation of Kenotrons with Cold Cathodes.—V. V. Sorokina. (*Bull. Acad. Sci. U.R.S.S., sér. phys.*, 1944, Vol. 8, No. 6, pp. 343–345. In Russian.) A brief description is given of a kenotron developed in Russia and consisting essentially of a nickel cylinder (the anode) in a cylindrical glass envelope on which a layer of caesium oxide (the cathode) is deposited. A characteristic of the kenotron is plotted and discussed.

An abstract in English was noted in 2387 of 1946.

621.385 : 519.24 **582**

Analysis of Special Electronic-Tube Tests.—J. H. Campbell & C. G. Donsbach. (*Trans. Amer. Soc. mech. Engrs*, July 1946, Vol. 68, No. 5, pp.

481–486.) Illustrates the improvements in valve manufacturing technique which may be accomplished by controlled tests on valves in the course of production, followed by statistical analysis of the results.

621.385 : 621.317.723 **583**

Improvements in the Stability of the FP-54 Electrometer Tube.—J. M. Lafferty & K. H. Kingdon. (*Phys. Rev.*, 1st/15th June 1946, Vol. 69, Nos. 11/12, p. 699.) Greater stability was obtained by increasing the activation time from 8 to 40 minutes. Filament end shields also reduced rapid fluctuations. A special split tube using both oxide-coated and thoriated tungsten filaments was made which eliminated long-term drift in a bridge circuit and reduced rapid fluctuations tenfold. Summary of Amer. Phys. Soc. paper.

621.385 : 621.395.613 **584**

“ Vibrotron ” Tube.—R.C.A. (*Rev. sci. Instrum.*, July 1946, Vol. 17, No. 7, p. 282.) A small electron tube for translation of mechanical motion into variable electron flow, which can be used in microphones. When used in a gramophone pickup it is claimed that the tube will perform up to the highest requirements of fidelity and sensitivity. The tube is a metal triode about 1 inch in length, and ¼ inch in diameter weighing $\frac{1}{15}$ oz.

621.385.029.63/.64 **585**

The Travelling Wave Valve.—R. Kompfner. (*Wireless World*, Nov. 1946, Vol. 52, No. 11, pp. 369–372.) Amplification in transit-time valves may be greatly increased if a field travelling at the speed of the electrons is used instead of a stationary electric field. By this means electron acceleration is obtained in both half cycles of the wave. Such a field can be produced if the signal travels along a helix of suitable dimensions. The presence of the electron beam also causes amplification in the wave itself, hence the helix—electron-beam system is an amplifier. Experimental data on this type of tube are briefly mentioned, and future applications, including television and u.h.f. transmissions, suggested.

21.385.029.63/.64] **586**

Traveling Wave Tubes.—M. A. Barton. (*Radio*, N.Y., Aug. 1946, Vol. 30, No. 8, pp. 11–13 . . 32.) . simple description of the new centimetre-wave tube, in which an electron beam is transmitted along the axis of a long narrow helix, which acts as a waveguide with a low velocity of propagation. The tube gives high gain over a broad band in the region of 4 000 Mc/s. For another account see *Elect. World, N.Y.*, 21st Sept. 1946, Vol. 126, No. 12, pp. 20–21.

21.385.1 **587**

The Theory of a Reflex Klystron.—S. Gvozdover. *Zh. eksp. teor. Fiz.*, 1945, Vol. 15, No. 9, pp. 521–531. In Russian.) The resonant frequencies of a reflex klystron are calculated as a function of its dimensions and the applied voltages. Graphs and formulae for computation are given.

21.385.1 **588**

The Maximum Efficiency of Reflex Oscillators.—. G. Linder & R. L. Sproull. (*Phys. Rev.*, st/15th June 1946, Vol. 69, Nos. 11/12, p. 700.) formula is given for maximum efficiency with optimum electron bunching and loading. Possible methods of increasing efficiency are investigated. Summary of Amer. Phys. Soc. paper.

621.385.12 : 621.396.822 **589**

Cold-Cathode Gas Tubes as Noise Generators.—S. Ruthberg. (*Phys. Rev.*, 1st/15th July 1946, Vol 70, Nos. 1/2, p. 112.) A glow tube, a mercury arc with mercury-pool electrodes, and a corona discharge monode were examined. The glow tube gave spectra from 0.05 to 5 Mc/s, and oscillations and noise were affected by a transverse magnetic field. See also 3267 of 1946 (Gallagher & Cobine). The mercury arc was not sufficiently stable for quantitative measurements, and the corona monode gave noise of a steep pulse character.

