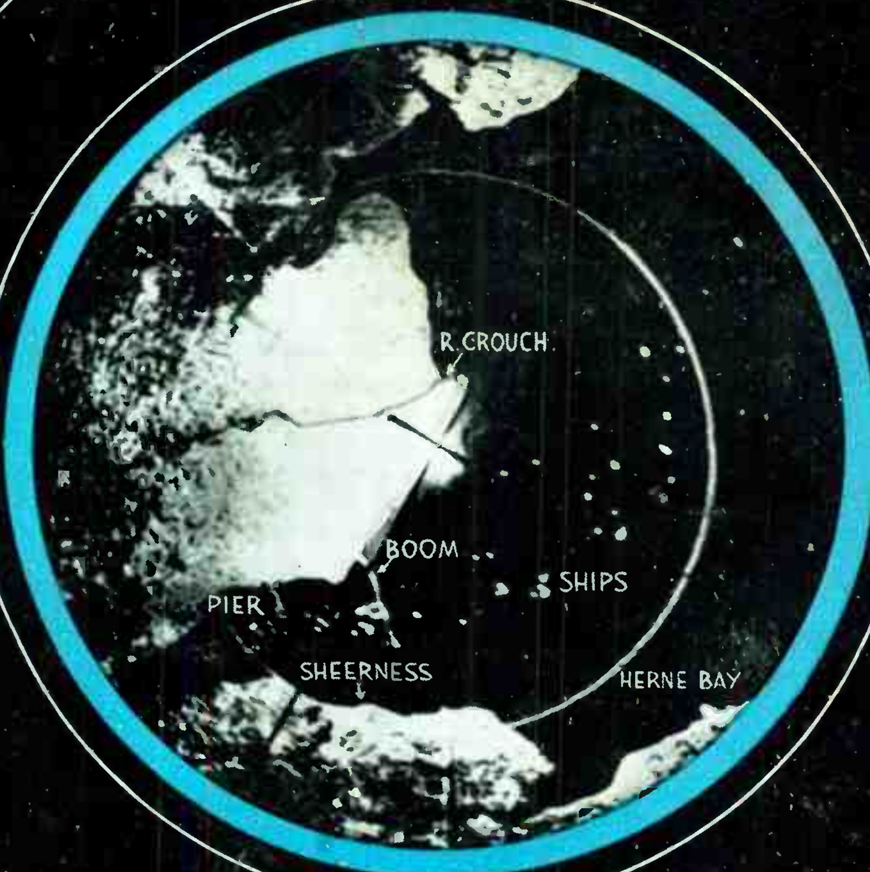
Wireless World

RADIO and ELECTRONICS



DEC. 1945

1/6

Vol. LI. No. 12

IN THIS ISSUE: AC/DC QUALITY AMPLIFIER

World Radio History

Robert Sharp & Partners B.R.14

AVO

Regd. Trade Mark

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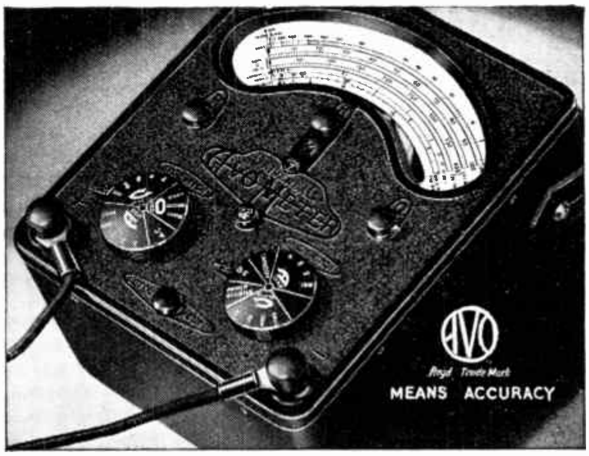
HIGH accuracy, simplicity, exceptional versatility and proven reliability have won for "AVO" Instruments a world-wide reputation for supremacy wherever rapid precision test work is demanded. There is an "AVO" Instrument for every essential electrical test.



The **MODEL 7** *50-Range Universal*

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with High Voltages

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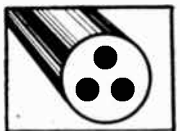
A

Technical Reasons Why

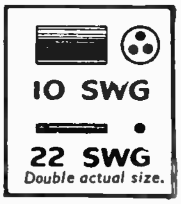
★ ERSIN MULTICORE SOLDER

Is the Finest Cored Solder in the World



Three Cores of Flux ensure flux continuity. No lengths without flux are wasted. Consistent high quality joints are obtained with comparatively unskilled labour. Exactly the correct proportions of solder to flux are provided. Separate fluxing operations are obviated and no extra flux is required. The three cores of flux being evenly distributed over the cross section of the solder provide thinner solder walls than otherwise. This gives rapid melting and speeds up soldering. The flux does not tend to run out of the cores; so there is always a supply available for the next joint. The utmost economy of solder and flux is achieved.

Ersin, contained in the three cores of Ersin Multicore Solder, is the fastest non-corrosive flux. Possessing all the non-corrosive advantages of rosin, it enables joints to be speedily made on oxidised or "difficult" surfaces such as nickel. Ersin not only avoids oxidation during soldering but removes surface oxide already present—this is particularly advantageous in respect of materials that have been in stock or apparatus that is being serviced. The use of Ersin Multicore, with correct soldering technique, avoids "HR" or dry joints.



Ersin Multicore Solder is made in most gauges between 10 and 22 S.W.G. (·128—·028″) (3·251—·7109 m/ms). For general radio and electrical production and maintenance 13 and 16 S.W.G. are in most demand.

Virgin Tin & Lead

Five alloys of Ersin Multicore Solder, made from virgin metals, are available—all antimony free. Under present circumstances 45% tin and 55% lead is the most widely used alloy.

Technically, Ersin Multicore Solder is far superior to any other cored solder. A practical laboratory or production test will demonstrate this and show you that it is the most economical solder to use. The majority of British and overseas manufacturers already enjoy the advantages of Multicore. If you do not, and are engaged upon Government contracts, write for further technical information and free samples.

Single reel rate nominal 1 lb. reels.

13 SWG	-	4/10
16 SWG	-	5/3

Above prices subject to usual trade discount.

¼ cwt.—ton lots at bulk rate. 6d. cartons for home use, available at most good radio and electrical dealers, ironmongers, etc.

MULTICORE SOLDERS LTD.

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T... REGent 1411 (P.B.X. 4 Lines).

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High grade reduction drives have been in short supply. We can now offer famous Burndept slow-motion dial, dual ratio, panel mounting instrument type, calibrated degrees, 3½in. overall diameter **12/6**

Four-Gang Condensers

Ceramic insulation, 300 m.mfd. per section, capacity increases anti-clockwise **17/6**

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Specialised radio components are now becoming easier in supply. New designs keep EDDYSTONE the pre-eminent name in Short-wave technique.

Flexible Driving Shaft

Type S530. Frequentite insulation, drives through 90 deg. Length adjustable between 4¾in. and 6in. **5/-**

H.F. Chokes

Type 1010.	The best S.W. choke, 5/180 metres	**2/-**
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Type S481. New and compact design, size 1½in. × ½in. × 1¼in. high. 1.5 to 4 m.mfd., Frequentite insulation, silver plated brass. 2,000 v. R.M.S. max. .. **3/6**

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Type 916.	Beehive type stand-off ..	**1/3**
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Type 1018.	Cone type lead through..	**1/3**

Temporary leaflet showing other available EDDYSTONE components 2½d. post free.

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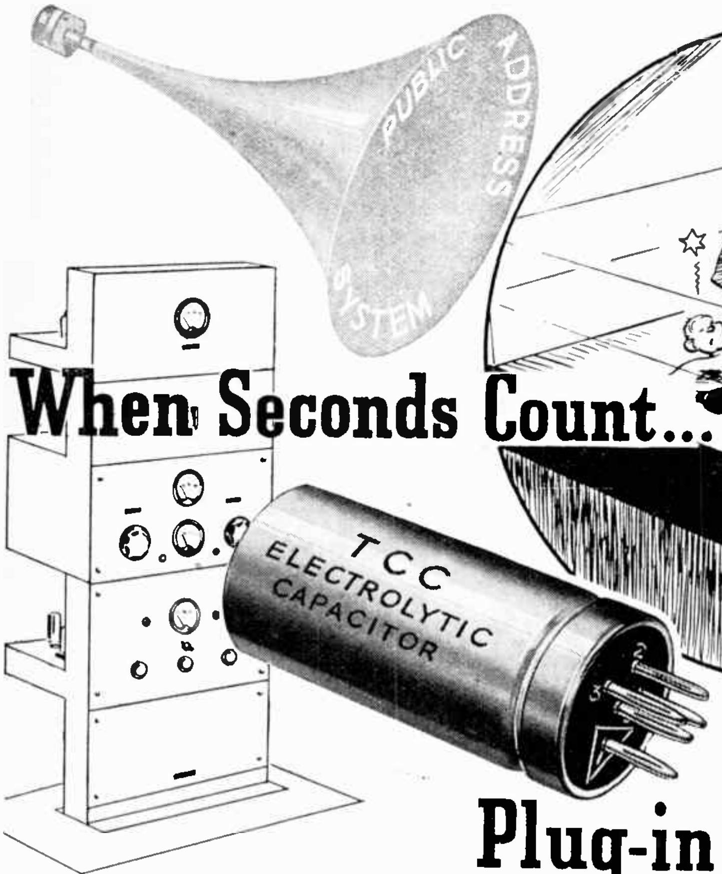
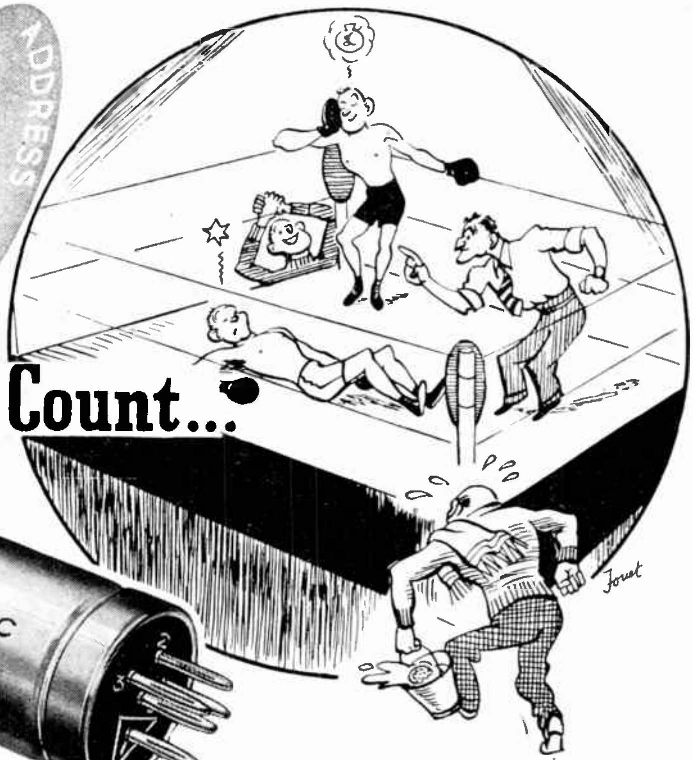
We are available 9 a.m. till 6 p.m. for OFFICIAL business, but please note our revised SHOP HOURS—9 a.m. to 5 p.m. weekdays. (Saturdays 9 a.m. to 1 p.m.)

World Radio History

When Seconds Count...





Plug-in Electrolytics

RANGE

Capacity MFDS.	Peak Working Volts
SINGLE	**SECTIONS**
16	500 (600v. Surge)
32	450 (550v. Surge)
100	250
250	100
500	50
1000	25
2000	12
DUAL	**SECTIONS**
8-8	500 (600v. Surge)
16-16	450 (550v. Surge)
32-24	350v.
TRIPLE	**SECTIONS**
8-8-4	500 (600v. Surge)
16-16-8	450 (500v. Surge)
20-20-20	350v.

We show above the range at present standardised in an aluminium can measuring 3½" × 1⅜", fitted with 5-pin valve base. This list will be added to from time to time, according to demand.

From being the wayward child, the Electrolytic Capacitor, as a result of continuous research and the rigours of hard usage under years of active service conditions, has become the model offspring in the matter of reliability and efficiency.

Even so, accidents must and will happen, and particularly at public meetings and functions it is vital to be able to locate and correct a cause of breakdown instantly . . . or even before it happens.

It can be more than a mere inconvenience to have to locate by test a defaulting capacitor, disconnect from the wiring and replace with a new one. The advent of the T.C.C. Plug-in Electrolytic reduces such anxieties to almost nil and the replacement time to a matter of seconds. It now takes no longer to replace than a valve.

Although the present-day dependability of T.C.C. productions is such that you may never have to do this, you should be prepared for the time. . . .

WHEN SECONDS COUNT.

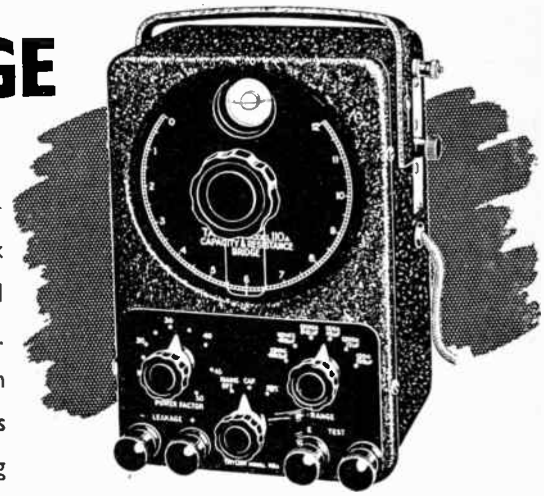
TCC CAPACITORS

THE TELEGRAPH CONDENSER CO., LTD.
RADIO DIVISION
NORTH ACTON · LONDON · W·3 Telephone. ACORN 0061

The

TAYLOR A·C· BRIDGE

MODEL 110A



These instruments give quick and accurate measurements of Capacity and Resistance. There are six Capacity ranges covering from .00001 to 120 mfd. and the Power factor can also be measured on each range. Six Resistance ranges are available measuring from 1 ohm to 12 megohms. This bridge is A.C. mains operated and a leakage test is also available for detecting leaky paper or mica condensers. **Price £14 14s. 0d.**

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6 RANGES OF CAPACITY
RANGES OF RESISTANCE

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Tel: Slough 21381 (4 lines) 'Grams: "Taylins", Slough.

3½" unit 9,000 lines.

Wharfedale

LOUD SPEAKERS

25/-

These two units, although so different in size, have much in common. Both are fitted with new high-efficiency Magnets, and die-cast, rustless, non-resonant chassis with accurate rear-suspension and both . . . . are Wharfedale products.

W.12 13,000 LINES **130/-**

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CAMBRIDGE ARTERIAL ROAD, ENFIELD, MIDDX

World Radio History

RULE OF THUMB...

In communications, wherever measurement for testing purposes is involved, empiricism can be ruled out. Of no avail without scientific instruments is anything the eye can see, the hand feel or the most observant remember. The radio engineer, therefore, must have test gear on which he can rely and, thanks to the foresight of Marconi Instruments Ltd., has a wide selection from which to choose. And he finds exemplified in these Marconi products the qualities so characteristic of British engineering craftsmanship—rational design, precise workmanship and technical efficiency.

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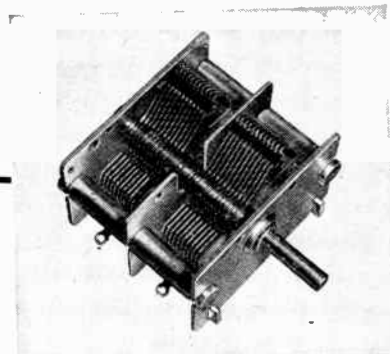

M.G. 1, 2 or 3 GANG CONDENSER

This small size condenser is of rigid construction, and is made in various capacities up to 540mmf. with tropical finish. It can be supplied with trimmers built in if required. The 2 Gang Frame is $2\frac{3}{4}$"x$1\frac{33}{32}$"x$2\frac{9}{16}$" over all.

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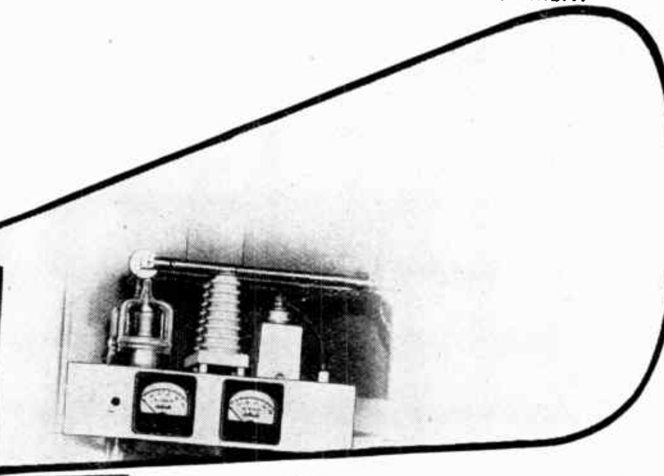
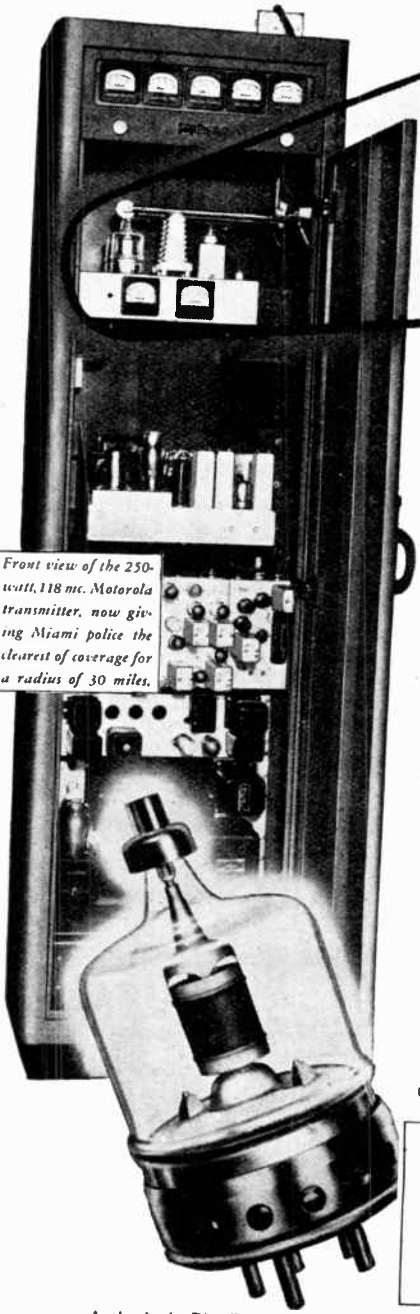
Eimac VALVES THE COUNTERSIGN OF DEPENDABILITY IN ANY ELECTRONIC EQUIPMENT





Front view of the 250-watt, 118 mc. Motorola transmitter, now giving Miami police the clearest of coverage for a radius of 30 miles.

Top Spot

IN FM POLICE SYSTEMS

EIMAC TETRODE 4-125A

Top honors to Galvin Manufacturing Corporation for building it, and a salute to the police and fire departments of Miami, Florida, for putting it to work in spite of the skeptics! It's the first two-way police radiotelephone system in the United States on frequencies *above 100 mc.* Twenty-four hours a day, 12 patrol cars in Miami's busy area tune in on signals as solid as a dinner table conversation from this Motorola 250 watt, 118 mc. FM transmitter.

From the earliest experimental stages of FM broadcasting, Eimac valves have been lending a hand. Naturally, there are Eimac 4-125A tetrodes (pictured above) in the vital power output stage of Galvin's new Motorola success. Eimac 4-125A's were a logical choice for this transmitter because of their superlative high frequency performance capabilities and their low driving power requirements.

FOLLOW THE LEADERS TO

Eimac VALVES

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Plants located at: San Bruno, California and Salt Lake City, Utah
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ELECTRICAL CHARACTERISTICS—4-125A TETRODE

Filament: Thoriated Tungsten		Direct Interelectrode Capacitances (Average)	
Voltage	5.0 volts	Grid Plate (Without shielding, base grounded)	0.03 uufd.
Current	6.2 amperes	Input	10.3 uufd.
Plate Dissipation (Maximum)	125 watts	Output	3.0 uufd.

Transconductance (i_b = 50 ma., E_b = 2500 v., E_{c2} = 400 v.) . 2450 umhos

Authorised Distributors: BERRY'S (SHORT-WAVE) LTD., 25 HIGH HOLBORN, LONDON, W.C.1.

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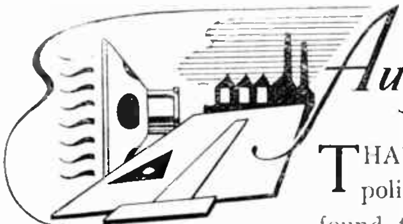

Augury for TOMORROW....

THAT tomorrow must be taken care of today has always been Goodmans policy. Constantly thinking and planning ahead Goodmans inevitably found themselves leaders in the field of Sound Reproduction. As a result, during the past critical years Goodmans have been entrusted with many onerous tasks in the designing and production of Loudspeakers, Microphones, and Earphones. True to their policy Goodmans tested and sifted to build data which might serve in the days to come. Now Goodmans stand ready to give of their greatly enhanced knowledge to the no less onerous tasks of Peace.

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GOODMANS *Loudspeakers*

GOODMANS INDUSTRIES LTD · LANCELOT RD · WEMBLEY : MIDDX

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EX STOCK (subject to being unsold on receipt of order).

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METAL RECTIFIERS

TYPES LT.41, LT.42, HT.41 & HT.42

TYPE	OUTPUT		PRICE *
	VOLTS	AMPS	
LT.41	12	1	27/-
LT.42	6	1	21/-
HT.41	200	0.1	25/-
HT.42	450	0.1	38/6

* *Subject to alteration without notice.*

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ROTHERMEL-BRUSH PIEZO-CRYSTAL MICROPHONES. Resumption of our former popular offer of D.104, specially housed with knuckle-joint mount (for angle adjustment) and with 6ft. screened lead. To-day's greatest value in "quality" microphones, **78/6.** STANDS to suit, Table model, all chromium, extending, **29/6.** Collapsible Floor model, ext. to 5ft. 6in. and folding to 2ft. all chrom., **47/6.**

P.A. PROJECTOR SPEAKERS (we are large stockists of this equipment). Latest Vitavox 10-watt P.M. Unit (15 ohms) with 30-inch all-metal square projection Horn, spec. offer, **£9 10s.** (desp. 7/6). Or with 42-inch all-metal round projection Horn, **£10 10s.** (desp. 7/6). Also new G.E.C. type "A" Unit (10 watt, 15 ohms) with line transformer incorporated, on 30-inch Horn (as above), **£11** (desp. 7/6). On 42-inch Horn (as above), **£12** (desp. 7/6). Immediate despatch.

HIGH-FIDELITY M/COIL SPEAKERS. The celebrated Vitavox K12/10 (10 watts, 15 ohms coil) fitted high-efficiency Ticonal Magnet, 12-inch dia., **£7.** Also the K12/20 (same spec. handling 20 watts), **£11** (desp. either 5/-). We also supply from stock the amazing new Vitavox "Bitone" Speaker comprising 12-inch hi-fi P.M. Unit and special "Tweeter" P.M. Unit with 6-cell horn and filter, all in massive grey-enamelled cabinet 32 by 17 by 15 inches, **£31 10s.** (ex this address, or we can quote for despatch).

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SLIDING RESISTANCES, all fully enclosed and constantly rated. 100-watt range: 4 ohms 5 amps, 10 ohms 3 amps, 50 ohms 1.4 amp, 100 ohms 1 amp, 200 ohms 0.7 amp and 400 ohms 0.5 amp, any one **25/-.** Also 150 watts, 1100 ohms 0.375 amp, **29/6.** **DIMMERS** for Stage Lighting, controlling stated load from full-bright to blackout (220/240 v.) with slow motion drive and handwheel, 1000 watts, **£6 17s. 6d.**; 1500 watts, **£8 8s.**; 2500 watts, **£9 17s. 6d.** (desp. either 7/6 plus 20/- for returnable case).

L.F. CHOKES, 10 henry 150 m.a. (150 ohms), **18/6**; 15 henry 100 m.a. (320 ohms), **12/6.**

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(Guaranteed products of British Physical Laboratories.)
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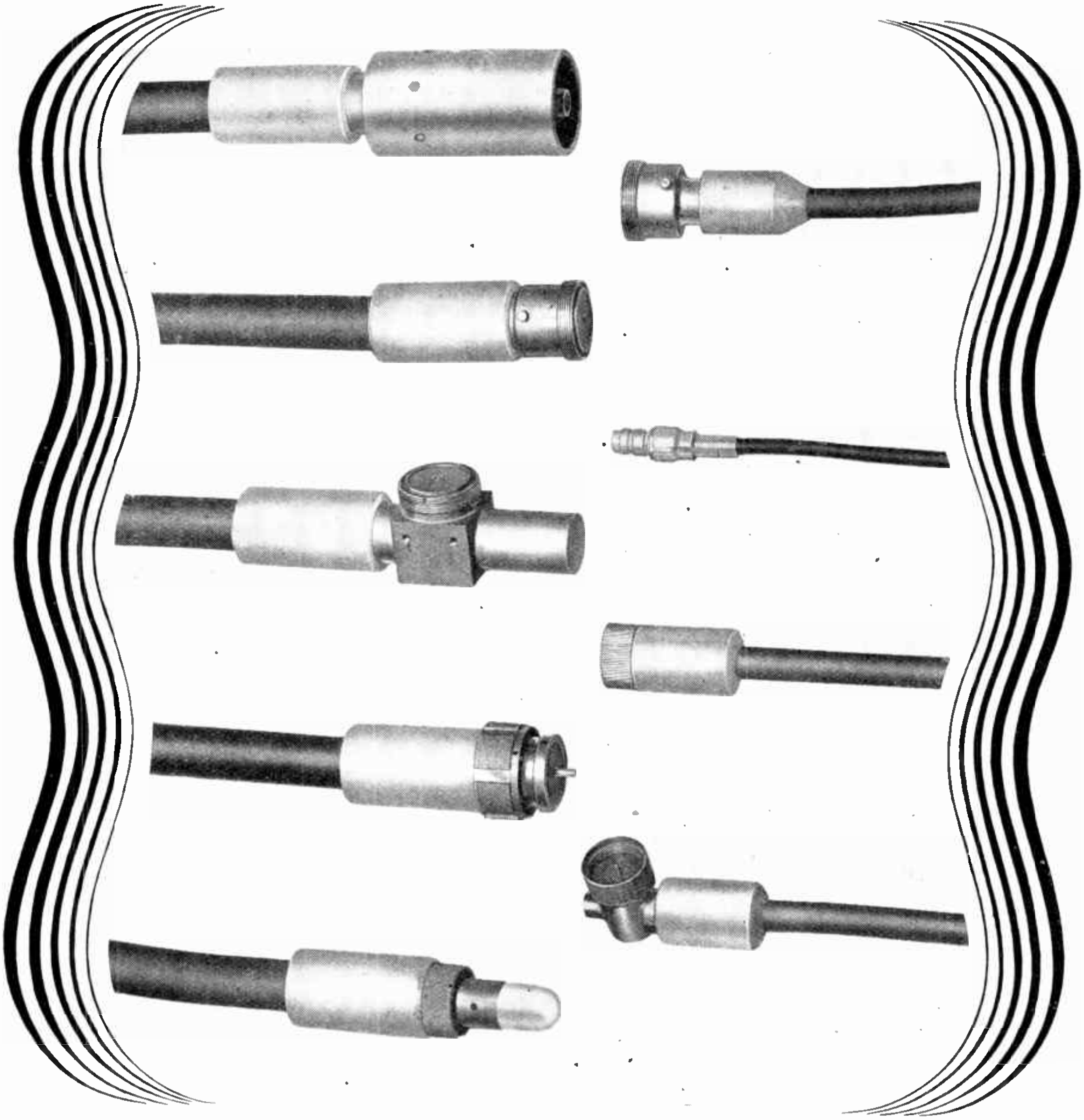

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POLYETHYLENE MOULDED CONNECTORS

Pressure moulded by a new process that cannot yet be described in detail, these fittings are terminations and connections used in electronic circuits. The production of these polyethylene mouldings in quantity is the result of a new manufacturing technique successfully evolved by this company.

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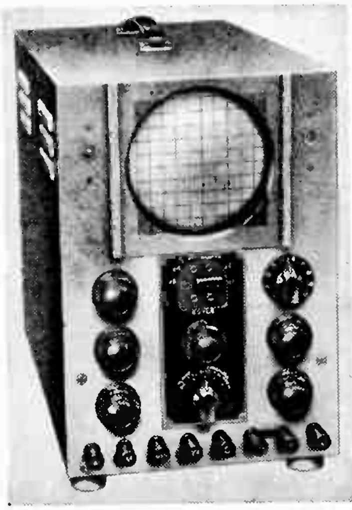

STATIC TWO-DIMENSIONAL visual delineation of any recurrent law.

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RELATIVE TIMING OF EVENTS and other comparative measurements with extreme accuracy.

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The **Model 339 Cossor Oscillograph** thus equipped is invaluable on all problems of research, production or operational testing, when the effect examined is applied as a voltage. When recurrent the traces are studied visually and when transient are recorded photographically, using Model 427 camera.

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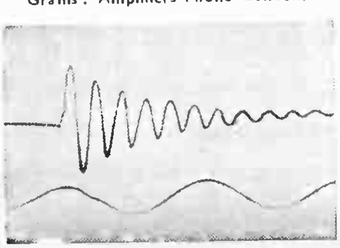

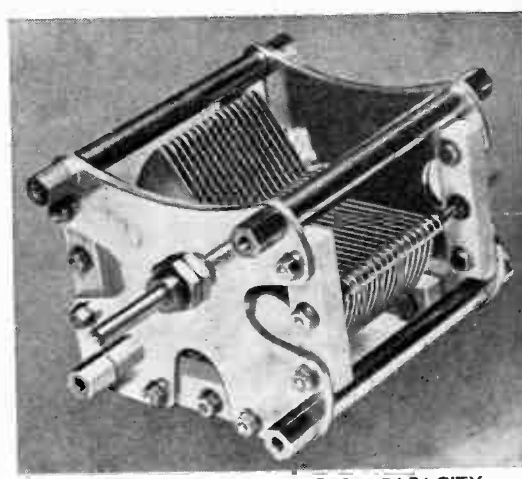

TYPE S.L.C. LINEAR CAPACITY

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Variable Capacitors

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World Radio History

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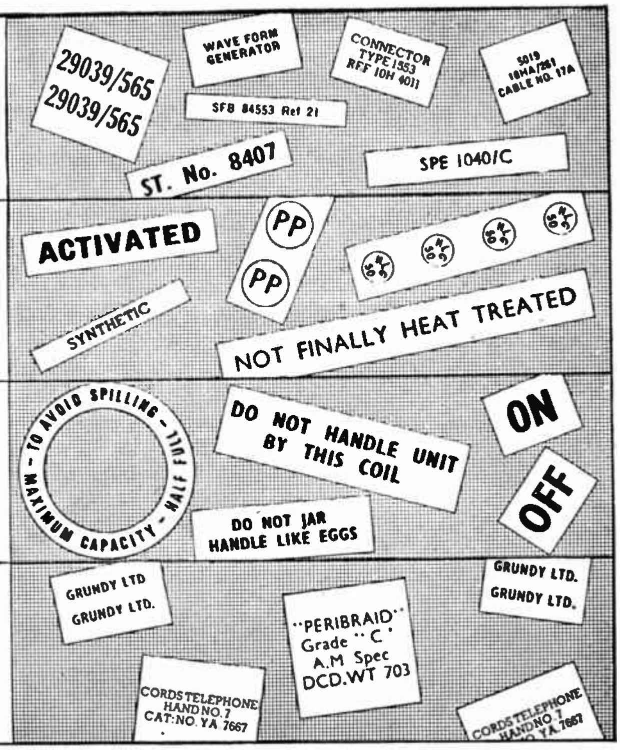

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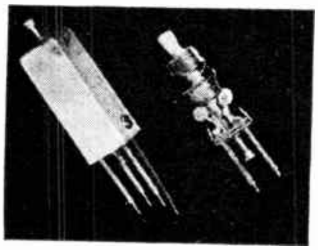

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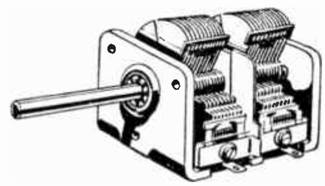

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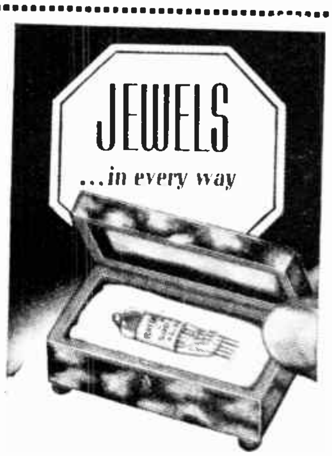

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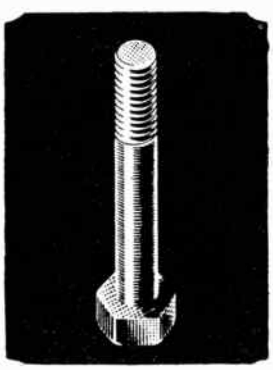

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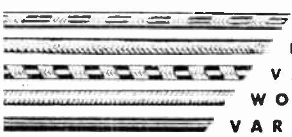

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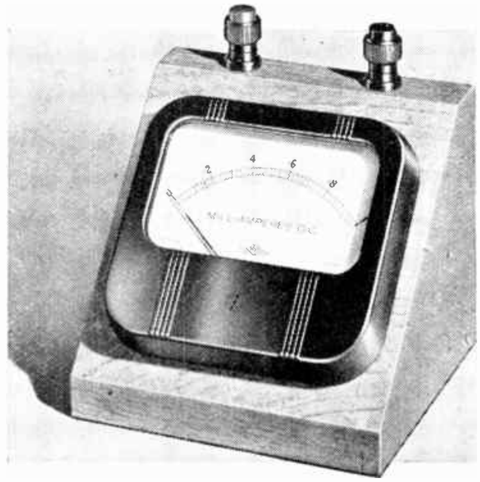

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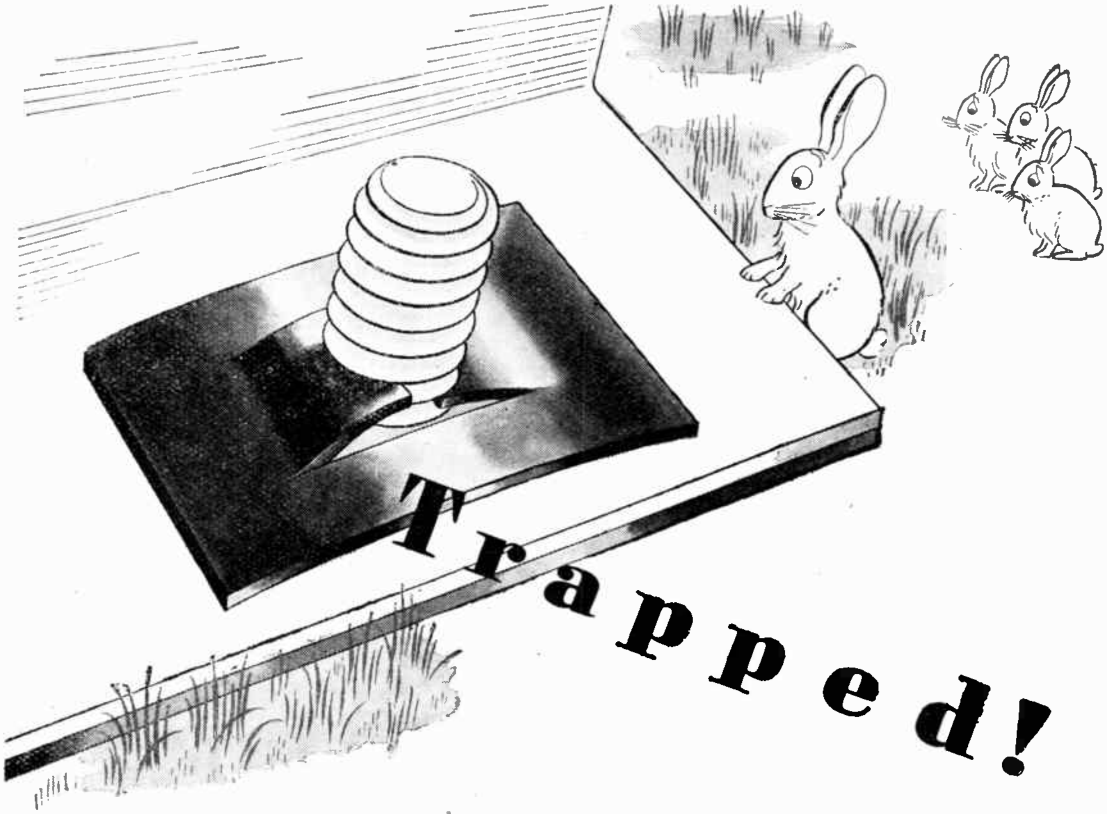

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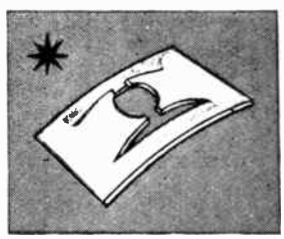

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Radio and Electronics

35th YEAR OF PUBLICATION

DECEMBER 1945

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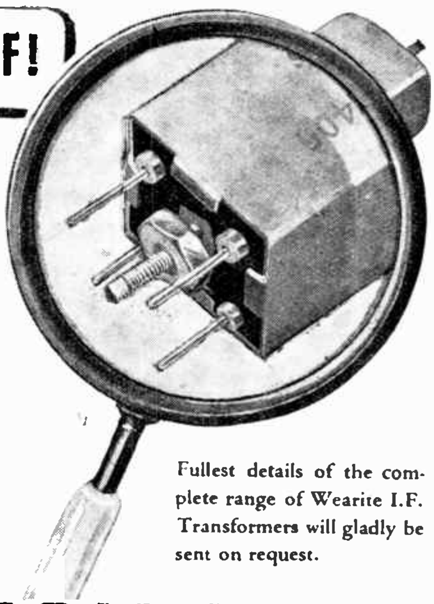

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Wireless World

Radio and Electronics

Vol. LI. No. 12 DECEMBER 1945 Price 1s. 6d.

Monthly Commentary

Invitation to the Industry

SPEAKING to a conference of research associations early this month, Mr. Herbert Morrison, Lord President of the Council, said that the present Government would do everything possible to encourage British industry to use scientific research. He hoped that large firms would establish or extend research departments of their own, and went on to stress the advantages of co-operative organisations to the smaller concerns, which cannot be expected to have adequate departments of their own. Most of Mr. Morrison's speech was on this subject of co-operative research, to which he gave not only general assurances of Government support, but also concrete promises of financial help. Grants will be made indefinitely to a research organisation so long as the Department of Scientific and Industrial Research is satisfied with its work. In addition, extra grants may be made "to finance capital expenditure for such special purposes as buildings and re-equipment, the purchase of particularly expensive apparatus or the provision of semi-scale plant."

In radio we have all seen during the past few years the blessings of research, which has yielded radar as a kind of unexpected bonus. To many members of the industry the Government gesture, though made to no one in particular, will seem almost like an unspoken invitation to those concerned to form a co-operative Radio Research Association. Should such an invitation be accepted?

We imagine that few of the smaller manufacturing firms would welcome a state of affairs where their factories would become mere assembly lines, turning out products developed and designed by a central organisation. But that is not the idea; so much was made quite clear by Sir Edward Appleton, secretary of the Department of Scientific and Industrial Research, the body which has the task of implementing Government policy in this matter. Sir Edward's speech, which followed that of Mr. Morrison at the conference, touched as many points of real interest to the wireless industry. He supported the idea that even the smaller firms should employ some scientific staff, even though they could not afford research organisations of their own. He also stressed the need for workers in research associations to retain their originality and freshness by frequent contacts with other organisations and expressed the opinion that one of the results of the war would be that many first-rate recruits for such associations would come forward.

The question of whether or not we need a Radio Research Association is arguable, but it is a question that should at least be argued—very fully and dispassionately. The first point to be settled is whether there are in fact suitable lines of research that could usefully be investigated by such an organisation for the benefit of a reasonably large proportion of its potential member firms. As Sir Edward Appleton shrewdly pointed out, a successful organisation is not brought into being by thinking of a sum of money, doubling it, and then trying to devise ways of spending it.

★ ★ ★

Wartime Hangovers

IS it inevitable that the broadcast listener should continue to endure a hangover from the wartime system of distribution? Now, nearly eight months after the end of the European war, complaints as to the poor quality of B.B.C. transmissions are coming in thick and fast from many parts of the country. Those whose great interest used to lie in high-quality musical reproduction have cheerfully tolerated six years of wartime conditions, but are now out of patience with a system that sometimes fails even to afford intelligible speech. We all know something of post-war difficulties, but at the least a frank and detailed statement from the B.B.C. is overdue.

Another wartime hangover is the excessive use of recordings. The greatest asset of broadcasting is its power of presenting living actualities, and failure to exploit this power is a psychological error of the first magnitude.

World Radio History

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AC/DC QUALITY AMPLIFIER

Two-watt Output : Negative Feedback

IN AC/DC equipment there is virtually no alternative to the pentode output valve because of the limited HT voltage available. A pentode has a higher power efficiency than a triode, and it requires less grid bias. As bias is invariably obtained from the HT supply it robs the anode voltage, and when the HT voltage is fixed a valve needing a high value of bias must be operated at a lower anode voltage than one needing but little bias. This again results in a higher output from a pentode than from a triode.

These two factors make the pentode much more suitable than the triode for the output stage of AC/DC apparatus. But a pentode has certain drawbacks. Its anode AC resistance is very high, with the result that amplitude distortion is very likely to occur in the output transformer. The load circuit exercises very little straightening effect on the dynamic characteristics of the valve, and because of this, amplitude distortion in the valve itself is likely to be higher than with a triode.

Fortunately the same remedy cures both these faults. Negative feedback can give the amplifier a low output resistance, which eases transformer design, and it linearises the valve characteristic. From the point of view of quality the pentode with negative feedback can equal the triode, but its improved power efficiency is retained.

What is lost in using negative feedback is the high sensitivity of the pentode. The ability to obtain a large power output for a small signal input is sacrificed to obtain quality, and on both sensitivity and quality triode-type performance is obtained.

If the pentode with feedback gives results which are so close to those of a triode, it may be asked why one should contemplate its use, for the triode is not only a simpler valve, but its circuit is simpler and demands fewer components. In the case of AC equipment in which the use of a mains transformer permits any desired HT voltage to be obtained easily, the choice between the two alternatives is often a difficult one.

If there is nothing to choose between the two on the grounds of quality and sensitivity, the selection must be made on the basis of their relative simplicity, reliability and cost. The pentode amplifier is slightly the more complicated and needs rather more components, but its higher power efficiency demands a smaller power supply.

There are two cases where the preference nearly always lies with pentodes. The first is in AC/DC equipment because of the limited HT voltage. The second is in AC apparatus of large output—say, over 15 watts—because the higher power efficiency cheapens the HT supply unit.

In AC equipment with outputs below 15 watts, there is often very little to choose between the two methods, and the greater simplicity of the triode is often the deciding factor in its favour.

Output Transformer

The AC/DC method of operation is particularly convenient when an undistorted output of less than about 2 watts will suffice, for this can be obtained with an HT current within the limitations of a single rectifier valve. If larger outputs are needed the HT current is heavier and the voltage lost in the smoothing equipment is greater; also more than a single rectifier valve will often be needed. The AC/DC system then soon becomes uneconomic.

Even when the output is 2 watts only, transformer distortion can be serious unless negative feedback is used. It is convenient to assess the distortion reduction of feedback in terms of the reduction of the effective output resistance of the amplifier, since this enables a direct comparison with a triode to be made. In general, sufficient feedback to bring the output resistance to about the same figure as with a triode should be applied. This entails sufficient feedback to reduce a valve resistance of some 35,000 ohms to about 1,000 ohms.

The low-frequency response of the output stage and transformer is then governed by the reactance of the transformer primary in relation to the parallel values of the output resistance and the load resistance. If these are 1,000 ohms and 4,500 ohms, respectively, their combined value is 820 ohms. At 100 c/s, a primary inductance of 6H causes a drop in response of only 2 db. A considerably greater drop than this is usually permissible from the point of view of quality, and it would seem that a lower primary inductance could be used.

It is, however, necessary to consider the effect of the inductance on the load of the valve. At low frequencies the total load is the load resistance in shunt with the reactance of the primary of the transformer. With the above values, it becomes 2,850 ohms only.

With a pentode without negative feedback, the reduction of the load does not affect valve distortion to any appreciable extent. The alternating current is substantially independent of the load, and the voltage falls off as the load falls.

With a triode, however, there is an increase of distortion because with the low resistance of the valve the current increases and, with its optimum load, the valve is already giving its maximum undistorted current output. The effect with a

World Radio History

pentode and negative feedback is similar although the mechanism is different. The fall in output voltage with a drop in the load results in a smaller feedback voltage and hence in an increased input voltage to the output valve. This in turn increases the output current and the valve cannot give a bigger current without distortion. Matters are made still worse by the fact that the load has a reactive element and there is a phase angle between current and voltage.

For this effect to be negligible the transformer primary reactance should be some four times the load resistance, or about 18,000 ohms in this case. At 100 c/s, this calls for an inductance of 29 H and at 50 c/s, some 58 H. A single output valve means that the anode current, which is rarely less than 40 mA, flows through the primary, and it is not practicable to employ such large inductances with such values of direct current. They could be obtained, of course, but it would almost certainly be cheaper to adopt a push-pull output stage.

As amplitude distortion is much worse than frequency distortion, the most practical course is to convert the amplitude distortion to frequency distortion. If the lower frequencies are attenuated somewhat at the input to the amplifier, then the conditions as regards amplitude distortion become very much as though the transformer had a large primary inductance.

If the input is constant at all frequencies, then the output current tends to constancy, but the output power falls off at low frequencies. Without the pre-attenuation, the output current would increase and become distorted at low frequencies, but the output power would not fall off as much.

This procedure is a very satisfactory one to adopt in apparatus of limited output, where it is impracticable to employ a transformer inductance as high as theory would indicate to be necessary. With careful design, the loss of bass is small and it becomes possible to employ a 6-H primary with a pre-attenuation of only 4 db. at 100 c/s. In general, however, it is not necessary to go as far as this and a loss of some 2 db. only at this frequency is a reasonable compromise.

Fig. 1 shows the circuit of a two-stage amplifier built on these lines. The pre-attenuation circuit is C1R2; R2 is made as high as possible—some 2 MΩ—and C1 is made only 0.001 μF.