Summary of an Amer. Phys. Soc. paper.

621.385.16 **590**

How the Magnetron Works.—“ Radionyme ”. (*Toute la Radio*, Jan. 1946, Vol. 13, No. 102, pp. 26–28.) The performance of three types is noted : (*a*) British, with 8 resonant cavities 100-kW peak power, 1-μs pulses, 600 pulses per sec, wavelength 9 cm, 15-kV anode voltage, 20-A anode current, magnetic field 1 700 oersteds, and efficiency 30% ; (*b*) Russian, with 116 W on c.w. at wavelength 9 cm, and efficiency 22% ; (*c*) German, with peak power 8 kW and wavelength 1.75 cm.

621.385.8 : 538.6 **591**

Magnetically-Controlled Gas Discharge Tubes.—R. E. B. Makinson, J. M. Somerville, K. R. Makinson & P. Thonemann. (*J. appl. Phys.*, July 1946, Vol. 17, No. 7, pp. 567–572.) In these tubes, a glow discharge is initiated by means of a magnetic field pulse. Ions from this discharge produce an arc spot on the pool of mercury through which the main current passes. A current pulse of 200 A of duration 1 to 10 sec can be used.

621.385.8.032.21 : 537.525.83 **592**

The Normal Cathode Fall for Molybdenum and Zirconium in the Rare Gases.—T. Jurriaanse, F. M. Penning & J. H. A. Moubis. (*Philips Res. Rep.*, April 1946, Vol. 1, No. 3, pp . 225–238.) In gas-discharge tubes with molybdenum or zirconium cathodes greater stability of the voltage maintaining the discharge has been obtained by sputtering the cathode material over the whole of the walls of the tube. The action of this metallic layer is thought to be partly due to absorption of gases released from the walls during the discharge and partly to its screening action which prevents the liberation of such gases.

621.385.82.029.3 : 621.395.61 **593**

[The development of] **a High Power Thermionic Cell using Positive Ion Emission and operating in a Gaseous Medium.**—S. Klein. (*Onde élect.*, Oct. 1946, Vol. 26, No. 235, pp. 367–373.) The cell is small, cylindrical in shape and comprises an axial heater surrounded by a ceramic sheath on the outer surface of which finely divided platinum is deposited. This anode is surrounded by a silver cylindrical cathode ; the inter-electrode spacing is about 1 mm. Positive ion currents of the order of several tens of microamperes are produced at atmospheric pressure for a polarizing voltage of a few hundred volts. Since the current depends on pressure, the cell may be used as a microphone at audio and sub-audio frequencies. Conversely the cell may be used as a loudspeaker since energy from the pulsating ion stream is lost to the air molecules. A ‘ triode ’ version of the cell is also described for the loudspeaker application. The pressure/current characteristic for the diode is given.

621.385(075) **594**

Elektronenröhren. [Book Review]—A. Daeschler. Archimedes Verlag, Zürich, 1945, 104 pp., Swiss Fr. 6.80. (*Tech. wet. Tijdschr.*, April/May 1946, Vol. 15, Nos. 4/5, p. 50. In Flemish.) First of a series of textbooks on radio, intended for the radio serviceman.

MISCELLANEOUS

001.8 **595**

Scientific Information Services.—(*Nature, Lond.*, 14th Sept. 1946, Vol. 158, No. 4011, pp. 353–356.) Editorial on the report of the Royal Society on needs of post-war research, with special reference to publication and scientific intelligence. It is estimated in the report that in physics and chemistry alone, at least two thousand papers will now be released for publication but cannot be published without substantial assistance from Treasury funds.

001.89 : 621.396 **596**

The 7th General Assembly of the International Radio-Scientific Union.—A. Haubert. (*Onde élect.*, Oct. 1946, Vol. 26, No. 235, pp. 391–393.) Held in Paris, 27th Sept. to 5th Oct. 1946. Committees were set up on measurements, propagation (ionospheric and tropospheric), atmospherics and radiophysics.

535.65 : 001.4 **597**

International Names of Colorimetry.—P. Moon & D. E. Spencer. (*J. opt. Soc. Amer.*, July 1946, Vol. 36, No. 7, pp. 427–428.) A study of internationality in the endings of scientific words shows that the following endings are ordinarily used with the same meanings in most of the languages of Europe and America: *-or* = a device; *-tion* = a process; *-ance* = a passive property of a device; *-ity* = a passive property of a substance. Thus these endings may be regarded as international, and their use in the coining of new scientific terms should be encouraged.