In order to obtain adequate amplification with negative feedback, a high gain is needed in the input stage. An RF pentode is used and without any feedback its voltage amplification is about 100 times. Internal feedback from its cathode resistor reduces this to about 26 times.

The output valve is a high-slope pentode and the main feedback is taken from the output transformer secondary through R4 to the cathode of V1. The bias resistance of V1 consists of R3 and R4 in parallel, some 2,300 ohms. The amount of feedback depends on the transformer ratio and on the values of R3 and R4, while the transformer ratio depends on the speech-coil impedance of the loud speaker.

CIRCUIT VALUES

R1 = Volume control with tapered element and value to suit input circuit (0.25 MΩ is a good average value).
R2 = 2.2 MΩ, 1/10 watt, 20 per cent.
R3, R4 } See Table I, 1/10 watt.
R5 = 100,000 Ω, ¼ watt, 20 per cent.
R6 = 22,000 Ω, 20 per cent.
R7 = 330,000 Ω, 1/10 watt, 20 per cent.
R8 = 470,000 Ω, 1/10 watt, 20 per cent.
R9 = 680 Ω, ¼ watt, 20 per cent.
R10 = 220 Ω, ½ watt, 20 per cent.
R11 = 47 Ω, ¼ watt, 20 per cent.
R12 See Table II.
C1 = 0.001 μF 200 volts working.
C2 = 0.2 μF, C3 = 2 μF, C4 = 0.01 μF } 350 volts working.
C5 = 25 μF 12 volts working.
C6 = C7 = C8 = 8 μF 350 volts working.
C9 = 0.001 μF 250 volts AC working.
V1 = EF6 or EF36.
V2 = Pen 36c or CL33.
V3 = UR1C.
Ch1 = Ch2 = 10–20 H, 250 Ω DC resistance, 60 mA.
F1 = F2 = Fuse, 0.3 A.
T1 = Output transformer. See Table I for ratio, also text.

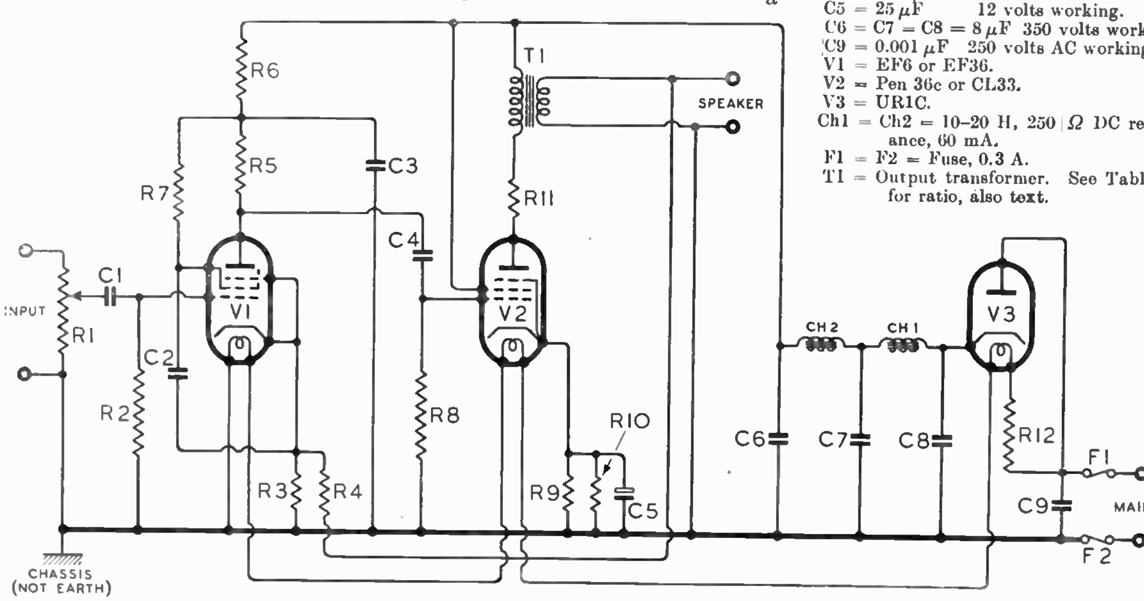


Fig. 1. The circuit diagram of the amplifier. The values of the feedback components R3 and R4 depend on the ratio of the output transformer T1.

AC/DC Quality Amplifier—

Table I gives the correct transformer ratios for a number of different speech-coil impedances and also the theoretical values for R3 and R4. The nearest "Preferred Values" are also given for a 5 per cent. tolerance. Such a tolerance is very desirable and puts a 10 per cent. tolerance on the amount of feedback. Resistors of this tolerance are likely to be hard to obtain at present, but the desirability of using them does not entail the necessity for buying them, merely for checking the ones used. Thus, for a 12,000-ohm resistor, the value can be 11,400—12,600 Ω. One may well find a 20 per cent. tolerance resistor of 10,000 Ω rating which is suitable, since a high limit resistor would be 12,000 ohms.

TABLE I

Speech Coil Impedance Ω	Transformer Ratio	Ideal Values (Ω)		5 per cent. Preferred Values (Ω)	
		R3	R4	R3	R4
2.5	39.5	3,100	9,300	3,000	9,100
4	30.8	2,850	12,500	2,700	12,000
7.5	22.6	2,640	18,000	2,700	18,000
10	19.6	2,600	21,400	2,700	22,000
15	15.9	2,550	26,500	2,700	27,000

Two resistors R9, R10 are shown for the cathode bias of V2, simply because the required value 167 ohms, is not a standard one. It can be obtained, however, by two standard values in parallel.

Values of components are listed under the heading "Circuit Values," together with their minimum ratings. There is, of course, no objection to using capacitors of higher voltage or resistors of higher power ratings. The value of R12 depends on the mains voltage and this will be found in Table II.

It will be noted that two smoothing chokes are used. This is unusual in AC/DC apparatus, but is necessary to keep the hum level inaudible without using very large capacitance values. The smoothing capacitors C6, C7 and C8 need be no more than 8μF apiece. They can be paper-dielectric types or electrolytic. If only one choke were used, it would not only have to be of considerably higher inductance than these, but the capacitors would have to be at least 16μF and possibly 32μF. Such a large capacitance for the reservoir capacitor greatly increases the peak current in V3 and so reduces its life.

TABLE II

Mains Voltage	R12	
	Ω	Watts
200	600	24
210	650	26
220	700	28
230	750	30
240	800	32
250	850	34

There are three things in the circuit which run very hot—the rectifier, the output valve and R12. It is important, therefore, to give these parts ample ventilation and to keep all capacitors well away from them.

The grid of V1 is a danger point for hum. The grid lead must be kept very short, and it is a good plan to mount C1 and R2 on a small paxolin panel combined with the grid clip and so carried by the top cap of V1. The leads can then easily be kept down to less than one-half inch. Even so, it may be necessary to fit a metal shield over the top of the valve and these components, the shield being joined to the chassis.

If used on radio, the volume control R1, can be the diode load resistance and a value of 0.25 MΩ is normally suitable. For gramophone work, the value of R1 depends on the pick-up; 0.25 MΩ is a good average value, but for a piezo-electric type some 2 MΩ is generally better.

It must not be forgotten that the chassis is live to the mains and it must, therefore, be protected against accidental contact. Do not forget to make sure that the grub screw of the volume control knob is deeply sunk and then covered with wax so that accidental contact is impossible. These are but elementary precautions with AC/DC equipment.

Some little difficulty arises in the pick-up connections from the safety point of view. A screened lead is necessary to avoid hum and the screening must be joined to chassis, not a local earth, if it is to be fully effective. It is, therefore, live to the mains. The screened lead itself must consequently be insulated, and there are in existence screened cables having external insulation, so that this point is satisfactorily covered.

The real difficulty is with a metal frame pick-up. It is definitely unsafe to connect the frame to the chassis, which is the right thing from the point of view of minimising hum. Some experiment may be needed to find the best solution, but in general, the pick-up frame should be earthed and connected to chassis through a capacitor. This capacitor should be rated for 250 volts AC working and be as small as possible; 0.001 μF is ideal, but hum considerations may demand a larger value.

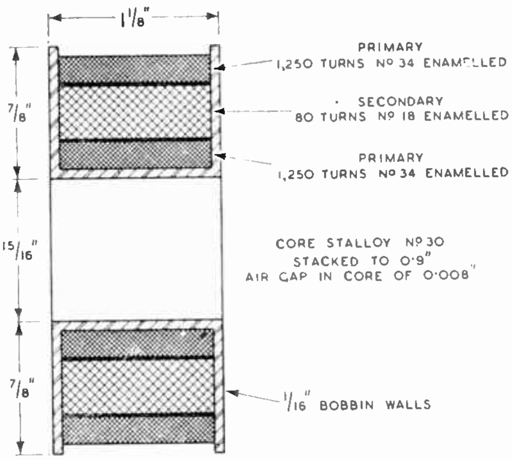


Fig. 2. This cross-section through a transformer bobbin shows typical windings for an output transformer. The secondary turns and wire gauge will vary with the ratio required.

The output obtainable is some 2 watts for a total distortion of rather less than 2 per cent. each of second and third harmonic. The input needed is 0.6 volt RMS.

Some details of a suitable output transformer are given in Fig. 2.

World Radio History

The primary consists of two sections wound in the same direction each of 1,250 turns of No. 34 enamelled wire. The outside of the inner section is connected to the inside of the outer. The secondary turns are 80 for a 4-Ω speech coil and No. 18 enamelled wire is suitable. They should be wound in the same direction. The connections for negative feedback will then be right if the insides of the primary and secondary are joined respectively to positive HT and chassis.

For other speech-coil impedances the number of secondary turns is found by dividing 2,500 by the turns ratio required. The wire gauge must, of course, be appropriately altered. Insulation between the sections is obtained by winding two layers of Empire tape between them.

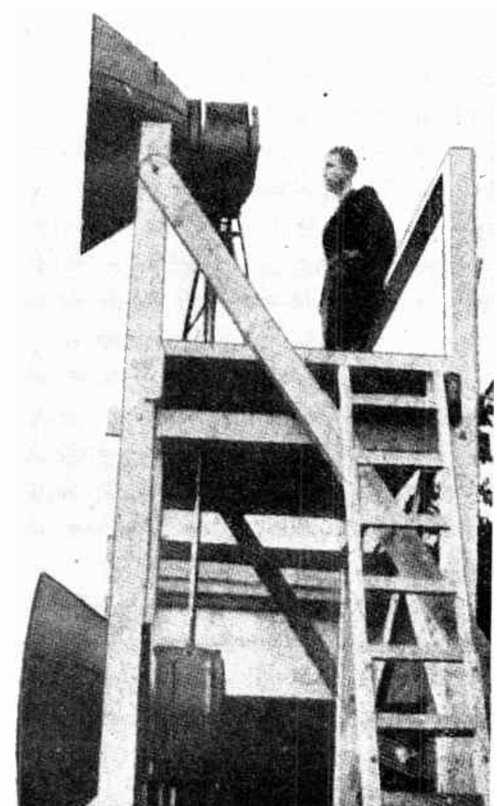
RADAR PRE-HISTORY

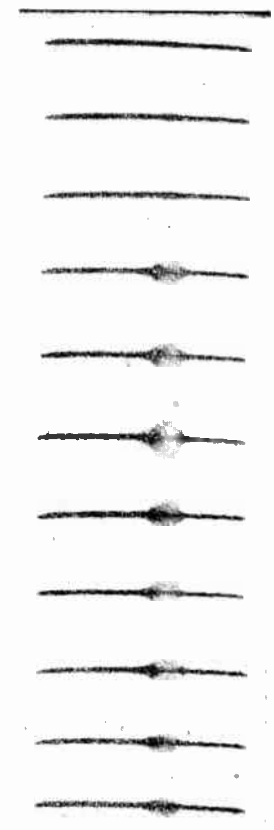
RF Scanning : French "Obstacle Detectors"

As *Wireless World* readers know, radar did not emerge fully fledged from nothingness during the war; its technique has been built up stage-by-stage from the contributions of many workers, and its history goes back for quite a respectable number of years. The main steps in the direct line of development have already been described in our pages, but as time goes on many other early uses of the radio echo principle will doubtless come to light.

British Patent No. 292,185, applied for by John Logie Baird as long ago as 1926, describes an arrangement that bears on the face of it a surprising resemblance to H2S, one of the most refined and highly developed applications of modern radar. Baird pointed out that wireless waves can be reflected and refracted like visible light waves, and contemplated "a method of viewing an object consisting in projecting upon it electromagnetic waves of short wavelength." Reflections from the object were passed through a scanning device to a receiver. The output of this receiver was to be used for modulating a source of visible light. A spot of light projected from this source would traverse a screen "in synchronism with the exploration of the object." The most obvious difference between Baird's scheme of 1926 and the present-day H2S is that scanning was done on the receiver side, and not by exploring the object with the transmitter beam.

French technicians were early in the radar field, and it would seem that the first "commercial" application of the principle was in the "obstacle detector" installed aboard the *Normandie* in 1935. In a general review of French technical progress, including that made under great difficulties during the German occupation, P. Brenot, of the Société Française Radioélectrique, gives some interesting sidelights on early radar work. In this review, published in *L'Onde Electrique* for September, 1945, there is a short description of an experimental "obstacle location" station installed in 1936 by SFR at the entrance to the port of Havre. The apparatus worked on decimetre waves.





From "L'Onde Electrique"

The Sainte Adresse (Havre) experimental obstacle detector. The two parabolic reflectors explored a large sector. The surprisingly modern-looking "display" is also shown. The series of traces indicate echoes from a tug; they grow in amplitude up to the time that the tug cuts the axis of the projector, which was fixed for this test. The trace length represents a total distance of 10km; the measured distance of the tug is here about 4km.

World Radio History

The SHORT-TIME-CONSTANT CIRCUIT

Graphical Illustration of the Fourier Principle

By M. G. SCROGGIE,
B.Sc., A.M.I.E.E.

LEAVING aside those who by some freak of nature are born mathematical, most students no doubt receive with a certain lack of conviction the teaching that *any* waveform which repeats during equal time periods can be regarded as being composed of sine waves of appropriate amplitude and phase and integral multiples of frequency. It is not so much that the instructor's word is doubted—after all, it is little use doubting it, for he can always reply with a heavy barrage of mathematical symbols—but that the student has difficulty in actually visualising how extreme shapes, such as narrow perfectly squared-off pulses, can be made up of easy flowing sine curves and nothing else. And even when this by no means obvious fact is apprehended there is still room for doubt concerning how far what may appear to be a mere theoretical concept is able to stand up to the sort of treatment to which fancy waveforms are subjected in actual circuits.

For example, when a square wave (Fig. 1*a*) is passed through a short-time-constant circuit (Fig. 1*b*) the result is a peaky wave (Fig. 1*c*). The usual explanation of this process says nothing about the sine waves of which (*a*) is alleged to be composed. If these sine waves are followed separately through (*b*), will the results add up to the same as (*c*)?

The most convincing answer is to try to see for oneself. Unfortunately, the process of plotting and adding up an infinite number of sine waves twice over (or even a selection of the most prominent of them) is unbearably tedious. So the atmosphere of suspicion hangs as thickly as ever around the doctrine of the late M. Fourier.

The war brought this matter well within the province of great numbers of students of the non-academic kind, and it will probably continue to be so in post-war radio technique. So the writer has plotted sufficient component sine waves to add up to a reasonably convincing square wave; has calculated what comes out of a typical Fig. 1*b* circuit when each of these sine waves is separately applied to it; and has plotted these output waves and added them up together, giving what he hopes is a reasonably convincing approximation to the result that would have been obtained by the more normal classroom treatment. All he asks from readers is either that they take his word that the differences between his results and perfect square and peaky waves are due solely to the limited number of component sine waves he had the patience to draw, or that they keep on drawing more of them until belief does set in.

To make sure of what it is with which this roundabout alternative method is being compared, here is a condensed version of the "normal classroom treatment." At time t_1 in the cycle of the perfect square wave, the Fig. 1*b* circuit instantaneously receives a certain positive voltage. It is impossible for a condenser to acquire a new voltage instantaneously through a resistance, as it needs time to charge; and therefore the whole of the applied voltage momentarily appears across R as shown in Fig. 1*c*, causing a current to start flowing through R into C, charging it in the well-known exponential manner.* The smaller R is, the greater the current; and the smaller C is, the quicker a given current will charge it; therefore if C × R is small the voltage across C will rise rapidly. Because the applied voltage is constant, that part of it which is across R will correspondingly die away, as shown by the exponential curve in Fig. 1*c* between t_1 and t_2. The circuit is described as having a short time constant; the time constant being the time necessary for the condenser to charge to 63 per cent. of the steady applied voltage. It is numerically equal to CR. At t_2 the process is repeated in the negative direction. And so on for successive waves.

Now for the synthetic method. The Fourier series for a square wave is a simple one; it consists of the fundamental and odd harmonics only, the amplitude of each harmonic being reduced in proportion to the number of the harmonic, and each is a sine wave starting off from scratch with no phase delay. It is, in fact, this simultaneous start of an infinite number of waves that adds up to

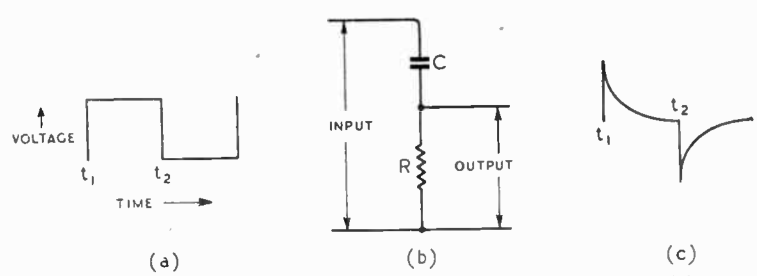


Fig. 1. When square waves, of which a sample is shown at (a), are applied to the input of a CR circuit (b) having a short time constant, the output is a peaked wave (c). This conclusion is arrived at via an unusual method in the following diagrams.

* I.e., one in which the rate of charge at any instant is proportional to the difference between the condenser voltage and the constant applied voltage, so that however rapidly it starts it dies away gradually.

World Radio History

form an infinitely steep wave front. Expressed mathematically, and assuming for simplicity that the peak amplitude of the fundamental is 1, the series is:

$$\sin \omega t + \frac{\sin 3\omega t}{3} + \frac{\sin 5\omega t}{5} + \frac{\sin 7\omega t}{7} + \frac{\sin 9\omega t}{9} + \ldots \text{ to } \infty$$

where ω is 2π times the frequency of the square wave and t is time. The amplitude of the 3rd harmonic is thus 1/3, that of the 5th harmonic 1/5, and so on. As tables of sines are in terms of angles, it is more convenient to express the series as $\sin\theta + \frac{\sin 3\theta}{3}$, etc., one whole cycle of the square wave, or fundamental, being divided into 360°. Fig. 2 shows the series plotted up to and including the 15th harmonic, for half a cycle. Adding up the ordinates at frequent intervals along the half-cycle gives the waveform drawn in heavy line. It is obvious from the way the harmonics come into phase again at the end of the half-cycle that if they were continued for the second half-cycle they would make the same pattern but inverted; and so the composite wave has been repeated upside down to complete the cycle. It will be seen to fit fairly closely around a square wave drawn, in heavy dotted line, with amplitude $\pi/4$ (about 0.8) times that of the fundamental sine wave. The frequency of the superimposed ripple is the same as that of the highest harmonic included. If more harmonics were used, the ripple would become higher in frequency and less in amplitude, until ultimately it would be indistinguishable from the square wave. Incidentally, the heavy line illustrates the amount of distortion that would be suffered by a perfect square wave passed through a system having a top cut-off just above 15 times the frequency of the square wave.

As each harmonic in the series is reduced in scale from the fundamental by the same factor in both horizontal and vertical dimensions, it has the same slope as the fundamental and the other harmonics at all corresponding parts of their cycles. The 1,000,001th harmonic starts off just as steeply as the fundamental, and as all start together the slope of the combined wave is infinitely great. It is only at half-cycle intervals that all harmonics come into phase and form the vertical parts of the square wave; everywhere else the increasing values of some harmonics are offset by decreasing values of the others, and the total remains constant to form the flats of the square wave.

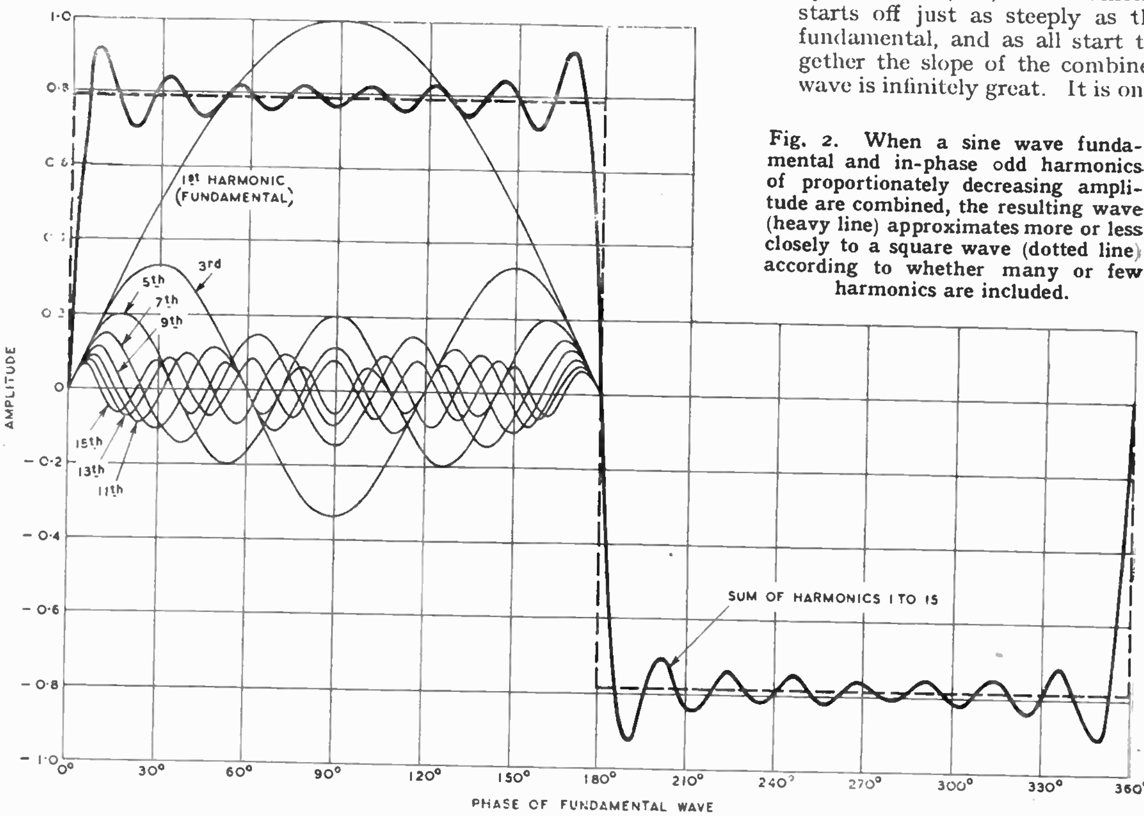


Fig. 2. When a sine wave fundamental and in-phase odd harmonics of proportionately decreasing amplitude are combined, the resulting wave (heavy line) approximates more or less closely to a square wave (dotted line) according to whether many or few harmonics are included.

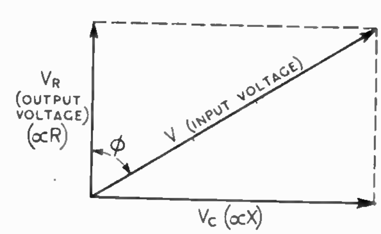


Fig. 3. Familiar graphical method of determining relative amplitudes of output and input sine waves.

Having pondered this sufficiently for the manufacture of sharp corners using only smooth curved ingredients to begin to look

World Radio History

Short-Time-Constant Circuit—

less like a conjuring trick, the reader should turn to consider the simple device through which it is proposed to pass the mixture—the short-time-constant circuit, Fig. 1*b*. Again there is absolutely no deception; only well-understood basic principles of simple sine-wave AC are to be used. There are a variety of methods of finding the amplitude and phase of the voltage at the output of such a circuit, relative to the input. In all of them it is necessary to know the ratio of the condenser's reactance, X, to the resistance, R; and this is derived from the time constant. For the sake of a nicely-proportioned diagram and simple numbers, the time constant has here been chosen to be equal to one-tenth of a full cycle of the fundamental. As the duration of a cycle is the reciprocal of the frequency, this relationship can be written as:

$$CR = 1/10f_1$$

where the suffix 1 indicates that f_1 is the frequency of the fundamental (and, later on, other suffixes will distinguish the harmonics concerned). The reactance, X_1, of a condenser at the fundamental frequency is:

$$X_1 = 1/2\pi f_1 C$$

which, from the foregoing

$$= 10R/2\pi = 1.6R$$

Similarly

$$X_3 = 1.6R/3,\ X_5 = 1.6R/5, \text{ and so on.}$$

A graphical method of deriving the output phase and amplitude for each harmonic is shown in Fig. 3. In this, the lengths of V_R and V respectively represent to the same scale the output and input voltages, and ϕ is the angle by which the phase of the former is advanced. For the fundamental, V_C is drawn 1.6 times as long as V_R (that is to say, in pro) portion to X_1 and R respectively- and at right angles to it; and, if the drawing is accurate, the

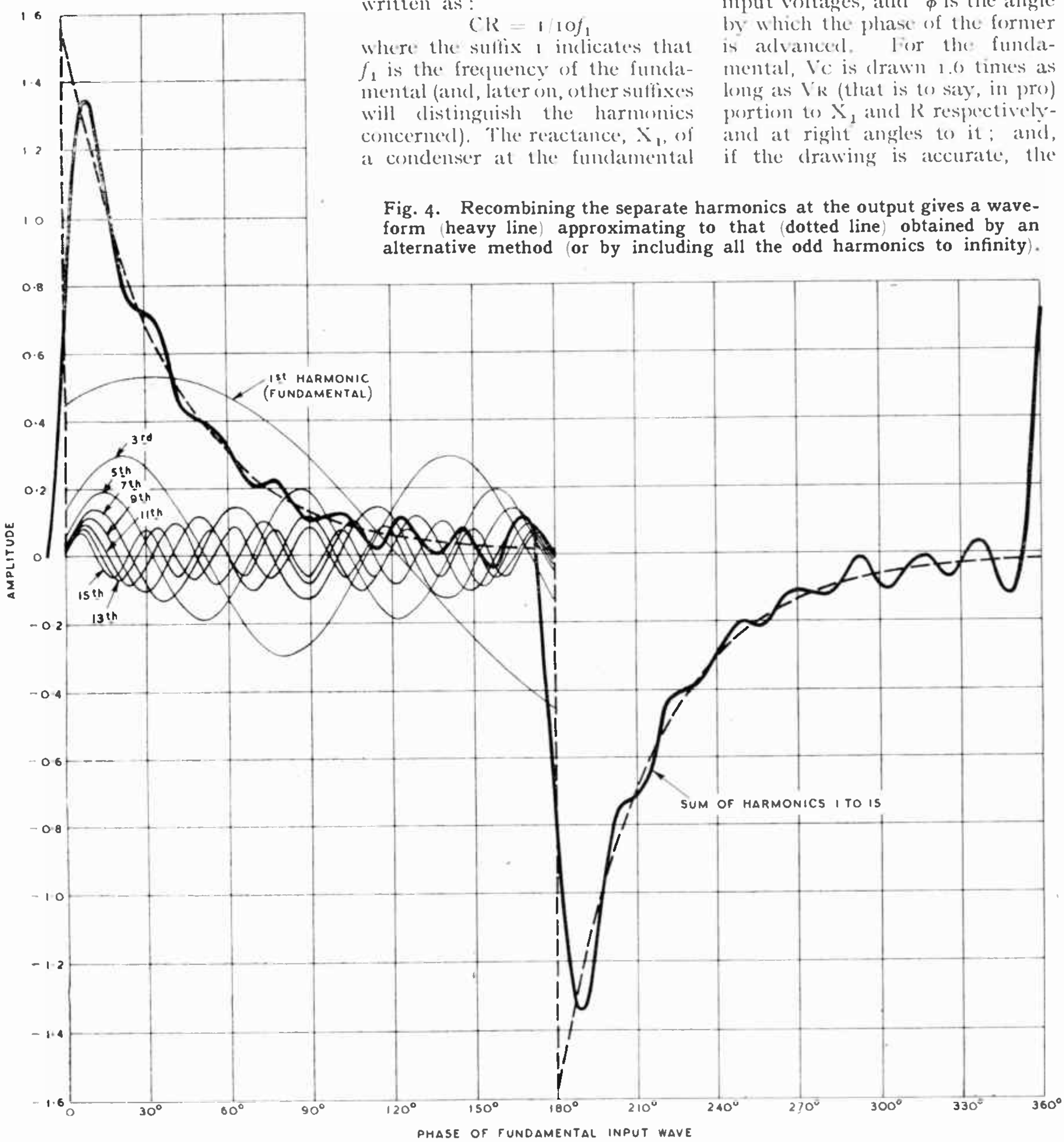


Fig. 4. Recombining the separate harmonics at the output gives a waveform (heavy line) approximating to that (dotted line) obtained by an alternative method (or by including all the odd harmonics to infinity).

World Radio History

amplitude ratio, V_{R_1}/V_1 is found to be 0.53, and ϕ_1 is 58°. For the third harmonic, Vc is drawn one-third as long, so ϕ_3 is much less and V_{R_3} (the third harmonic voltage across R) is more nearly equal to V_3. But it is really V_{R_3}/V_1 (ratio of third harmonic output voltage to *fundamental input*) that we want for plotting, and of course that is one-third as great. Similarly the phase shift in terms of the fundamental cycle is one-third as great as ϕ_3.

The graphical method calls for an accurate large-scale drawing; and as $\phi\pi$ is the angle whose tangent is X_n/R, and V_{R_n}/V_1 is cos ϕ_n/n, it is probably easier to derive them from tan and cos tables. Here are the results tabulated up to the 15th harmonic:

Columns 3 and 5 give the data with which each harmonic that emerges from the "peaker" has been plotted in Fig. 4. Re-assembling these mangled bits by adding ordinates again, the result is the heavy-line curve. Comparing this with the heavy dotted line, which is the exponential curve obtained by the "classroom" method, it must be admitted that it clings too closely for the resemblance to be dismissed as, in the film sense, merely "coincidental." In the geometrical sense, however, it would actually coincide if all the (infinite number of) harmonics were included.

Harmonic (n)	ϕ_n	ϕ_n/n	cos ϕ_n	cos ϕ_n/n
1	58°	58°	0.53	0.53
3	28°	9.3°	0.88	0.293
5	17.5°	3.5°	0.95	0.190
7	13°	1.9°	0.97	0.138
9	10°	1.1°	0.98	0.109
11	8.5°	0.75°	0.985	0.090
13	7°	0.54°	0.99	0.074
15	6°	0.4°	0.992	0.066

Some of us, oppressed with experience of our own fallibility, are never very happy or confident about the correctness of our calculations, be they financial or scientific, unless they reach the same answer by at least two entirely different routes. So it is hoped that the recognisably similar results achieved by such different approaches as the exponential charge and discharge of a condenser, and Fourier analysis and synthesis combined with plain alternating current theory, will increase readers' confidence in both these methods.

PULSE-WIDTH MODULATION

The Basic Principles Described

Pulse modulation has many practical applications. One example of its use will be found in the Army "10 Set" described elsewhere in this issue. The pulse-width system explained in this article is employed in the Pye television sound apparatus, details of which are given on another page.

Of recent years pulses have become associated with radar to such an extent that one almost begins to believe that this is their only use. In fact, however, it is only one among many applications. Pulse technique was used in pre-war television to a very large extent and one has only to recall the line and frame synchronising pulses of the vision signal to realise their importance.

The use of pulses in sound transmission is not so widely known, however, and in certain cases it has important advantages. Before going into this, it will be well to clear up a possible source of misunderstanding, for the term "pulse modulation" is unfortunately often used in two different senses. It is used to describe the modulation of a radio-frequency carrier by pulses and also for the modulation of a series of pulses by some, usually audio, signal. In the former case, the pulses themselves may or may not be modulated and in the latter the modulated pulses may or may not themselves be used to modulate an RF carrier. In radar, the carrier is modulated by pulses which are themselves unmodulated; in a communication system, the carrier is modulated by modulated pulses so that it is analogous to a sub-carrier system in which the pulses form the sub-carrier. In this article, pulse modulation refers to the modulation of the pulses by an audio signal.

If a series of recurrent pulses is generated, it is possible to employ it to carry intelligence by varying some characteristic of the pulses in accordance with the intelligence. One can vary the amplitude, the duration, or the interval between the pulses for this purpose. For the present we need consider only one of these—pulse-duration (or pulse-width) modulation.

Ten pulses of a recurrent unmodulated series are shown in Fig. 1 (*c*). Each pulse lasts for a time interval t_1 and is followed by an interval t_2 in which nothing is transmitted. The total time t_1 and t_2 of one pulse and one interval is the time of one pulse cycle, and the pulse recurrence frequency is the reciprocal of this. It is usual to speak of recurrence frequency or pulse frequency and of pulse duration or width. To say that the pulse frequency is 10 kc/s and the pulse width is 40 μsec. means that there are 10,000 complete pulse cycles a second and that one pulse cycle, therefore, lasts for 1/10,000 sec., or 100 μsec. The interval between pulses is then 60 μsec. Referring to Fig. 1 (*c*), in such a case t_1 is 40 μsec., and t_2 60 μsec.

When such a pulse train is modulated in duration, the width of individual pulses is varied so that it is proportional to the amplitude of the modulating signal at that instant. This

Pulse-width Modulation—
is shown in (*a*) and (*b*) of Fig. 1: (*a*) is one cycle of a sine wave and represents the modulating signal and (*c*) is ten cycles of the pulse waveform in the unmodulated condition; (*b*) shows the modulated wave.

In the case shown the trailing edges (i.e., the right-hand edges) of the pulses occur at the same time whether they are modulated or not, but the timing of the leading edges depends on the modulating signal. It is clear that as the waveform (*a*) grows, the pulses of (*b*) start earlier and earlier, so that their duration increases. The maximum width occurs when the voltage (*a*) has its maximum positive value. After this point the pulse width decreases, and when (*a*) swings negatively the leading edges of the pulses start later than those of the unmodulated ones. Therefore the pulses are shorter. The minimum width occurs at the negative maximum of (*a*).

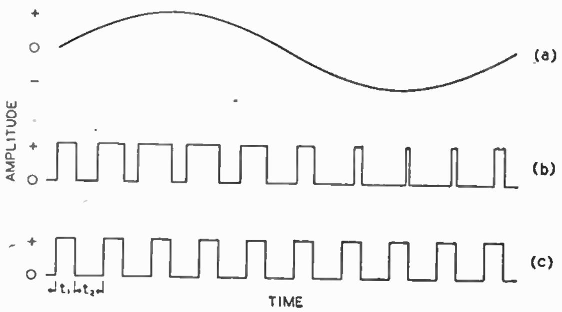


Fig. 1. This diagram shows a single sine wave at (a), and an unmodulated pulse train of ten times the recurrence frequency at (c). The modulated pulses are shown at (b); note that their duration depends on the instantaneous amplitude of the modulating wave (a).

Modulation Depth

If the unmodulated pulse width is t_1 and it is symmetrically modulated, the maximum possible amplitude of modulation is also t_1 and then the pulse varies between the limits of $t_1 \pm t_1$, or from zero to $2t_1$. This is, of course, provided that the pulse t_1 is equal to or less than the interval t_2 between unmodulated pulses. This represents 100 per cent. modulation.

In practice, such deep modulation is undesirable because it means the disappearance of the pulse on the negative peak of modulation and in addition very narrow pulses demand an excessive frequency band for their transmission. In general, a modulation depth of 80 per cent. is about the maximum allowable. For the case quoted of 40 μsec. pulses this would mean a variation of 32 μsec., so that the minimum or maximum pulse lengths would be 8 μsec. and 72 μsec. respectively.

It will be observed that the system virtually samples the modulating signal at intervals and in consequence the signal is not transmitted continuously. There is a minimum number of pulses needed for each cycle of the wave to be transmitted, therefore, if faithful reproduction is to be obtained. One would expect this would be at least several hundred, but in actual fact no more than three pulses are needed and with some care quite good results are obtainable with two pulses per cycle only!

Usually, one takes it that the minimum pulse recurrence frequency is three times the highest modulating frequency, or some 30 kc/s for high-fidelity reproduction or 9 kc/s for ordinary commercial grade telephony.

So long as the sides of the pulses are vertical, the linearity of the apparatus handling the modulated pulses is unimportant; it is possible to use amplitude filters without causing distortion and often with a considerable reduction of noise. This is analogous to the methods frequently adopted in television reception of limiting the sync pulses to reduce the effects of noise and other interference.

The disadvantage of pulse modulation is the wide band of frequencies needed for its transmission. The highest frequency needed is of the order of the reciprocal of the narrowest pulse duration. In the example above this was 8 μsec., so that the highest frequency is about 125 kc/s. This is very high for a maximum modulation frequency of some 3–5 kc/s only. The band-width radiated is, of course, double this for the usual double sideband transmission, so that the system is not one which is ever likely to be adopted on ordinary wavelengths where the space available is strictly limited.

Multi-Channel Systems

It is, however, of very great advantage on very short wavelengths where ordinary methods of modulation are difficult and where the band-width needed becomes unimportant. It also lends itself well to multi-channel working.

If the unmodulated pulse duration is considerably less than the interval between successive pulses, then another series of pulses, representing another channel of communication, can be inserted in these intervals. This is what is done in the Pye television system described elsewhere in this issue. The sound pulses are of 3 μsec. duration and vary between 1 μsec. and 5 μsec. The whole vision signal, representing a second channel, is inserted in the gaps between them.

Before concluding, something should be said on the demodulation of the pulses to produce the audio-signal again at the receiver. With a single channel, the detector output is of the form of Fig. 1 (*b*) and it is necessary to produce from this the original wave (*a*). Surprising as it may seem, this can be done with nothing more than a simple low-pass filter. Mathematical analysis of the wave (*b*) shows that it is nothing but the wave (*a*) with the addition of a large number of higher frequency components of which the lowest is the pulse recurrence frequency and it is only necessary to filter out all these to obtain the original wave.

With the multi-channel systems, it is first necessary to sort out the pulses for each individual channel. In the Pye system, the pulses of the sound channel are of greater amplitude than the vision signal and can be separated by a simple amplitude filter. Passing the separated pulses through a low-pass filter then produces the audio signal.

World Radio History

FUNDAMENTALS OF RADAR

3. *Radar as a Weapon of Offence: ASV and H2S*

IN the previous two articles in this series we examined radar in its original role as detector and locator of enemy aircraft, first from the ground as a warning device and later both from ground and air for counter-offensive action. This was part of what may be called the RDF phase of radar.

Airborne radar reached its peak with the introduction of H2S, and this month we shall examine the workings of H2S and its close relation ASV.

From September 1939 to the end of hostilities a continuous battle went on in the Atlantic, which was only kept in precarious balance by the sustained efforts in the radar laboratories. Only the use of ASV ("air to surface vessel" radar) enabled the submarine offensive to be contained. ASV development went through several stages of wavelength shortening, just as did AI, each new design appearing as the radar-tactical situation changed.

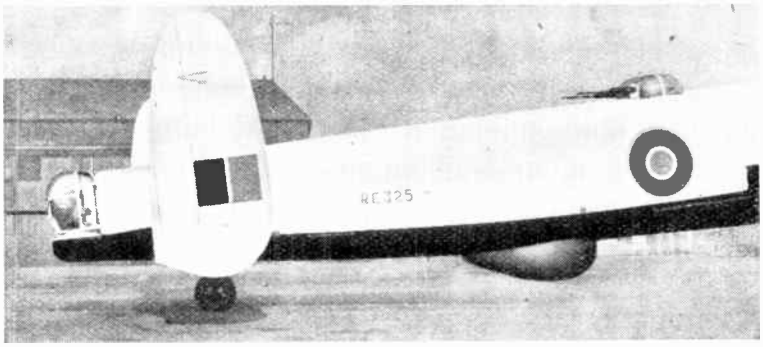
The first experimental ASV equipment was demonstrated during the fleet manœuvres in September 1938. It became operational in October, 1939, and was thus the first airborne radar of the war; improvements in 1941 made possible the detection of surfaced submarines. This first ASV was in the 1½ metre band, in which most of the equipments of the period were working. It closely resembled the corresponding marks of AI equipment in principle. The transmitting aerial was carried on the nose of the aircraft and was beamed slightly to floodlight the sea in front of the aircraft. Out on each wing were mounted receiving aerials. These were usually of the "Yagi" type, giving a fairly narrow beam. The echoes from a target were picked up by the receiving aerials and presented alternately on the cathode ray tube by means of a rotating switch. This "split" display enabled the operator to judge when the aircraft was heading towards the target by the consequent equality of the echoes. The distance of the target was given by the interval between the transmitted pulse and the echo. The final attack was made by visual bombing, eventually assisted at night by the Leigh Light which was introduced in the summer of 1942.

The range of this 1½ metre ASV equipment was about 10 miles for ship detection, but surfaced submarines could only be detected at shorter ranges. A single aircraft could, however, sweep a very large area of sea during a single flight. Another important feature of ASV was that aircraft returning from anti-submarine patrols could home on beacons, which transmitted artificial echoes when illuminated by radar pulses. Navigation problems were thereby simplified. for when the aircraft had arrived within about 50–100 miles of its base it could be navigated by ASV. This greatly increased the number of patrols which could be flown in bad weather.

By the end of the summer of 1942 it had become clear that radar was acting not only as a detector of submarines but also as a warning to them. Listening sets picked up the ASV pulses at ranges of possibly 50 miles, and long before the echoes were strong enough to be detected by the aircraft the submarine could submerge undetected. This installation of listening sets was part of a private war which went on all the time, about which very little can be written. The original idea of radar was to detect "non co-operating objects." In doing so, the radar station itself co-operated in enabling the "object" to find the radar station. The blacked-out ship and unlit aircraft were carrying brilliant radiators of electromagnetic waves, and it was constantly necessary to introduce new wavelengths so that the enemy could not use the information thus offered to him. Much of the story of wartime radar development is a story of a search for novelty which would provide the element of surprise.

The ASV problem was already solved. Centimetre equipment was ready to go into service by the early spring of 1943, just as the enemy were seeking to profit by his 1½ metre listening sets and his apparent tactical freedom from air attack. The impact of a new radar technique against the unjustified confidence of the enemy submarine commander had a most devastating effect.

In many ways centimetre ASV resembles centimetre AI. The family likeness appears in the use of the magnetron, the Sutton tube local oscillator and the gas gap for common transmission and reception from the same aerial. We may digress at this point to indicate the action and use of the gas gap. The problem is to



The blister enclosing the H2S scanner on the latest R.A.F. heavy bomber, the Lincoln, can be seen below the roundel.

World Radio History

Fundamentals of Radar—

connect, as efficiently as possible, a powerful transmitter and a sensitive receiver with a crystal mixer to the same aerial. Without some special precautions the crystal would be burnt out by the transmitter power, and the receiver would also absorb much of the power. The basic circuit is

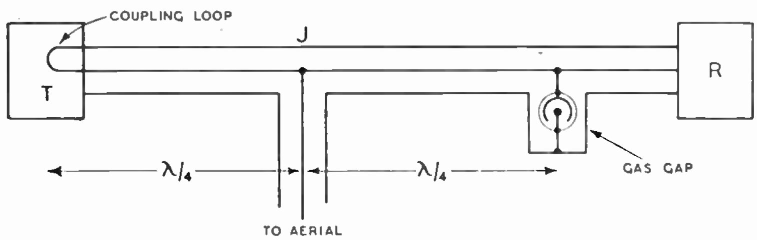


Fig. 1. Aerial switching arrangement in centimetre radar equipment.

shown in Fig. 1. The gas gap consists basically of two electrodes in a "soft" valve. When the transmitter is on "space," the coupling loop acts as a short circuit, and by the usual impedance-transforming property of a quarter-wave line an infinite impedance is presented by the left-hand section at J. Received pulses therefore pass to the receiver. The gas in the protective tube being unionised, the gap absorbs no energy and the whole signal reaches the receiver. When the transmitter "marks," the gap breaks down and the ionised gas provides an effective short circuit. The receiver line presents infinite impedance at J and all the power goes to the aerial. In practice refinements are necessary; the capacity of the gas gap must be allowed for in designing the system, impedance transformations are introduced to give maximum protection, and biasing voltages are applied to encourage the gas gap to ionise as soon as the transmitter mark begins. These details are not material to the present outline.

The display unit of ASV differs from that of AI in using a true PPI, which provides the observer with a map of the sea, with ships and coastline shown, just as the GCI operator was given a picture of the position of aircraft in the sky, so the ASV operator could see, as though plotted on a chart, the positions of all ships and coastlines within range. Often, of course, it resembled the Bellman's Chart*

"representing the sea,
Without the least vestige of land:
And the crew were much pleased when they found it to be
A map they could all understand."

For convoy protection, however, the view of the whole convoy was invaluable.

Beam Shape in ASV

The aerial system was mounted in a turret placed below the nose or belly of the landplanes of Coastal Command. Inside the fairing an aerial and reflector were mounted so that they could rotate about a vertical axis.

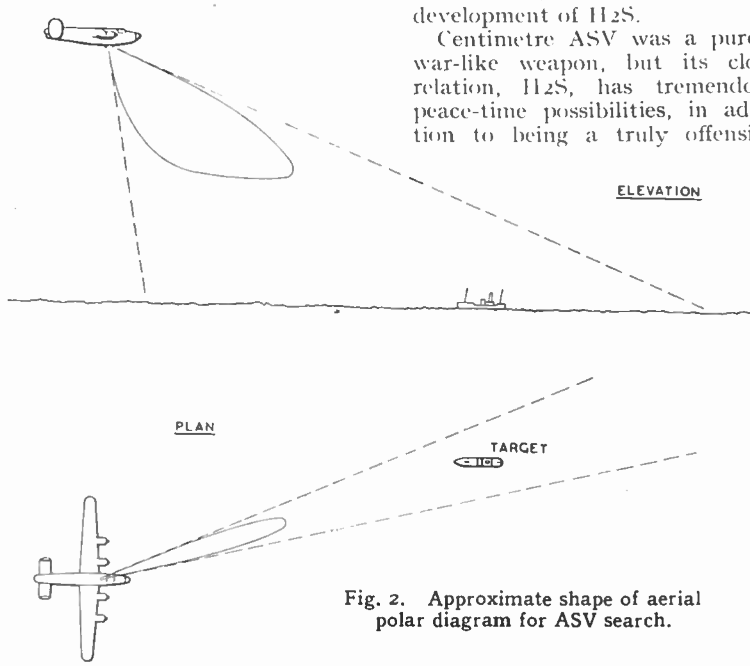


Fig. 2. Approximate shape of aerial polar diagram for ASV search.