6(43) **598**

A Classified List of Industrialists' Reports on Germany [up to 27th July 1946].—CIOS, BIOS, FIAT, & JIOA. Obtainable from H.M. Stationery Office.

Section F covers electrical engineering industry, including radio; Section D includes plastics; Section G, glass and ceramics; and Section K, metals.

620.193.8(213) **599**

The Deterioration of Materiel in the Tropics.—Hutchinson. (*See* 438.)

621.3 : 371.3 **600**

Post-Graduate Courses in Electrical Engineering, including Radio.—(*J. Instn elect. Engrs*, Part III, Sept. 1946, Vol. 93, No. 25, pp. 363–364.) Summary of I.E.E. Radio Section discussion led by W. Jackson and J. Greig on the " means by which qualified electrical engineers might acquire, and sustain, an intimate knowledge of the particular branches of the subject in which their individual contributions [are] to be made." See also 2435 of 1946.

621.38/.39 + 331(07) : 621.3 **601**

Post-War Development Report.—(*J. Brit. Instn Radio Engrs*, Oct./Dec. 1944, Vol. 4, No. 3, pp. 135–161.) In part 1 the whole field of electronics is briefly surveyed, and the outstanding problems in each branch are mentioned. In part 2 the provision of staff for the development programme, and their education and training, are discussed.

621.395(091) **602**

A Critical Review of the History of the Controversy concerning the Invention of the Telephone examined in the Light of Contemporary Literature.—C. Frachebourg. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Feb. 1946, Vol. 24, No. 1, pp. 36–42. In French.)

621.396.9 **603**

I.E.E. Radiolocation Convention, March 1946.—(*J. Ins'n elect. Engrs*, Part I, Oct. 1946, Vol. 93, No. 70.) Summaries of the survey papers read at the Convention are given. A bibliography of the remaining papers connected with the Convention is also included; these papers together with fuller versions of the survey papers are being published in *J. Instn elect. Engrs*, Part IIIA, 1946, Vol. 93, Nos. 1–9, and will be abstracted in due course.

621.882.082.2 **604**

The Unification of Screw-Thread Practice.—(*Engineering, Lond.*, 13th Sept. 1946, Vol. 162, No. 4209, pp. 253–254.) Proposal for a modification of the standard Whitworth thread, to one of 60° angle with flat or rounded crests, and rounded roots.

621.38 (02) **605**

An Introduction to Electronics. [Book Review]—R. G. Hudson. Macmillan, New York, 93 pp., $3.00. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1946, Vol. 7, No. 10, p. 31.)

621.396 **606**

The Wireless Trader Year Book. [Book Notice]—Iliffe & Sons, London, 1946, 160 pp., 10s. 6d. (*Electrician*, 19th July 1946, Vol. 137, No. 3555, p. 185.)

621.396 **607**

Radio. [Book Notice]—National Bureau of Standards, 87 pp. (*U.S. Govt. Publ.*, July 1946, No. 618, p. 730.) Revised classification of radio subjects dated 11th Jan. 1946.

621.396 **608**

Précis de Radioélectricité. [Book Review]—E. Divoire. Éditions Desoer, Liège, 1945, 222 pp., 171 figs. (*Tech. wet. Tijdschr.*, Oct./Dec. 1945, Nos. 10/12, p. 114. In Flemish.) " . . A survey of the theory and applications, addressed to engineers, scientists and university students, who wish to extend their knowledge to this new field . . ."

621.396(075) **609**

Experimental Radio. [Book Review]—R. R. Ramsey. Ramsey Publishing Co., Bloomington, Indiana, 4th edn 1937, 196 pp., $ 2.75. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1946, Vol. 7, No. 9, p. 29.) " Very little theory appears in the text, it being the aim of the author to make the student think for himself." A very practical and useful book, " which does not suffer as a result of the age of its subject matter."

621.396.029.6 **610**

Ultra-High-Frequency Radio Engineering. [Book Review]—W. L. Emery. Macmillan, New York, 1944, 281 pp., $ 3.25. (*Proc. Instn Radio Engrs, Aust.*, Sept. 1946, Vol. 7, No. 9, pp. 37–38.) " . . . The treatment is generally fairly simple and confined to basic principles."