A cut-down paraboloid is used and the resulting beam is narrow in azimuth, where the reflector has its full dimensions. In elevation, however, the beam is spread out in such a way that although most of the energy is sent out at a few degrees below the horizontal, the lobe is deformed at greater angles from the horizontal, and is free from minima (Fig. 2). The shape of the deformed lobe is such that an aircraft flying at its normal operational height will receive echoes of approximately equal strength from all targets within range.

By rotating the aerial system the whole sea can be searched within a circle whose radius equals the range of the equipment. As the aerial system rotates, the radial timebase of the PPI goes round in synchronism, and echoes brighten up the beam of the cathode-ray tube. When the aircraft comes within range of land the coastline is clearly shown and salient features can be used for navigation. This fact was made full use of in the development of H2S.

Centimetre ASV was a purely war-like weapon, but its close relation, H2S, has tremendous peace-time possibilities, in addition to being a truly offensive war-weapon. If an ASV set is operated over a coastline it is found that in general land scatters back more energy than water and buildings scatter back more than open country. Thus over

* "*Hunting of the Snark*, Fit the Second."

World Radio History

land, rivers and lakes appear as black marks against a faint "land" background, while towns stand out quite brightly on the PPI. Changes in detail design

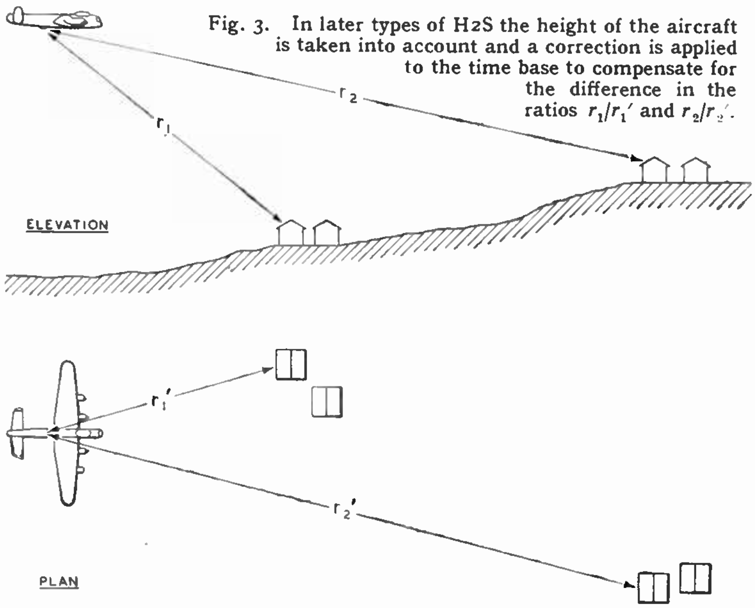


Fig. 3. In later types of H2S the height of the aircraft is taken into account and a correction is applied to the time base to compensate for the difference in the ratios r_1/r_1' and r_2/r_2'.

are necessary, for the operating height of a bomber is greater than that of a sea reconnaissance machine. In addition, the map presented on the PPI is a "slant range" map and is thus badly distorted in the region immediately below the aircraft. This is inconvenient both for navigation and for bombing, and it is necessary to distort the PPI timebase to make the H2S map resemble the ordinary geographical map. The difference can be seen from Fig. 3.

The H2S system is probably the most interesting radar device. It represents the introduction of a new sense for man, that of vision at centimetre wavelengths, with apparatus which can be carried in a fairly small aircraft.

We saw last month that the range of a radar system in free space was proportional to the fourth root of the transmitter power. In calculating the range of air-to-ground radar systems we must take into account the effect of the wave which reaches the target after reflection from the ground as well as the direct wave. For the case of horizontal polarisation we proceed as follows.

A transmitter T is at a height h_1, above the ground, and a reflecting object O is at a height h_2. Both heights are such that we may consider the ground range R equal to the slant range: that is we can write $1/R^2$ in the inverse square law. The field strength at O produced by a transmitter of power W at T can be shown to be:

$$\frac{40\pi h_1 h_2}{\lambda} \cdot \frac{\sqrt{W}}{R^2}$$

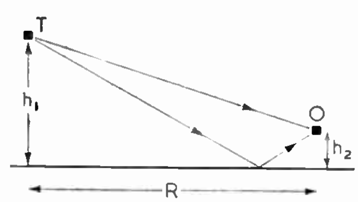


Fig. 4. Ground reflections must be taken into account in the H2S radar system.

If the power scattering coefficient of the reflector is Q, the power re-radiated will be

$$Q\left(\frac{40\pi h_1 h_2}{\lambda}\right)^2 \cdot \frac{W}{R^4}$$

This produces at T an available signal power which is proportional to $\frac{QWh_1^4h_2^4}{\lambda^2R^8}$. This expression must be multiplied by the power gains of receiving and transmitting aerials, and if these are both equal to G the power available at the receiver will be

$$W_n \propto \frac{Qh_1^4h_2^4G^2}{\lambda^2R^8} \cdot W$$

Thus as the range is fixed by the minimum detectable value of W_n, which is a constant of the receiver, the range R is proportional to $W^{1/8}$, the eighth root of the power. The use of ten times the power results in a range only 33 per cent. greater. As we saw in the description of the free space case, the choice of G and λ are the most important factors in radar system design.

[The photograph of mechanism for spiral scanning on p. 328 of Part 2 of this series was reproduced by courtesy of the makers, Nash and Thompson of Tolworth, who were the principal producers of radar scanners.—ED.]

RADAR MAP

THE illustration on the front cover of this issue shows the trace reproduced on the CR tube of the latest version of H2S (designated H2X) when the aircraft was flying in dense cloud over the Thames estuary.

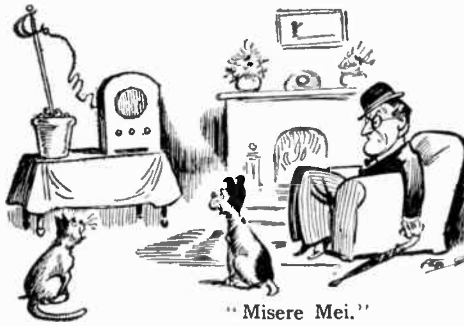
RADIO IN NORWAY

SIX of the sixteen broadcasting stations in Norway were destroyed during the war. They are those at Porsgrunn, Notodden, Vigra, Vadsoe, Narvik and Bodoe. As a result, listening conditions in many districts, particularly in the north, are very poor. To alleviate the difficulty a transportable 20-kW transmitter has been erected at Vigra until the new 100-kW transmitter is completed. New transmitters are being constructed as well as replacing those destroyed. Among the new stations is a 50-kW short-wave transmitter, which will replace the present 5-kW station, and is intended particularly for Norwegian listeners abroad.

Wireless sets valued at about 120,000,000 kroner (approximately £6,000,000) were confiscated by the Germans in Norway in 1941. A large number of these have now been restored to their owners, but many more are needed to meet the demand. The present policy is to import the components and manufacture the sets in Norway. The Norwegian Broadcasting Service has, therefore, ordered components for 120,000 sets, some of which are expected to be on sale at Christmas.

UNBIASED

By FREE GRID



"Misere Mei."

A New Menace

DISQUIETING rumours reach me from some of my fifth columnists who toil for certain of the big wireless manufacturers. From what I hear, it seems that when the industry gets settled down once more to real and full-time peace production, we are likely to be provided with push-button broadcast receivers without any tuning dial at all, the argument being that push-buttons form the quickest and best method of tuning, and the elimination of dial tuning will greatly cheapen production, which will please the average citizen, who won't have to pay for a feature of the set which he doesn't want.

I can only hope that my information is wrong and that the counter-intelligence service of the manufacturers is putting out these rumours to throw dust in my eyes, for no policy could be more short-sighted and misguided than the omission of dial tuning. To illustrate my point let us suppose that we *do* get saddled with "push-buttons-only" sets. People will get to like them because of their simplicity, and in a few years a generation will spring up which has no more idea of how to tune in a station than the present-day motorist has of how ignition could be provided by non-electrical means which, of course, it actually was, round about the time of Majuba Hill, as I well remember.

"I hear from my spies."

Once this new generation has sprung up, the first part of the mischief will have been done, although it could only bring forth its evil fruit in the admittedly not very likely event of some home-grown Adolf suddenly seizing power in this country and dealing with us as the original Adolf did with his fellow Teutons. The nett result would be almost as bad as if broadcasting by radio had been replaced by some wired method of programme distribution; namely, we should have to listen to what the "government" of the day wanted us to hear, for very few people would have the skill to delve into the set's innards and readjust the pre-set tuners to the wavelength of an oversea freedom station.

It is true that the freedom transmitter could adjust itself to the fixed wavelength of one of the receiving channels, but all the same I don't like it. The people must retain their old skill and cunning with a tuning dial and they can only do that if manufacturers continue to turn out sets fitted with dials as well as with push buttons.

The most disquieting thing of all is that I hear from my spies that the whole business is sponsored by the G.P.O. mandarins as a sort of thin end of the wedge to a revival of their pre-war wired broadcasting ambitions which were so effectively nipped in the bud by those who saw the menace.

"Sursum Corda"

LATELY I have been spending a good deal of time reading wireless literature in the shape of elementary text-books in general, and, in particular, the instructional manuals which set manufacturers always give away with their products. As a result of my reading I am in a very depressed state indeed. To possess a wireless set is, I can well see, not for me and still less is it for the average non-technical citizens. The care and attentions which a set requires obviously calls for more time and patience than I or anybody else can afford to spend on it unless we are to desert our wives and children and all other interests and enter the cloisters of a sort of wireless monastery in order to devote our whole lives to it.

My complaint against these books is that trouble—with a capital "T"—is the theme-song running through them with nary a *sursum corda* anywhere to enlighten what Newman so aptly described as the "encircling gloom." Unfortunately, the writers of these books, however learned they may be in matters pertaining to the "elements" of wireless, don't seem to have studied the elements of psychology, for there is no joy in their writings. I am, therefore, thinking of writing a handbook myself on the elements of writing an elementary book on wireless—or, for that matter, on any other subject, for wireless books are not the only ones at fault.

Pick up an instructional book on any subject you like; keeping a dog, for instance. What do you find? Unless the dog is brushed regularly and its ears carefully examined every morning, the very least of its troubles will be mange and canker, whilst further "neglect" will mean diseases too ghastly to mention. An even worse instance is afforded by the "Keep Fit" and "Every Man His Own Doctor" books. I recently read one of these with the result that I had only just sufficient strength to totter to the telephone and ring up for the undertaker to come and take me away. It was fortunate for me that I got the wrong number and instead of the sepulchral voice which I had expected, I heard the comparatively joyous tones of the local dentist.

But to return to the wireless books. My aerial (so the book tells me) must be high but at the same time the downlead must be short, and, of course, the insulators must be cleaned regularly, whilst periodically the earth plate must be dug up and inspected. The receiver must be placed in such a position that it is free from damp but at the same time it must not be near the fireplace owing to the evil effects of the "products of combustion" (smoke. I suppose) which may get into it; in fact, I must be on the look-out for this during my diurnal dusting of the condenser vanes.

But I give up. *Misere Mei.* I would end it all with my ceremonial hara-kiri sword, but apparently Mrs. Free Grid is using it stuck in a flower-pot as an earth connection.

World Radio History

CRYSTAL-CONTROLLED FREQUENCY MODULATION

Direct Modulation of the Natural Frequency of the Crystal

By S. K. LEWER, B.Sc.

ONE of the most difficult problems in the design of FM transmitters is to provide for adequate variation of the frequency of the modulating signal while retaining a satisfactory measure of stabilisation of the mean frequency of the carrier.

It is customary in some types of FM transmitter to use a crystal-controlled oscillator for the generation of a frequency-stabilised mean carrier frequency and to produce the required frequency modulation by transitorily varying the phase of the oscillations in accordance with the modulation signal. This is the method used in Armstrong's system.[1] Unfortunately the extent to which the frequency can be made to deviate from its mean value by this application of phase modulation is quite small. In some applications, as in high-quality broadcast, it is necessary to increase the effective deviation by a process of frequency multiplication, perhaps as much as 3,000 times, but where the requirements are less stringent a multiplication of about 75 times has proved sufficient.[2]

In another system, a valve is used as a variable reactance in conjunction with the tuned circuit which determines the frequency of the fundamental oscillation. Although the degree of frequency excursion which can be accomplished by this method is so much greater as to require a multiplication of only a few times, it is necessary to incorporate a rather elaborate arrangement for the self-stabilisation of the mean frequency. This adds considerably to the general complexity of the complete transmitter.

Other methods have been proposed, but like the two just mentioned they all suffer from various drawbacks. With sufficient enterprise these drawbacks can in most cases be eliminated, but the possibility remains that with further effort new methods may be brought to light and eventually prove superior.

The problem is fundamentally one of varying the frequency sufficiently without appreciably altering its mean value.

The system of frequency modulation described here is offered as an alternative to the schemes which have so far been considered. Whether or not it possesses any features which might render it preferable to the methods at present in favour is a matter for further experiment.

Crystal Cuts

The basic principle of the new method is the direct modulation of the natural frequency of the piezoelectric element which is used for controlling the mean carrier frequency. As is well-known, a piezoelectric crystal possesses the property of changing its dimensions when a potential gradient is applied parallel to the electric axis. For the purpose of the present description there is no need to go into the question of crystal structure and the orientation of the various crystallographic axes. It will be sufficient to consider the properties of the simplest and most convenient type of crystal element, namely, an X-cut quartz plate.[3]

Nowadays the X-cut crystal is seldom mentioned in radio engineering. It has been superseded for most purposes by more intricate cuts, such as the AT and BT-cuts, in the demand for higher frequency-stability.[4] Nevertheless, the old-fashioned X-cut has certain features which can be utilised to great advantage in FM systems.

In high-frequency crystal plates the natural frequency of vibration is dependent on the thickness of the plate. The frequency is inversely proportional to the thickness. This is true for the thickness-shear vibration, as used in the AT and BT-cuts, and also for the simple thickness vibration, as used in the X-cut.

When a polarising potential-difference is applied to the electrodes of an X-cut plate there is a corresponding change in the thickness of the plate. The natural frequency of the thickness vibration is then modified, rising when the direction of the polarising potential is in such a direction as to cause a diminution of the thickness and falling when the direction is reversed. Over a range wide enough to be of practical interest, the relation between the frequency of oscillation and the polarising potential is substantially linear.

In comparison, the AT and BT-cuts would appear to be unsuitable for use in this system. The applied potential produces a thickness-shear in such plates, and the variation of natural frequency with potential-difference would be negligibly small, if not actually non-existent.

Experimental measurements have shown that with an X-cut plate having a fundamental frequency of 6.8 Mc/s an applied voltage of 300 volts DC produces a shift in frequency of 60 c/s. Over this range the variation was observed to be strictly linear. Expressing this in general terms, the relationship is $\delta f/f = 3V \times 10^{-8}$,

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[1] E. H. Armstrong, *Proc. I.R.E.*, May 1936, Vol. 24, pp. 689-740.

[2] A. Hund, "Frequency Modulation," (McGraw Hill) pp. 118, 231.

[3] C. F. Booth and E. J. C. Dixon, *J.I.E.E.*, 1935, Vol. 77, p. 197.

[4] W. P. Mason, *Bell Syst. Tech. J.*, January 1940, 74.

World Radio History

Crystal-controlled Modulation—

where f is measured in cycles per second and V in volts.

The fundamental frequency f of an X-cut plate is related to its thickness t by the equation $f \times t = 2.87 \times 10^6$ where f is again in cycles per second and t is in millimetres. Therefore, the FM characteristic of an X-cut plate may be expressed as $\delta f = f \times 3V \times 10^{-8} = 8.61 \times 10^{-2}$ V/t.

Obviously a limit will be set to the frequency shift by the maximum permissible value of V/t, for this is the potential gradient across the crystal, but from a practical standpoint a value of V/t=600 volts/mm. is perfectly safe. It is not suggested that this figure is a working maximum, and it is quite possible that much higher values may be found satisfactory. The experimental figures quoted here are intended merely to show that the effect is of a practicable order.

Although the principle in itself is simple, certain other aspects of the problem must be considered, such as the choice of fundamental frequency of the modulated crystal and the question of temperature stabilisation. These problems are discussed later.

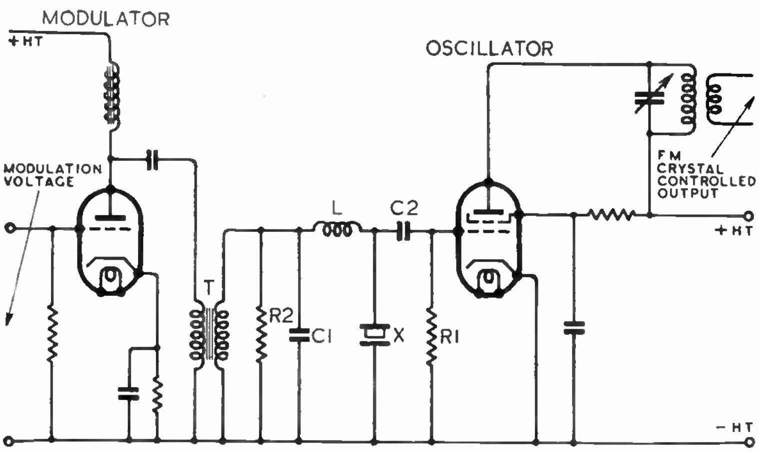


Fig. 1. Essential elements of a frequency-modulated crystal oscillator.

The frequency - determining crystal forms part of the RF generating circuit and also constitutes a load on the modulating system. Consequently, the modulator will be connected to the RF generator. In order to avoid spurious modulation effects, care should be exercised to prevent the modulating voltage from affecting the oscillator valve directly. Equally it will be necessary to exclude RF currents from the modulator system. Since the crystal-oscillator frequency is likely to be at least 100 times the maximum modulation frequency, this should be a straightforward matter of high-pass and low-pass filters.

The essential elements of a circuit arrangement utilising the principle of direct modulation of the crystal frequency are shown in Fig. 1. In the right-hand section there appears a conventional crystal-controlled RF oscillator, X being the frequency-determining crystal. The left-hand section shows the final stage of a normal AF modulation amplifier. The output from the latter is applied through a suitable impedance-matching transformer T and a low-pass filter LC1 to the electrodes of the crystal.

If the modulation voltage were allowed to reach the grid of the oscillator valve, a certain amount of amplitude modulation would result. Probably the modulation voltage thus applied would also influence the frequency of oscillation adversely by reason of the varying impedance load across the crystal. A low-stop filter R1C2 is therefore inserted between the crystal and the oscillator grid.

The impedance-matching transformer T is desirable in view of the high impedance which the crystal presents over the range of modulation frequency. The use of a shunt resistance R2 to provide a suitable load simplifies the design problem and assists in achieving a linear overall frequency/voltage characteristic.

A numerical example will now be given to illustrate the practicability of the method and to indicate the magnitude of the various factors involved.

It is assumed in the first place that the mean carrier frequency will be of the order of 50 Mc/s, for FM is hardly suitable as a system of communication at frequencies much lower than this. Further, it may be supposed that the mean carrier frequency is to be maintained constant to within ±0.01 per cent. The maximum deviation will be taken as ±75 kc/s, which is the figure at present accepted as standard for high-quality broadcasting.

Some degree of frequency multiplication will obviously be necessary, for the grinding of X-cut crystals to a frequency as high as 50 Mc/s is still a prohibitively expensive proposition and nothing short of scientific trickery. To simplify the arrangement of frequency-multipliers and amplifiers as far as possible, it would be preferable to choose a crystal having a high fundamental frequency. Since the frequency deviation achieved by the piezoelectric change of thickness for a given modulation voltage increases with the fundamental frequency, this constitutes a further reason for choosing a crystal with as high a frequency as possible.

Taking the figures specified above, it is seen that the required shift of frequency of 75 kc/s in 50 Mc/s is 0.15 per cent. To produce a frequency deviation of this order directly with an X-cut plate would call for a peak modulation voltage of over 50,000 volts (according to the relationship $\delta f/f = 3V \times 10^{-8}$). This is unquestionably excessive from several points of view. With a lower voltage, no amount of direct frequency multiplication would yield this degree of frequency deviation.

It is therefore necessary to resort to the method used in Armstrong's system whereby the percentage deviation is artificially increased. The frequency-modulated oscillation is subjected first to a reasonable amount of multiplication, perhaps 10 times, and

World Radio History

the resultant is heterodyned with a fixed oscillation having a frequency suitably close to it. The heterodyne difference-frequency is, of course, much lower than either of the two component frequencies, but the amount of the deviation of the difference-frequency from its mean value is the same as that of the modulated component.

Thus, suppose the initial generator produces an oscillation of 1 Mc/s which is modulated to the extent of ±50 c/s. After a multiplication of 10 times, this modulated oscillation has a frequency of 10 Mc/s±500 c/s. If this is heterodyned with a fixed oscillation of 10.02 Mc/s (or 9.98 Mc/s), the mean difference-frequency will be 20 kc/s and this will be modulated to the extent of ± 500 c/s.

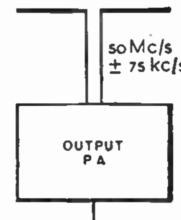
The highest frequency for which an X-cut plate can be prepared, apart from laboratory curiosities, is about 10 Mc/s. Let us suppose that a 5-Mc/s crystal is used. From the experimental relationship $\delta f = 3fV \times 10^{-8}$, we may expect a frequency variation of ±150 c/s for a modulating potential of ±1,000 volts peak. The frequency deviation directly obtainable is thus $150/5 \times 10^6$ or 0.003 per cent. This must be increased to 0.15 per cent. if we are to produce a modulation of ±75 kc/s with a carrier frequency of 50 Mc/s as specified above.

Suppose the initial crystal-controlled modulated oscillation of 5.0 Mc/s±150 c/s is multiplied 5 times so that it becomes 25.0 Mc/s±750 c/s. By heterodyning this with a fixed oscillation of 25.5 Mc/s (or 24.5 Mc/s), a modulated difference frequency of 0.5 Mc/s±750 c/s is obtained. When this is multiplied 100 times, the required output of 50 Mc/s ±75 kc/s is produced.

A block diagram setting out the general arrangement of such a system is shown in Fig. 2.

The degree of frequency stabilisation (±0.01 per cent. in the above example) specified for the output obviously applies to the master oscillator stage from which the output is multiplied. The same degree of stabilisation is not necessarily required in each of the oscillators (A and B in Fig. 2), for it is merely the difference between their frequencies which has to be maintained constant within 0.01 per cent. If they both drifted higher or lower with a constant difference (in a manner analogous to tracking in a superheterodyne receiver) there would be no effect on the output frequency.

It would be preferable, however, to maintain one of the oscillators with a reasonably high stability and to provide automatic correction for the other oscillator so as to stabilise the difference frequency. Oscillator A must depend on an X-cut crystal, since this is required for the modulation process, and therefore it will be subject to a closely predictable variation of frequency with temperature. An X-cut crystal has a frequency-temperature coefficient of −23 cycles/Mc/deg. C., whereas with other high-frequency cuts



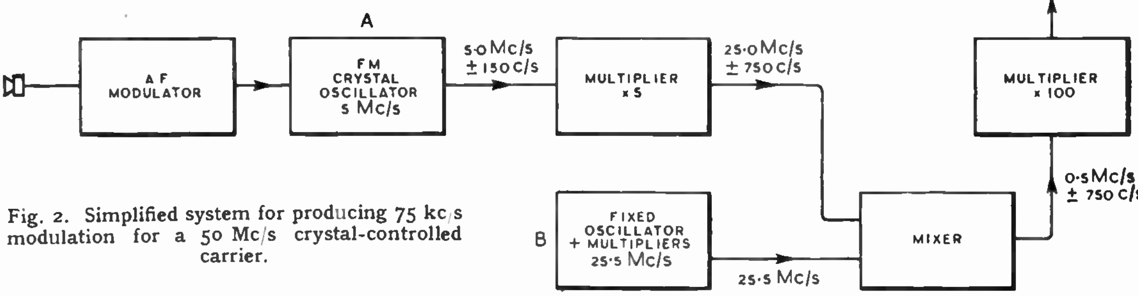


Fig. 2. Simplified system for producing 75 kc/s modulation for a 50 Mc/s crystal-controlled carrier.

Here the original modulation of 50/1,000,000 or 0.005 per cent. has been converted to one of 500/20,000 or 2.5 per cent.

This carrier frequency of 20 kc/s could be multiplied again by, say, 50 times, after which the frequency would again be 1 Mc/s but now with a modulation of ±25 kc/s. If necessary, a further stage of the heterodyning and multiplying process could be added to increase the percentage frequency deviation at the same carrier output frequency.

The degree of frequency multiplication and the frequency at which heterodyning is best effected are matters to be settled by consideration of the specific circumstances. No definite rules can be laid down. For the present, it need only be remarked that the principle of magnifying the deviation is sound, that it is being successfully used and that there is a large measure of flexibility in adapting the principle to a specific problem.

the temperature coefficient, although much smaller, varies with the temperature and is dependent to some extent on the dimensions of the particular crystal. The oscillator may well be provided with any convenient high-stability crystal, perhaps thermostatically controlled, so as to generate a stable output of 25.5 Mc/s (or 24.5 Mc/s) through one or two multipliers.

The variation of frequency with temperature in the X-cut crystal of oscillator A can be used in the difference - frequency stabilising process by means of temperature control. Normally, the X-cut crystal would operate at some elevated temperature, say 60 deg. C., and its frequency would then be adjusted automatically higher or lower by a suitable lowering or raising of its temperature. The heating current fed to its oven would have to be made to depend on the amount of drift of the difference - frequency from its mean value.

World Radio History

Crystal-controlled Modulation—

At this stage the problem involves nothing which is not already available in established techniques, and for the sake of brevity only an outline will be given of a suggested arrangement.

The difference frequency which is to be stabilised can be heterodyned by a standard oscillator having an output of, say, 500 kc/s. Such an oscillator can be designed to have a very high order of stability. A 500 kc/s crystal mounted in a thermostatically controlled oven which regulates the temperature to within 1 deg. C. may be expected to maintain its frequency to within a tenth of a cycle per second.

The output thus obtained can be passed through a frequency-selective filter and rectified, so that a variation in the main difference-frequency will appear as a variation in a rectified voltage. This can be used to control the temperature of the oven in which the X-cut crystal is mounted (for instance by means of a gas triode) and so regulate the difference-frequency.

Any variation in the frequency of oscillator B in Fig. 2 is automatically taken care of and, in effect, the mean frequency of oscillator A will follow any shift in B while maintaining a stabilised difference.

Fig. 3 illustrates the basic arrangement of the suggested frequency-stabilising system.

It will be readily appreciated that the modulation of frequency which appears throughout the generator system has no effect on the stabilising process for, as a consequence of the thermal capacity of the temperature-controlling device, all transitory changes in the frequency due to normal modulation will be smoothed out.

Of course, any other method of automatic frequency-control may be used for maintaining the required difference-frequency, provided that it holds the frequency within sufficiently close limits. The technique of AFC is now well established and its adaptation to the present problem should be a straightforward matter.

This article is not intended to be in any sense exhaustive. Its purpose is merely to outline a possible method of frequency-modulating a crystal-controlled oscillator and to suggest the directions in which experimental work could most profitably be undertaken.

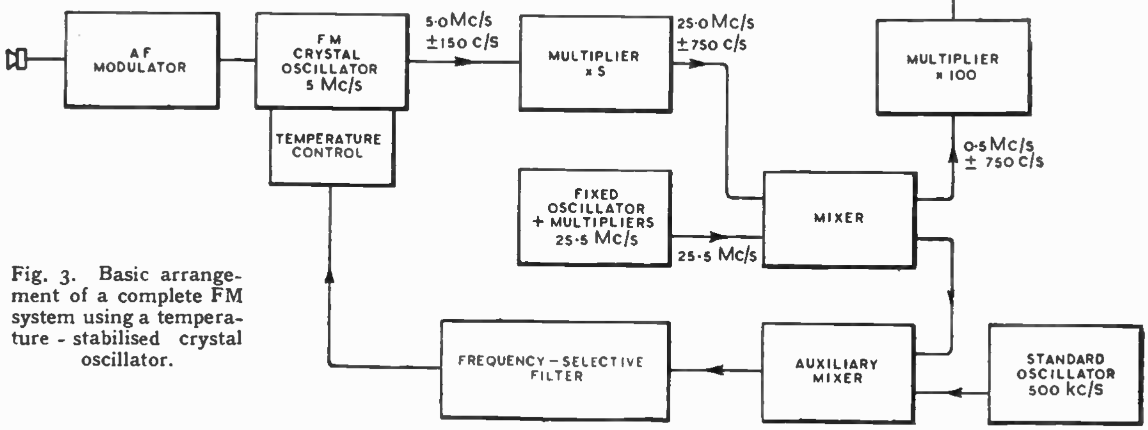


Fig. 3. Basic arrangement of a complete FM system using a temperature-stabilised crystal oscillator.

THE TELEMOBILE portable control desk for use with two television cameras. The equipment is mounted on hinged chassis which can be opened out for maintenance. It operates from AC and several units can be employed together if more than two cameras are used. It is designed by Television Products Inc., Hollywood, U.S.A.

World Radio History

TELEVISION DEVELOPMENTS

Sound and Vision on One Carrier

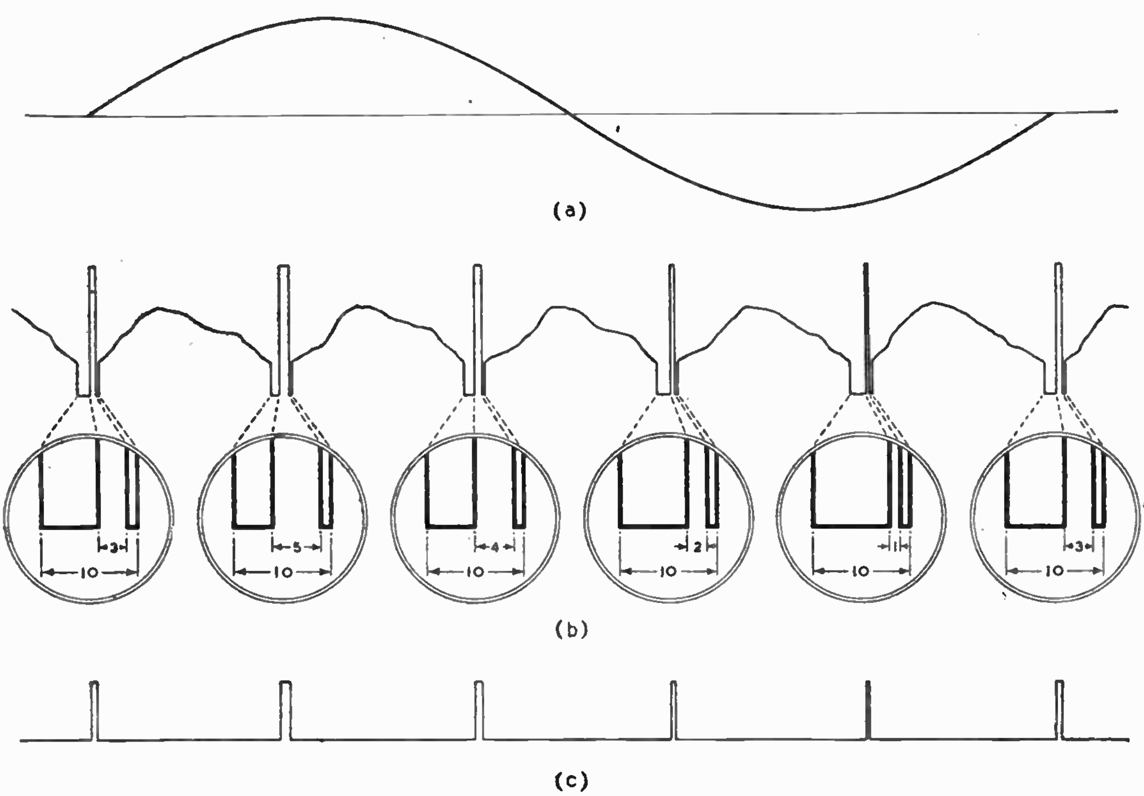
AN extremely interesting development in television technique was recently demonstrated by Pye, Ltd. It consists in utilising the time normally wasted by the transmission of synchronising pulses for the sound accompaniment. This not only saves the separate sound transmitter normally required but much of the sound receiver, and at the same time it reduces the total frequency band occupied by a complete television system.

The television signal itself is quite unchanged. The scanning system and video signals, and general form of the synchronising pulses are the same as in pre-war transmission. This means that the line scanning frequency is 10,125 c/s, so that the time available for scanning each line and transmitting the line sync pulse is 98.5 μsec. Of this time the sync pulse itself occupies 10 μsec., and it is obtained by suppressing the carrier of the vision transmitter for this period.

The leading edge of the pulse triggers the time-base in the receiver at the end of the line and the pulse itself also suppresses the spot on the cathode-ray tube during the fly-back. While a pulse length of 10 μsec. is not necessary for synchronising, a time interval of this order is needed for the fly-back, and it is difficult to reduce it economically. It does, however, represent waste time as far as the actual picture is concerned.

This time, however, can now be utilised to convey the sound programme without detriment to the picture. Within the period devoted to the line sync pulse, a pulse-duration modulated signal can be inserted. This is a series of pulses with a mean duration of 3 μsec. and a recurrence frequency of 10,125 c/s—the same as the line frequency. These pulses are all of constant amplitude, but their duration varies, within the limits of 1 μsec. to 5 μsec., in accordance with the amplitude of the sound signal at the instant of their occurrence.

The pulse amplitude is greater than the maximum video amplitude, and if the former is taken as 100 per cent. of the RF carrier, the maximum video amplitude corresponding to a peak " white "



This diagram shows how a width-modulated pulse carrying the sound programme is inserted within the line sync pulse.

World Radio History

Television Developments—
signal is about 75 per cent. The waveform is shown in the figure where (*a*) shows one cycle of the audio wave and (*b*) illustrates a few lines of the complete television signal. The video signal and line sync pulses are clearly seen, and within the latter are the large-amplitude pulses conveying the sound signal.

Separation of the sound signal in the receiver is accomplished by a simple limiter which passes only signals of greater amplitude than the level corresponding to peak white. It thus provides an output only on the sound pulses of greater amplitude, and this separated waveform is shown at (*c*).

The sound causes no interference with the vision signal because it is non-existent during the scan time. It occurs during the fly-back, and it is necessary only to ensure that the scanning spot is completely blacked out during this time to avoid any trace of the sound signal on the picture.

This entails some slight complication in the receiver, for the sync pulse itself is usually employed to suppress the spot during the fly-back. It will no longer do this because of the sound pulse within it, but other methods of blacking out the spot are not hard to find.

The advantages of the system are obvious. Applied to a system such as that used before the war it would reduce the frequency band from 6 Mc/s to 5 Mc/s, since, as there is no separate sound transmitter, the 1 Mc/s guard band between the two is abolished also. This eases the design of the receiving aerial.

There is an obvious saving in the transmitter, since no separate sound transmitter is required and there is also a saving in the receiver. This is not quite so obvious, for many sets had several valves common to both sound and vision. The chief saving comes about through the easier separation of the sound and vision signals. With separate transmitters this must be effected by tuned circuits, and it is not always easy to secure adequate selectivity. With the new system only a simple limiter is needed. A further advantage is that with the pulse system ignition interference on sound should be less. The large amplitude sound pulses also provide an easy way of obtaining automatic gain control.

The sound frequency response obtainable is, of course, limited by the recurrence frequency of the pulses and this in turn is fixed by the number of lines in the picture. Sound and picture quality thus becomes intimately tied together. With the 10,125-c/s pulse frequency set by a 405-line picture, the sound frequency limit is about 5,000 c/s and in practice would probably be somewhat less. The system is, therefore, one which lends itself better to very high definition television. With a 1,000-line 25-frame system, for instance, the pulse recurrence frequency would be 25 kc/s and there should then be no difficulty in obtaining high quality sound with a response up to 10,000 c/s.

The system was demonstrated using a local transmitter and gave exceedingly good results. Picture and sound were normal and free from mutual interference. The sound quality was of the standard reached in ordinary broadcasting and it was impossible to tell by looking or listening that sound and vision were on a common carrier.

The principle of inserting pulses within the time allocated to sync pulses is one which can be carried further. It would, for instance, be quite possible to insert two pulses in each line pulse and so obtain two independent sound channels which could be used to give binaurial sound. Such pulses could also be used for conveying some of the additional information required in colour television.

LONG-WAVE ADAPTOR

Add-on Unit for Wartime Civilian Receivers

THE description, in last month's issue, of a long-wave converter for the Wartime Civilian Receiver has brought details of a commercially made article which provides the same facilities. This employs a 6K8 frequency changer, pre-set tuning and a range switch and it is designed to fit inside the cabinet of the parent receiver.

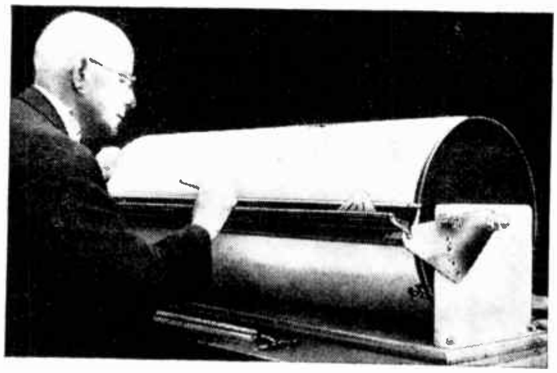
Installation is very simple as no modifications are required to the set; HT and LT are obtained by removing the output valve, plugging in an adaptor and inserting the valve in a socket provided on this adaptor.

The unit is designed for permanent fitting and should be screwed to the inside of the cabinet, a ¼in. diameter hole being required to pass out the spindle of the range switch. This range switch serves a three-fold purpose. In one position it provides long-wave reception, in another the 6K8 valve is converted into a low-gain RF amplifier, while in the third position the converter is muted and the aerial changed over to the parent receiver, thus reverting to the normal state.

The oscillator in the converter is pre-tuned before despatch to 360 kc/s, so that for reception on 200 kc/s (1,500m) the parent set must be tuned to 560 kc/s (536m). Reception is also possible of the BBC European programme on 250 kc/s (1,200m) by tuning the parent set to 610 kc/s (492m).

Made by I. Raleigh and Co., 239, Kilburn High Road, London. N.W.6, the converter, which is for AC sets, costs £2 17s. 6d. complete with valve.

CYLINDRICAL DRAWING "BOARD"



This "board" was devised by Metrovick draughtsmen for their own use in preparing circuit diagrams. The drum, covered with semi-transparent paper backed by guide lines, is free to rotate. Horizontal lines are drawn along the straight edge, while vertical lines are made by rotating the drum against a fixed pencil point.

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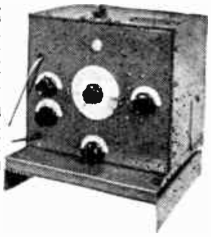

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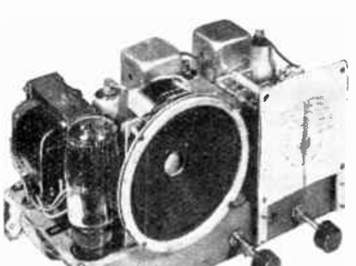

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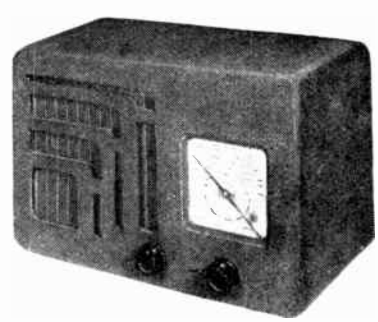

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BIOLOGICAL AMPLIFIERS

2.—"Compressor" Input Stages : Design for a Complete Amplifier

By D. H. PARNUM, B.Sc., A.R.C.S., Ph.D.

(Concluded from page 340 of the November issue.)

If push-pull stages throughout are not desired, the output from the balanced input stage must be "compressed" to operate a single-ended amplifier. Apart from the saving in cost and complexity, the final indicator may well be a cathode-ray tube of the type which needs an earthed input, so that the signal must be compressed sooner or later. The original Matthews circuit (Fig. 2 in Part 1 of this article) can be used for this purpose by a simple device. First the output is earthed at Q ; but if the cathodes are also directly earthed, the second valve will be shorted out from anode to cathode, so the cathodes are earthed through a high resistance. This amounts to connecting the resistance across the anode and cathode of the second valve, reducing its gain and slightly unbalancing the stage. The unbalance could be corrected by connecting an equal resistance across anode and cathode of the other valve. But the stage is not really satisfactory, because it is almost entirely floating above earth. The floating batteries will be likely to cause erratic effects, and so will bad subject-earth insulation. In view of later developments there is no necessity to use this type of compressor to-day.

The circuit of Fig. 8 (a), described in the same year by both Matthews[5] and Tönnies[6], has been widely used. V1 and V2 are valves of the same type ; there is a large common cathode resistor R_k, but only V1 has an anode load, across which the output is taken.

For inphase signals the output is obviously small, since there is adding of currents in R_k and much negative feedback. The action for antiphase signals is understood better from Fig. 8 (b). Half the signal is applied to A and the other half, in opposite phase, to B. Since V2 has no anode load it acts as a cathode-follower, and, the signal at B appears with very little loss at C, in the same phase. This voltage e' is injected into the cathode circuit of V1 at D. Thus the total grid-cathode voltage of V1 is $e + e'$, which is practically $2e$, the total signal. It might appear, however, that V1 would suffer negative feedback since its cathode returns to earth through R_k ; but this is not so, because the cathode impedance of V1 is the output impedance of V2 acting as a cathode-follower. This is very low, about 200 Ω if the mutual conductance of V2 is 5 mA/V. The antiphase gain is therefore practically the full gain of V1 ; actually V1 behaves as if its internal resistance were doubled.

The exact expression for the gain ratio (which for compressor stages is obviously the same as the output ratio) is :

$$r = \frac{1}{2} \cdot \frac{\mu_1 R_a + (\mu_1 - \mu_2)}{\mu_1 R_a + (\mu_1 + \mu_2 + 2\mu_1\mu_2)}$$

where

R_a = internal resistance of V2,
μ_1 = amplification factor of V1,
μ_2 = amplification factor of V2.

This result has been given in full because it has been incorrectly given elsewhere. An article by Debski[7] derives an incorrect result which is unfortunately quoted by Parr and Walter[8] in an otherwise excellent paper. Debski also makes the error of comparing interference of e at each grid to a signal of $+e$ and $-e$, i.e. a total signal of $2e$. This naturally makes the stage look more favourable by a factor of 2.

When the valves are of the same type, $\mu_1 - \mu_2$ is small ; if we also assume that R_a is much less than R_k, r becomes practically $1/g_m R_k$, where g_m is the mutual conductance of V2. With g_m = 5 mA/V and R_k = 50,000 Ω, this is 1/250. The condition for good discrimination is high g_m and R_k, valve matching being unimportant. If V1 is a pentode, the signal gain is increased. $\mu_1 - \mu_2$ is no longer small, and re-arrangement of the expression for r gives roughly $r = 1/\mu_2$, i.e. of the order of 1/50.

The discrimination is quite good, and the circuit has been used successfully by many workers, but it is natural to enquire if r cannot be reduced to zero. The condition is at once

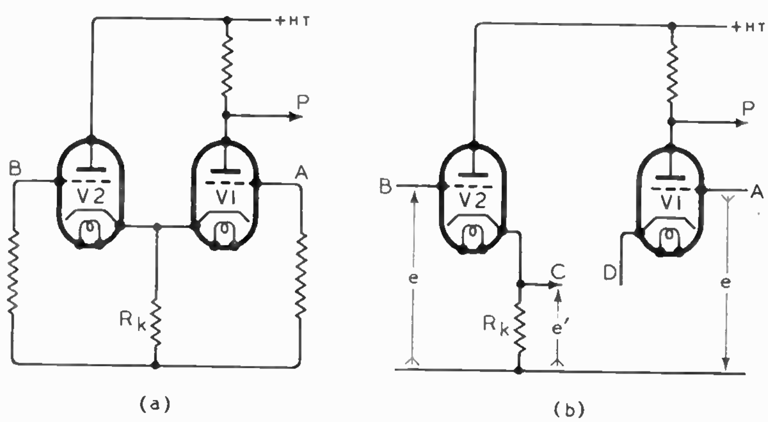
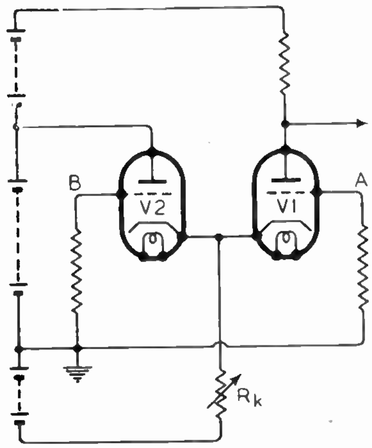


Fig. 8. "Compressor" input stage due to Matthews and Tönnies for feeding single-ended amplifier.

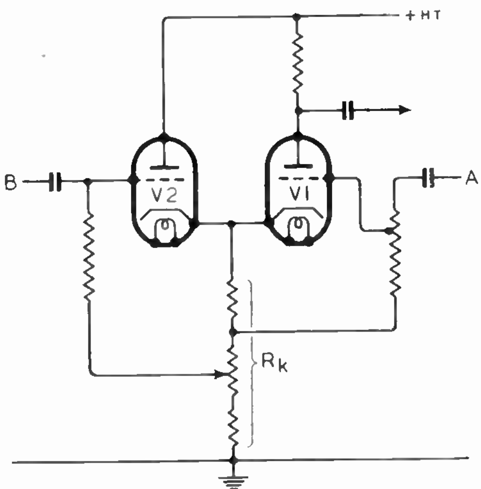
Biological Amplifiers—
found by putting the exact expression for r equal to zero, which gives

$$\mu_1 = \mu_2 R_k/(R_k + R_a).$$

This shows that μ_1 must be somewhat less than μ_2. The required reduction in μ_1 can be made by shunting V1 from anode to cathode with a resistance of value R_k. Unfortunately this reduces the signal gain noticeably—it effectively increases the internal resistance of V1 four times, if R_k is half the anode load—and if the shunt is made variable so as to act as an interference control, the gain variations would be a nuisance. Also there are practical difficulties in applying such a shunt. Altogether this stage is little better adapted to interference control than the push-pull circuits.



(a)



(b)

Fig. 9. Tönnies compressor circuit in a ZF amplifier. (a) with batteries (b) suitable for mains operation.

Fig. 9 (*a*) shows the practical arrangement of the Tönnies compressor as a ZF amplifier; this is also the only suitable arrangement as a biological input stage. V2 operates at a lower HT voltage than V1 in order to bring the anode currents to roughly the same value. Correct grid bias is obtained by returning the lower end of R_k to a negative battery tapping. This tapping is adjusted initially to give approximately correct bias, and the final adjustment made by adjusting R_k.

Fig. 9 (*b*) shows an AC version. Grid bias is now obtained by taps on R_k, and blocking condensers are used in the grid leads. This circuit is not really suitable as an input stage for biological work, because it requires an earth return on the subject. It is included because it is a useful compressor circuit for AF amplifiers. As V1 and V2 can now be given separate bias, it is convenient to do this, as shown, and run both valves at the same HT voltage. The circuit gives signal gain, and will handle a large inphase input—roughly μ times its normal input. For this application the fitting of a correcting shunt to give zero r is practicable, but it is simpler in this case to reduce the input to V1 slightly with a grid potential divider as shown.

It has already been noted that any balanced stage may be used as a single-ended amplifier. Fig. 9 is interesting in this way; a signal applied between A and earth gives a reversed phase output in the usual way, but when applied between B and earth gives an output in the same phase. The non-active grid must be tied to earth.

An interesting compressor has been described by Schmitt[9] using two pentodes. Signals are applied to the two control grids; one pentode reverses the phase of its own signal and applies it to the screen of the other. By suitable adjustments inphase signals can be made to cancel in the "mixing" pentode. This stage would not probably handle large inphase inputs, since there is no negative feedback and screen characteristics are seldom linear. It has the merit that variation of r is possible.

Inter-stage Coupling

There is one main choice: RC coupling or some type of ZF coupling. RC coupling is really satisfactory for nearly all biological work; the only point to consider is the LF loss. Suppose 4 μF condensers and 1 MΩ grid resistors are used; the time constant RC is 4 sec. The fractional loss per stage at frequency f is $1/8\pi^2(fRC)^2$ provided the loss is not too large. At $f = 0.1$ c/s the loss per stage is about 9 per cent. For four stages the loss will be about 30 per cent. This is probably good enough even for cardiography. RC coupling has considerable advantages: there is no difficulty about grid bias, the amplifier is not subject to long-period drift, and complicated initial adjustments are not needed. The only operating objection is that the later grids block when an abnormal input signal occurs, and owing to the long time constant it is some time before the amplifier is usable again. The trouble usually occurs when making adjustments to the subject, and as the gain control can be turned down while doing so, the objection is not serious.

Where there must be no doubt about the LF response, however, a ZF amplifier is the only solution. Since this means effectively a direct connection from each anode to the grid of the next stage, the chief practical difficulty is obtaining correct grid bias for all stages beyond the first. The difficulty of eliminating the effect of drift, due to valves or batteries in the first stage is almost as great. Undoubtedly the best solution of both difficulties is to use push-pull throughout in the manner of Fig. 6 of Part 1 of this article. Considering the coupling between the first and second stages as an example, the second stage cathodes

World Radio History

are lifted above earth by the drop in the common cathode resistor, and this backs off the large positive voltage received from the first stage anodes. Push-pull working is essential to remove the otherwise intolerable loss of gain due to negative feedback in the cathode resistor. It follows that the cathodes of each succeeding stage are at a progressively higher voltage, so that eventually no HT-cathode voltage is available, but with the number of stages normally needed this point is never reached.

The effect of valve and battery drift is greatly reduced by this method, because such drift is about the same in each half of the amplifier and is equivalent to an inphase signal. There is also the considerable practical advantage that only one HT supply, without tapping points, is needed. Goodwin states about the circuit of Fig. 6 that, after running-in, drift is less than 100 μV per hour, and less than 10 μV per hour when precautions against room temperature variations, etc., are taken.

An interesting variant of this method is used by Miller[10]; it consists of a series of Tönnies stages used as single-ended ZF amplifiers with the non-active grids held at a fixed voltage. This circuit is not really so good as a push-pull amplifier, since it uses just as many valves and does not have the push-pull freedom from drift.

Power Supplies

It is common practice to operate at least the first stage, and often the first two, entirely by batteries. This is not so inconvenient as it sounds, because in these stages the signal level is very small, and only a small HT voltage is needed. The advantages are considerable: good stability over long periods is assured; the whole stage and its power supplies can be isolated and screened; and there is no possibility of AC ripple being introduced (even with stabilised mains HT, ripple may enter via the heaters if these are fed with AC). To secure these advantages with a mains-operated supply is complicated and costly. Miller's amplifier is all-mains, but even here the valve heaters are fed in series from an electronic voltage regulator employing 5 valves, and the maximum gain is only 250,000. For gains of over 1 million batteries are not only cheaper but better.

It must not be forgotten that the LF response of biological amplifiers is so good that ordinary decoupling of the HT feeds is useless; so that if one supply is used to feed more than two stages instability will result. HT batteries help here, because they can be used for the first two stages and mains HT for the last two. More than four stages are seldom needed.

It seems wise in general to stabilise mains HT where used. Gas-tube regulators[8] have slight inherent flicker and drift, but should be quite satisfactory for any but ZF amplifiers. Electronic regulators can be as good as is desired; references (4), (10) and (12) will be found helpful.

Design of an Amplifier

Some general conclusions will have emerged from the foregoing. A balanced input stage is essential. The main choice is then between push-pull throughout, or a compressor followed by a single-ended amplifier. If frequencies below about 0.1 c/s must be passed, then the choice is a ZF push-pull amplifier. Fig. 6 of Part 1 is an excellent prototype.

For frequencies above 0.1 c/s, RC coupling with a time constant of 4 sec. is perfectly satisfactory. Most of the push-pull advantages are not needed, and a Tönnies compressor input stage (Fig. 9a) followed by a single-ended amplifier is one of the best solutions.

The purpose of negative feedback has sometimes been misunderstood. Although the details cannot be gone into here, it can be said that it gives no reduction in background noise or valve drift. It has chiefly been used

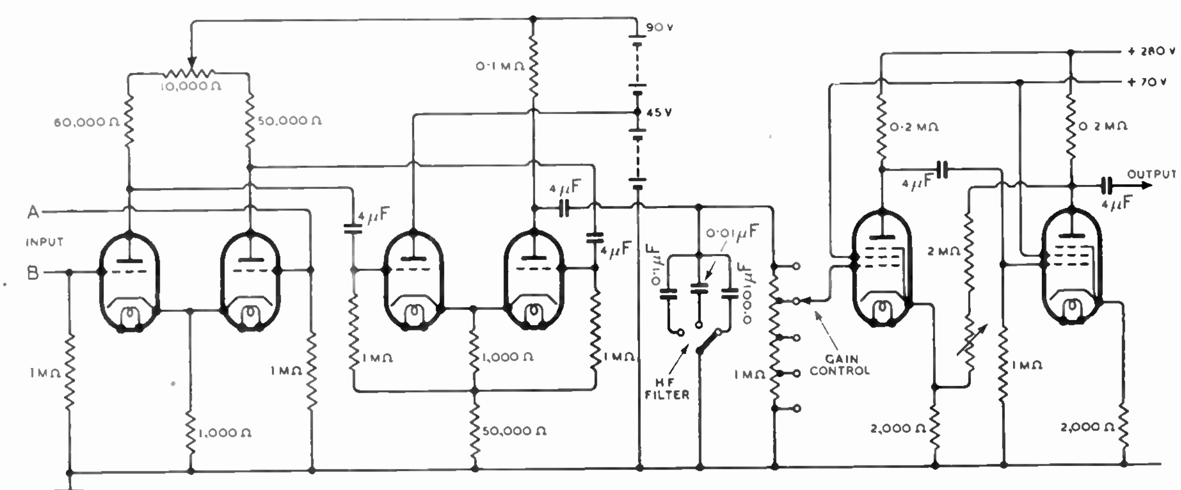


Fig. 10. Suggested amplifier circuit with input interference control and feedback in the output stage. Heaters of first two stages are fed from batteries.

Biological Amplifiers—

in the early stages; its value here, as has been shown, is to give inphase/antiphase discrimination; but it is pointless to use it on the signal, because the voltage level is so low that there is no possibility of distortion. There is a good case for using signal feedback over the output stages, but here the principle of varying the feedback factor to control gain is not worth while unless the feedback is enormous. It seems better to use the maximum feedback available and reduce gain in steps by a tapped grid resistor in a preceding stage.

Fig. 10 is shown more as an illustration of these and some other points than as a recommended circuit; it has not been given a practical test. The output indicator is assumed to be a cathode-ray tube with a sensitivity of about 1V/mm, and requiring an earthed input. The first stage is push-pull without a large bias resistor, and fitted with an interference control as in Fig. 7 of Part 1; the adjustment shown will control interference inequality of about ± 1%. One of the fixed anode loads is larger than the other to compensate for the residual inphase transmission o the second stage, which is f Tönnies compressor. These twa stages are operated from a 90 Vo battery, tapped at 45 V; this allows the grid bias of both compressor valves to be the same, and makes the full battery voltage available for the first stage. The last two stages are supplied from a "Stabilovolt" regulator, which is convenient because it provides a 70 V low-impedance source for the screens.

Using high-slope triodes for the first two stages, or triode-connected high-slope pentodes, their gain will be at least 1,000. The last two stages, using SP41's, have an internal gain (allowing for the negative feedback in the cathode resistors) of about 14,000; the overall feedback reduces this to about 1,000. The total gain is thus about 1 million, giving an output sensitivity of about 1 μV/mm. The output feedback reduces distortion to about 1/15, and a swing of 200 V peak-to-peak is available with not more than 2 per cent. distortion. Gain control is by the tapped grid resistor of the third stage, operated by a good-quality selector switch. This can conveniently be arranged to give gain ratios of 1, 2, 4, 8, etc., or 1, 2, 5, 10, etc., as desired. The basic gain can be adjusted to a convenient round figure by the variable portion of the feedback resistor. When the correct value has been found by calibration, the variable might well be replaced by a fixed resistor to improve stability. The 2-megohm resistor must in any case be a high-stability component.

A simple HF filter is fitted between the second and third stages. It is always desirable to limit the HF response to that required by the signal, because this reduces background noise considerably. As far as thermal agitation and shot noise is concerned, analysis shows that there is no advantage in using anything sharper than a simple RC filter. The three values shown give pass-bands of about 0.1, 1, and 10 kc/s; the exact value depends on the internal resistance of the preceding valve, which has been assumed to be 10,000–20,000 Ω.

It is emphasised that many of the component values shown are tentative. The cathode resistors of the first two stages need adjusting to give a bias between 0.8 and 1 V, to avoid grid current yet to maintain gain. The bias of the output stages should be adjusted to give an anode voltage of about 150 V. The use of cathode bias, instead of battery bias, throughout allows the optimum bias to be given to every stage. There is no LF loss on this account because all the bias resistors are un-bypassed.

The writer wishes to thank Dr. G. H. Bell, of Glasgow University, for the suggestion that he should undertake this review, and also for supplying a number of references.

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TIMING BY RADAR

THE Radar Division of the Royal Aircraft Establishment recently installed experimental equipment at Herne Bay for investigating the potentialities of radar for timing the high-speed Meteor aircraft.

Basic radar principles of measuring the time a pulse of radio energy takes to travel from a transmitter to an aircraft and back to an adjacent receiver are employed, but additional circuits have been added to an otherwise standard centimetre-wave radar set. By means of these additions two artificial signals are mixed with the received signals; the timing of these artificial signals is so adjusted that if they were fed to a cathode-ray tube, with a suitable time-base, they would appear as "blips," one corresponding to the distance of the start of the course from the transmitter, and the other marking its finish.

When the echo signal from the aircraft exactly coincides with the first marker pulse a circuit is tripped and an electronic device commences to count the pulses emitted by the transmitter.

The pulse repetition frequency of the transmitter, and the frequency of the marker pulses are both known very accurately, so that the number of pulses emitted during the time the aircraft echo takes to travel from the first to the second marker pulse is a measure of the speed and is easily converted into miles per hour.

Actual measurement of distance is unnecessary with this method, as distance is converted into time intervals in terms of pulse repetition frequency and the velocity of radio waves. Thus in order to obtain an artificial course length of 3 km, the time interval between the two marker pulses must be 1/50,000th second, bearing in mind the fact that a radar signal makes a double journey. This is the exact time of one complete cycle of a 50 kc/s oscillation.

Taking into account all sources of error it seems possible to achieve an accuracy in timing to 1 mph in 600 mph and the speed can be given in a matter of seconds after the aircraft has finished its run. H. B. D.

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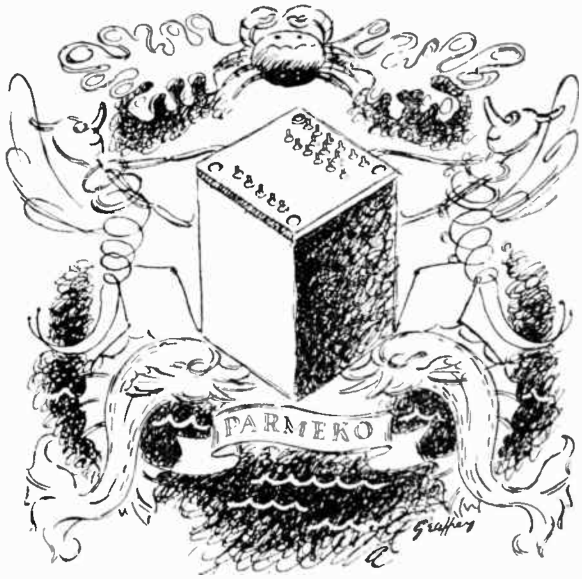

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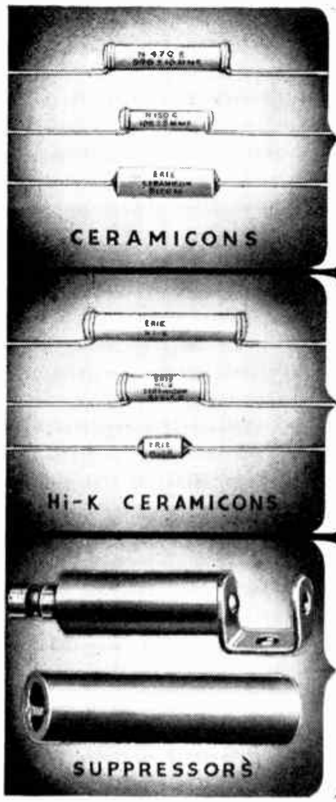

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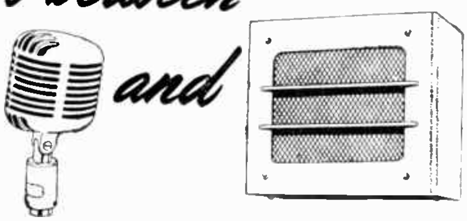

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WAR REPORTING

Equipment Used by the B.B.C.

By W. D. RICHARDSON and P. H. WALKER, B.Sc., A.M.I.E.E.

(Engineering Division, British Broadcasting Corporation)

LONG before the invasion of Europe it was decided that means must be provided for giving B.B.C. listeners direct reports from the front line, starting from the first landings and continuing up to the conclusion of the campaign. Clearly, radio provided the only possible means, but the detailed problem was not easy. The initial radio link might have to cover merely a short Channel crossing or, if the landings were made at more remote points, distances of several hundred miles. In the first case short waves would be unsuitable, but medium waves would be equally unsuitable for longer distances; therefore a wide range of frequencies would be needed. It was finally decided that the following sets of equipment, complete with their own power supplies and accessories, should be designed and built:—

(1) One highly mobile 250-watt set, covering the frequency range 500-15,000 kc/s for use at the invasion landings.

(2) Two 7½-kW equipments, less highly mobile, to work on short waves only; at the stage where they would come into operation, the Army would have advanced beyond economical medium-wave range of U.K.

(3) One or more fixed stations.

All the gear had to be arranged for morse transmissions, to provide a link between London H.Q. (where a morse transmitter was installed in Broadcasting House) and the various units on the Continent. The fullest possible use was made of available commercial apparatus capable of being adapted for use as mobile transmitters, but much of the incidental technical equipment had to be specially developed. For example, commentators used a midget disc recorder,* designed for almost automatic operation and weighing under 30 lb. More substantial disc recorders were installed in ambulance trucks.

The 250-watt transmitter, which gave its output into a balanced load of 600 ohms or an unbalanced load of 50 ohms, was mounted in a three-ton Army lorry together with its 2-kW petrol-driven motor generator set, drive unit, re-broadcast and communication receivers, a small desk equipped with morse key and microphone, and all tools, spares, aerial and portable mast equipment. Needless to say, the layout was somewhat cramped, but in spite of this the transmitter gave sterling service on the Normandy beachhead and afterwards.

* Wireless World, May, 1944.

No mobile transmitters of the required power were available for the 7½-kW sets and the B.B.C. decided to convert two stationary broadcast sets for the purpose. These transmitters used air-blast cooled valves, and their size and weight was such that it was impossible to mount them as they stood in any single vehicle. It was, therefore, decided to divide each transmitter into two parts: (a) the RF unit, complete with its modulator, and (b) the various HT and GB rectifiers.

These units were mounted directly on to the chassis of separate trailers with anti-vibration mountings of the bonded rubber-to-metal type. To save weight, the modulation feed reactor, weighing 10 cwt., was dispensed with, the HT feed to the modulated amplifier being passed through the secondary of the modulation transformer; quality was not sensibly affected, and was quite satisfactory for the service contemplated. The RF trailer (No. 1) carried complete speech input equipment, re-broadcast and communication receivers, a complete twin-turntable gramophone unit, also monitoring and morse transmitting gear.

MCN parked in a factory yard in Germany. The transmitter trailers are in the rear while the studio and stores vehicles are in the foreground. In this instance factory chimneys were used for supporting the aerial.

The second trailer carried the 2,000V, 4,000V and 6,000V HT rectifiers, the 1,500V grid bias rectifiers and the two RF drive units.

All connections between the two trailers were made by 20-yd. lengths of flexible cable. The power supply cable was 100 yds. long so that advantage could be taken of any available alternative supply, and

World Radio History

War Reporting—
in order to cater for such an eventuality the transmitter was powered via an auto-transformer covering the range of 380 to 440 volts input.

One of the towing vehicles carried a 27.5-kVA diesel generator set, three 110ft. portable masts, stays, anchor plates, aerials and feeders. The other was loaded with sets of spares and tools to meet all eventualities.

A third lorry housed complete studio facilities, including reproducing gear, microphones and amplifiers sufficient to enable the various commentators to broadcast "live" to the listeners at home or to record their material for use later on. The power supply for this unit (a 6-kVA diesel generator set) was separate and independent of that used for the transmitters so that, if necessary, the studio could be divorced from the rest of the unit.

The whole unit was equipped with both main and emergency lighting, power sockets, etc., and in addition to normal equipment and a vast number of spares, a prismatic compass, first-aid box, cooking stoves, heaters and a battery charger were supplied.

The centre of the home organisation was the Traffic Room at Broadcasting House, London, where transmission schedules were arranged, and material received was passed on. The reception routine was not rigid, and could be modified to suit immediate needs. On one occasion we were unable to transmit an important story until after the 9 p.m. news had started, and yet we heard the story coming back in War Report only twelve minutes after it had been sent to London. On other occasions despatches were broadcast from the field transmitter direct into the B.B.C. programmes, but owing to the many interests of the Corporation it was impossible to make a regular practice of simultaneous rebroadcasting. American requirements were simpler, and whether their commentators spoke over our transmitters or their own whenever possible their despatches went "live" into the American network programmes. Australia, too, took from us many "live" contributions, relayed to them via the B.B.C. overseas service.

Traffic Room was linked with the Normandy beachhead first with the 250-watt set, described earlier. This, together with a petrol generator set, portable masts, aerial gear, microphone amplifiers, all fitted into a 3-ton truck, with a crew of four engineers and the call sign MCO, set out on D plus 7. Using a tent and later a room in a château near Bayeux as a studio, this transmitter was responsible for sending home a large proportion of the Second Front news stories used by the B.B.C. in the first eight weeks of the invasion.

MCO was followed by a 5-kW double-channel short-wave set of very compact design, crated and packed with all accessories into two 3-ton trucks ready for installation in a building as a fixed station on arrival in France. Due to delays, the transmitter was not in operation till after the American break-through from the beachhead and the people for whom it was intended had moved forward. This station was later reinstalled in Paris for the use of correspondents at SHAEF. It was timely that the first of the 7.5-kW mobile transmitters, MCN, arrived at the Mulberry port of Arromanches during the subsequent British breakthrough.

MCN travelled to Brussels before going into service. The site used was formerly a Belgian Government receiving station, though, as we found it, it had been stripped of all its equipment, including masts, by the Germans. From here MCN covered British Army and R.A.F. operations until shortly after the withdrawal of the remnants of the airborne forces from Arnhem. We were more than grateful to the Belgian radio authorities for the facilities given to us at their studios and transmitter, and for their efforts to get the badly damaged cable between their studios and our transmitter site into working order again.

Royal Canadian Air Force photograph

The filament leads being replaced on an air-cooled CAT3 valve on arrival at a new site

Soon after Arnhem, MCN moved up to Eindhoven and remained there until just before the Rhine crossing. In the meanwhile, some changes were made to the equipment. The towing trucks were replaced by Matador medium-gun tractors. It would be hard to find vehicles which were more suitable for the job.

The 27.5-kVA Diesel generator set was mounted on the floor of one Matador while the other

World Radio History

Matador was fitted up as a workshop, mess room and general store for transmitter spares, workshop materials and aerial gear.

As stated, MCN had been provided with additional studio facilities installed in another three-ton truck. Using the four-channel gramophone turntable unit, the most complicated mixing job could be handled easily; by letting down the small table a number of speakers could be grouped round a floor stand microphone, while the control room at the far end had in addition to normal microphone amplifiers and mixing circuits a comprehensive set of telephone line testing and equalising equipment. Every facility provided in this truck was used at one time or another and apart perhaps for smaller gramophone desks there is little that we would have had different in it.

Frequencies allocated to us were in the middle of Army operational bands, and, frankly, the Army did not like our high-power sets, because of the interference they caused. The use of directional aerials to reduce interference was desirable, but here various difficulties were encountered. Where necessary a rhombic aerial was used. This had the advantages that one aerial could be used for several wavelengths and any length of feeder required at a new site could be fitted without the need for retuning the transmitter output stage.

The transmitters in the American sector used principally dipole aerials, and sometimes horizontal V's—their fairly low power making it unnecessary to trouble unduly about back and side radiations. But the low power itself was a drawback in view of the tasks ahead. Arrangements were made for the second 7.5-kW mobile transmitter to come over and join the Americans. This set landed at Ostend and paused for a while at Brussels for testing, change-over to Matador towing vehicles, and for the modifications found desirable on MCN. The fixed station at Paris had been closed down and dismantled by this time so the new mobile took over the call sign MCP.

MCP went on from Brussels via Namur to Luxemburg, and thence followed the American armies to and over the Rhine, eventually reaching Berlin to report the triumphal march through the city, and commentaries on the Potsdam conference.

Before crossing the Rhine, the allocation of a new and higher frequency in the 7 Mc/s band enabled the transmitters to operate further away from the Service channels and anti-interference measures were less necessary. At first the frequency was so high relative to the distance from London that complete fadeouts were experienced, but as the advance continued the channel provided very reliable communication. The allocation of the new frequency coincided with experiments to find an easily erected fairly directional aerial. The type used by all transmitters till the end of the tour was a centre-fed horizontal one of 1.25 wavelength overall length, sometimes with two 0.5-wavelength directors, all suspended from two masts using side strainers to get the necessary spacing. This length of aerial gave a forward gain of some 3 db. over that from the normal full-wave dipole.

With the help of the new frequency the 250-watt transmitter continued to give good service and was in operation in Flensburg almost immediately after the German surrender and before British troops arrived there in force. MCN was at Luneberg at the time and was able to transmit to London recordings of the German surrender to Field Marshal Montgomery.

In spite of the size of the 7.5-kW equipment, it was possible after some experience, and the modifications made, to be in operation 2½ hours after arrival at a new site—compared with two days when first erected at Brussels. Morning despatches could be transmitted, the unit dismantled and moved some 60 to 80 miles, and be in operation again in time to send news reports home the same evening.

Much of the smoothness of the operation during the whole campaign was due to willing co-operation from the Public Relations Services, Royal Signals, and other technical units. This opportunity is taken of thanking them all for their assistance.

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WORLD OF WIRELESS

BROADCAST RECEIVERS

THE manufacture and supply of receivers is still controlled under the Musical Instruments and Wireless Receivers Order, 1944 (S.R. & O., 658/45); licences have, therefore, been granted by the Board of Trade to some 70 manufacturers for the production of civilian sets, of which about one million are planned for the next twelve months. Of this quantity 400,000 are intended for export. It is stated that undertakings have been given by the industry that 50 per cent. by value of the production for the home market will be devoted to sets to be retailed at £15 or less, exclusive of Purchase Tax.

Owing to the limited quantity of timber available for cabinets, many of the manufacturers will be using plastic materials.

Before the war, the average annual production of sets in this country was about 1,400,000, of which approximately 66,000 were exported. It will be seen, therefore, that whereas the present programme visualises an overall production of only about 70 per cent. of the pre-war figure, there is a six-fold increase in exports.

WEATHER REPORTS

THE removal of wartime restrictions on the use of radio by ships at sea permits officers of British merchant ships to resume their observations for the Meteorological Office. Since November 1st they have again been transmitting routine weather reports, a voluntary service undertaken for many years.

An Atlantic weather bulletin is now broadcast for merchant ships. This transmission, which is in plain language, includes details of existing weather and area forecasts in the North Atlantic.

The bulletin will follow the routine messages to British and Allied merchant ships broadcast by the Admiralty at 1000 and 2200 GMT. The frequencies employed are 149, 7,355 and 12,455 kc/s at 1000, and 149, 4,025 and 7,355 kc/s at 2200.

1924. One of the first pictures received by radio after crossing the Atlantic.

PICTURES BY WIRELESS

TWENTY-ONE years ago, on November 30th, 1924, the first picture was transmitted by wireless across the Atlantic.

When the half-plate photograph of the then Prince of Wales, reproduced below, was received in New York—having been transmitted from London—it had taken approximately twenty minutes to send. Now it takes only about six minutes to transmit a photograph double the size.

Before the war, Cable and Wireless operated only three phototelegraphic circuits, with Melbourne, New York and Buenos Aires. Traffic, however, was negligible, except on the New York circuit, which handled about 45 pictures every month.

To-day, although the whole of the London phototelegraph apparatus was lost in the fire which destroyed the company's Central Telegraph Station at Moorgate in May, 1941, eleven services are being operated with Empire and foreign countries, and nearly 2,000 photographs and facsimile documents a month are being transmitted and received. In addition to the direct circuits between London and Montreal, Melbourne, Capetown, Bombay, New York, San Francisco (relayed from New York by R.C.A.), Buenos Aires, Moscow, Stockholm, Berne and Cairo, there is a broadcast system from London, the phototelegrams being received regularly by Stockholm, Berne, Rome, Paris, Brussels, Lisbon, Casablanca, Leopoldville, Johannesburg, Cairo, Bombay and Istanbul.

Some idea of the advance made in phototelegraphy will be gained from a comparison of the two untouched photographs reproduced here.

The sub-carrier frequency-modulation system of transmission, which is at present in use, was introduced in 1939.

IN PARLIAMENT

THE Assistant Postmaster-General revealed in the House of Commons that no decision had yet been reached on the question whether the undertakings of broadcast relay companies should be acquired on the expiration of their licences as recommended by the Ullswater Committee in 1935, or whether the development of a Post Office service should be revived, plans for which were suspended in 1940. He also stated that the number of subscribers to the 274 relay exchanges was 584,018 on June 30th.

Several questions have been tabled regarding amateur activities.

Mr. W. A. Burke, the Asst. P.M.G., stated that no substantial change was contemplated in the conditions under which licences would be granted for experimental radio transmitters.

In reply to a question on November 1st it was stated that it was intended to begin returning impounded amateur gear to the 60,000 owners "in about a fortnight's time," but it would take some weeks to complete. Regarding the reallocation of wavelengths it was announced that the military authorities hoped to be able to release a limited number of frequencies for amateur working very shortly.

When asked whether, in view of the fact that many of those with special certificates as wireless operators were unable to qualify by sea service for second-class certificates

1945. A test picture transmitted from Stockholm and received in London in October.

World Radio History

owing to the absence of suitable vacancies, he would relax the condition as to sea service, or, alternatively, give some compensating advantage to holders of such certificates, the Asst. P.M.G. replied that as from January 1st, 1946, holders of special certificates as wireless operators might take the examination for second class certificates without having had any previous sea service; additionally, holders of special certificates obtained up to the end of 1945 might continue to serve on all British merchant ships until December 31st, 1946.

The President of the Board of Trade was asked if he was aware that "users of radio valves were being compelled to pay high prices through the operations of the B.V.A. ring." In reply he stated that he was asking the Central Price Regulation Committee to make enquiry and report whether the prices were, in their opinion, fair.

It is understood on enquiry from the B.R.V.M.A. that the Association has offered its help to the Central Price Regulation Committee in obtaining any information required.

The question of adapting wartime civilian receivers for the reception of long waves was raised by one M.P. In reply the President of the Board of Trade said that arrangements had been made with manufacturers for sets to be modified. Owners of utility sets who wish to have them adapted should get in touch with their retailers. The President stated that an adaptor costing 13s., including purchase tax, was on the market.

The Minister of Information announced that the B.B.C.'s capital expenditure on engineering works and equipment during the period September 1st, 1939, to March 31st, 1945, was about £3,550,000. In addition, Lend-Lease equipment to the value of £350,000 was brought into service by the Corporation.

It was stated by the Minister of Information, in reply to a question on the future of television, that steps were being taken to set up a Television Advisory Committee on the lines recommended in the Hankey Report. He added that, until this Committee is constituted and has taken stock of the position, it would be premature for him to make any statement on future television arrangements.

WIRELESS WORLD DIARY

PRODUCTION difficulties have delayed the publication of the *Wireless World* Diary, 1946, and it is regretted that copies will not be available until early in December. Owing to limited supplies, they will only be obtainable through booksellers or stationers, price 3s. 4½d.

AM/FM SETS

AMERICAN listeners have been advised by a member of the Federal Communications Commission to buy a combined AM and FM receiver when purchasing a new set. It was pointed out that the speed with which FM develops will depend on "how rapidly listeners accept this new method of transmission."

The commissioner predicted that within four or five years at least half the homes of the U.S. will have sets equipped to receive FM transmissions. He stated that the extra cost for the FM equipment in a receiver would not be great—perhaps not more than that paid for the short-wave coverage in an ordinary broadcast set.

PERSONALITIES

Dr. C. C. Paterson, F.R.S., Director of the G.E.C. Research Laboratories, is now one of the members of the Advisory Council to the Committee of the Privy Council for Scientific and Industrial Research.

Capt. Spencer Freeman has relinquished his special duties in relation to the reconversion of the radio industry and his position as business member of the Industrial and Export Council.

A. P. Rowe, C.B.E., has been appointed Deputy Controller for Research and Development at the Admiralty, in which position he assists the Controller of the Navy in supervising the application of science, technology and design engineering and advises the Board of Admiralty on research and development generally. During the war he was head of T. R. E. Malvern—the largest radar establishment in the country—which has been responsible for the radar equipment both of the R.A.F. and Fleet Air Arm.

Dr. P. Dunsheath, O.B.E., President of the I.E.E., Director and Chief Engineer of W. T. Henley's Telegraph Works Co., has been appointed Consultant and Adviser to the Director of Electrical Engineering at the Admiralty.

Maurice Gorham, B.A. (Hons) is to take charge of the B.B.C.'s television service. He joined the B.B.C. in 1926, from 1933-41 he was Editor of the *Radio Times* and from 1941-44 Director of the North American Service.

D. R. Parsons has joined the staff of R.M. Electric, Ltd., Team Valley Estate, Gateshead, where he will be responsible for the Development Laboratory of the Receiver Section. For the past eight years he has held a similar position with G.E.C.

IN BRIEF

1946 Components Exhibition.—Preliminary arrangements have been made for the 1946 Radio Component Manufacturers' Federation Exhibition, which is to be held at Grosvenor House, Park

H.A.5 DEAF-AID CRYSTAL MICROPHONE

ASTATIC is ready to serve you again with high quality piezo-electro devices now that the 'All Clear' of Victory has sounded. Astatic deaf-aid microphones can be supplied only if Import Permits are established. Model H.A.5 illustrated is used as standard by America's leading hearing-aid instrument makers.

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will again be a factor in the plans of far-sighted manufacturers of electronic equipment. From building precision parts for wartime devices the Croname group will turn to the processing of mechanical and decorative items for the electronic industry.

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World of Wireless—

Lane, London, from February 19th-22nd inclusive. As in previous years, admission will be by ticket only, and it will not be open to the general public.

Anglo-French Relations.—Sir Edward Appleton, Secretary of the Department of Scientific and Industrial Research and President of the International Scientific Radio Union, recently addressed the French Society of Radio Electricians at the Sorbonne, Paris, on "Recent Radio Research in Great Britain." Professor H. Abraham, President of the Society in 1940, and many members were arrested and deported to Germany during the occupation. There is still no news of their whereabouts.

American Amateurs have again been on the air. The F.C.C. authorised transmission on the 112-115.5 Mc/s band for about two months. During this time they shared the band with the War Emergency Radio Service, the operation of which ended on November 15th. Holders of licences which were valid up to December 15th, 1942, were permitted to operate their stations.

Radio Luxembourg.—The United States Army has handed back the high-powered broadcasting station in Luxembourg to the Government of the Duchy. It appears from this that there is now little likelihood of using it as a United Nations station as was proposed. A new network of stations, comprising Frankfurt, Stuttgart and Munich, is now operating in the American zone of Germany.

Restoration.—Four of the twelve Cable and Wireless Far Eastern stations which were occupied by the Japanese—Singapore, Hongkong, Batavia and Penang—have now been wholly or partially restored. From Singapore two-way wireless circuits are being operated via the "Press Ship" in the harbour.

Motor Jubilee.—Few realise that it is only 50 years since the first demonstration in this country of the "Horseless Carriage." This fact is brought vividly to mind by the publication of the Special Jubilee Number of our associate *The Autocar*—the world's first motoring journal—on November 16th.

U.S.S.R. Radio.—According to a broadcast from Moscow a powerful new transmitter has been completed in the capital and is working on 360.6 m.

Cabinet Design.—"Shapes of Things to Come" is the title of a competition organised by the Central Institute of Art and Design. Designs for all types of household furniture are invited from British subjects of either sex under the age of 30, for which cash prizes are offered. Section 3 includes designs for radio cabinets. Entry forms can be obtained from The Central Institute of Art and Design, The National Gallery, Trafalgar Square, W.C.2; closing date for entries is March 31st, 1946.

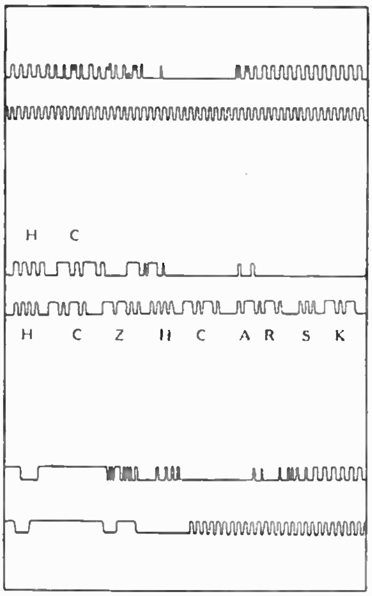
Juvenile Radio Lectures will be given by Sir Robert Watson Watt at the Royal Institution, 21, Albemarle Street, London, W.1, on December 27th, 29th and January 1st, 3rd, 5th and 8th, commencing at 2.30. The fee for juveniles between the ages of 10 and 17 is half a guinea.

Romford Radio Society is now having regular weekly meetings on Tuesdays at 8.30 at the Y.M.C.A. Red Triangle Club, North Street, Romford. Hon. Sec.—R. C. E. Beardow (G3FT), 3, Geneva Gardens, Whalebone Lane North, Chadwell Heath, Essex.

Edgware Short-Wave Society has commenced fortnightly meetings on the first and third Wednesdays of the month at the Constitutional Club, Edgware. Further details can be obtained from the Secretary, P. A. Thorogood (G4KD), 35, Gibbs Green, Edgware.

Leicester Radio Society is holding meetings at the Charles Street United Baptist Church (side entrance) at 7.30 on November 27th and December 11th. Hon. Secretary is O. D. Knight, 16, Berners Street, Leicester.

Decca Navigator.—It was announced by the Chairman of the Decca Record Company at the annual general meeting that the world rights and patents of the Decca Navigator, which we hope to describe in a forthcoming issue, are being transferred to the new subsidiary Decca Navigator Company.



BLESSINGS OF DIVERSITY. The advantages derived from diversity reception are graphically shown in this illustration. It shows three pairs of undulator tapes simultaneously recording the same transmission ; the upper of each pair was recorded on a good single-channel receiver and the lower on a diversity receiver. It will be seen from the centre pair that seven letters "lost" in single-channel reception were regained by diversity. Illustration from *AWA Technical Review* (Australia), March, 1945.

Change of Address.—The sales department of Measuring Instruments (Pullin), Ltd., is now at Phœnix Works, Great West Road, Brentford, Middx. (Telephone: Ealing 0011.)

Multicore Solders.—Owing to the continued Government requisitioning of their offices at Bush House, Multicore Solders, Ltd., are unable to return there. Their permanent address will, therefore, be Mellier House, Albemarle Street, London, W.1. (Telephone: Regent 1411.)

Marconi Instruments have established a Northern office at 30, Albion Street, Hull. (Telephone: Hull 16144.)

"Power Laundry."—This journal has now been acquired by our Publishers, and will in future be issued from Dorset House.

MEETINGS

Institution of Electrical Engineers

Radio Section.—Discussion on "Film Forming Materials used in Insulation" to be opened by C. R. Pye, B.Sc., on November 27th.

"The Design and Use of Radio-Frequency Open-Wire Transmission Lines and Switchgear for Broadcasting Systems" by F. C. McLean, B.Sc., and F. D. Bolt, B.Sc. December 5th.

Discussion on "The Servicing of Radio and Television Receivers" to be opened by R. C. G. Williams, Ph.D., B.Sc. (Eng.) on December 11th.

All meetings commence at 5.30 and will be held at the I.E.E., Savoy Place, London, W.C.2.

London Students' Section.—"Atmospherics and their Location" by C. Clarke, at 7.0, on December 18th at the I.E.E., London.

Cambridge Radio Group.—Repeat of Inaugural Address as Chairman of the London Radio Section by A. H. Mumford, B.Sc. (Eng.) at 6.0, on December 10th, in the Technical College, Collier Road, Cambridge.

British Institution of Radio Engineers

London Section. — "Ultra-High-Frequency Aerial Technique" by S. G. Button, at 6.0, on December 19th, at the Institution of Structural Engineers, 11, Upper Belgrave Street, S.W.1.

North-Western Section. — Discussion on "Post-War European Broadcasting" (R.I.C. Report), to be opened by G. Bernard Baker at 6.15, on November 28th, at Reynolds Hall, College of Technology, Manchester.

Scottish Section. — "Ultra-High-Frequency Technique" by Prof. M. G. Say, at 7.30, on December 11th, at the Herriot-Watt Memorial College, Edinburgh.

North-Eastern Section. — "Review of Industrial Electronics" by J. Hare and J. C. Finlay, at 6.0, December 12th, at the Mining Institute, Neville Hall, Westgate Road, Newcastle.

Midlands Section. — "Ultra-High-Frequency Aerial Technique" by S. G. Button, at 6.15, on December 14th, at Birmingham Chamber of Commerce, 95, New Street, Birmingham, 2.

Institute of Physics

Electronics Group. — "Dielectric Heating" by A. J. Maddock at 5.30, on November 28th, in the Lecture Theatre of the Royal Institution, 21, Albemarle Street, London, W.1.

World Radio History

ARMY SET No. 10

Centimetre Waves : Pulse Modulation : Multi-Channel

SOON after D-day the Army brought into use a piece of wireless equipment which was unique in the history of military communications. It was unique in that it combined the security from interception of the line circuit with the flexibility of wireless, and it achieved this primarily through the use of centimetre waves.

The military user of wireless communication has continually at the back of his mind the danger of enemy interception, and he has to regulate his use of wireless accordingly. There has consequently been in the past an understandable preference for line communications with which the chances of interception are much smaller.

The great drawbacks to lines, however, are the man-power and time needed for their erection and maintenance, and their vulnerability to enemy action. This will be realised when it is remembered that a line of only 20 miles requires the erection of some 700 poles for its support. The impossibility of erecting line circuits to follow up a rapid advance, such as that through France, is self-evident. It is here that centimetre-wave wireless steps in. Because of the peculiar properties of such waves, almost complete freedom from interception can be obtained, and yet a circuit can be established so quickly that communications can keep pace with the most rapid advance.

Centimetre Waves

The great advantage of the No. 10 set—its freedom from enemy interception—is secured through what is often considered to be a drawback of centimetre waves. This is the fact that their laws of propagation are very similar to those of light. Radiation progresses along substantially straight-line paths, and it is interrupted by any sizeable obstacles in its way. It is, however, unaffected by fog and rain, and it takes but little notice of small obstacles.

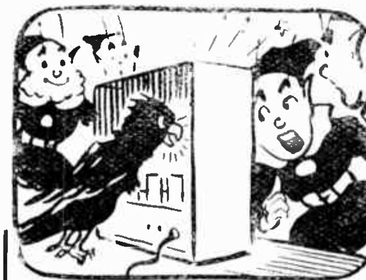
In addition, the aerial can be large in terms of wavelength while still small physically, so that the radiation can be confined to a narrow beam, not unlike that of a searchlight. It is easy to see that under these conditions enemy interception is virtually impossible unless the beam is pointing straight at his territory. This, of course, cannot always be avoided, for one naturally desires to work to and from one's own lines, but it is here that the liability of centimetre waves to interruption by obstacles comes in. By siting the station so that there is a hill between the receiver and the enemy the signal can be prevented from reaching him.

By the use of beams and by choosing sites so that there are hills to block the beam from the enemy, it is not difficult to secure freedom from interception. It should be noted, too, that these same factors also prevent mutual interference between one's own sets—a very important point in peace as well as war.

The range obtainable is limited chiefly by the terrain, for while it is desirable to site stations so that hills interrupt the beam beyond the receiver, it is necessary to site them so that it is not interrupted along the required path. The range depends more on the nature of the country than on the equipment, therefore, and is usually about 20 miles. It is, however, sometimes well over 50 miles.

The use of centimetre waves confers another advantage. Ether space is not restricted, and large band-widths can be used. This in its turn permits the use of pulse modulation, and this is very desirable if only because it lends itself to a particularly simple form of multi-channel operation.

The No. 10 set is designed to handle eight speech channels



THE "FLUXITE QUINS" AT WORK

"Would you believe it ?" said OH,
"I can't get this wireless to go . . ."
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Hark ! it's talking," cried OI,
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World Radio History

simultaneously. The transmitter accepts the audio signals from eight lines, arranges for each channel to modulate a train of pulses, mixes the eight trains, and radiates bursts of RF energy corresponding to the pulses. The receiving equipment performs the inverse function ; it sorts out the received pulses, routes them to their correct channels and demodulates them into the audio signals again.

The complete No. 10 set station is housed in a four-wheel trailer and is thus readily transportable. Circular mirrors form the aerials and are mounted on the roof, but if additional height is needed, a special transportable 60ft. tower can be employed to carry the mirrors.

The sets work in pairs to provide eight duplex telephone channels, and long distances can be covered by using relay stations. Great use was made of such relays on the Continent, and on at least one occasion no fewer than ten links were used to connect Luneberg and Brussels. At Brussels the circuit joined the normal land line. Direct communication between Luneberg and Whitehall was thus maintained by a mixture of centimetre-wave wireless and ordinary land line.

Development and Use

The idea of the No. 10 set first arose as far back as 1941, and the credit must go chiefly to W. A. S. Butement, A. V. Oxford, E. W. Anderson and J. G. Macmillan of the Ministry of Supply. In 1942 the first experimental two-stage link was set up between Horsham and the roof of Berkeley Court in London. Later trials were carried out on an overseas path from Ventnor, Isle of Wight, to Beachy Head, and then, just after D-day, came the first operational link—between Ventnor and Cherbourg. Thereafter, No. 10 sets followed the advance. For several weeks they provided the only speech communication over the Maas and the Rhine ; Field-Marshal Montgomery's Tactical H.Qs. were never out of touch with the whole of 21 Army Group and the War Office for more than one hour.

The security obtained was absolute, for although after the surrender the Germans claimed to have intercepted our wireless transmissions with ease, careful examination showed that they had never intercepted No. 10 set signals, and were completely unaware that we even possessed such equipment.

Letters to the Editor

Electrolytics : American Views • Colour-Coding for Valves • Radar Maintenance in the Field

In Defence of Electrolytics

WE are in sympathy with J. C. Finlay's defence of electrolytics, in the July issue. However, we are not in agreement on the method of rating he suggests or the implication that etched plate electrolytics cannot be made which perform satisfactorily in service.

In the first place we have examined some British electrolytics, and have found that a condenser rated 600 volts cannot be operated at this voltage continuously, particularly at a normal ambient temperature of 60 deg. C.

Consequently, this is not a "true rating" but rather indicates the maximum transient voltage which the condenser will withstand. Our practice is to put on the nameplate the maximum voltage at which the electrolytic condenser will operate continuously at a 60 deg. C. or 85 deg. C. ambient as the case may be. The condenser, however, will withstand a considerably higher voltage; on the average, up to 20 per cent. over the nameplate value without breakdown.

The Services in this country have used etched plate electrolytics with good results. The difficulties that have arisen resulted from the fact that certain condensers were "designed" by the equipment manufacturers and then the condenser manufacturers were required to make them.

We agree with the analysis that electrolytic condenser failures are due to improper design (or improper use, depending on the point of view). We would add that the quality of the product is a major consideration. What we would like to emphasise is that if the requirements of use such as maximum and minimum temperature, AC ripple voltage, maximum surge voltage, and operating voltage are specified we can design an electrolytic condenser, be it etched or plain plate, to meet the service. Furthermore, this results in the best compromise between reliability and minimum volume (two essentially contradictory requirements) for a given capacity and voltage rating.

J. BURNHAM,
Assistant Director of Research,
Sprague Electric Company.
North Adams, Mass., U.S.A.

Valve Coding

R. V. SHARMAN, in his letter in your July issue, seems to have overlooked that my original suggestion (June *Wireless World*) to colour-code valves was made under the assumption that valve standardisation comes through.

In both the previous attempts to standardise, viz., the American and the Continental European ones, it was the coding of heater ratings which let us down.

Otherwise I quite agree with him. The coding of functional groups should be done by letters preceding the type number. The Continental standard, of which we know in this country only its last

World Radio History

survivors, the "Red E" Series, showed a way. This, of course, will have to be improved on to satisfy present demands; for example:—

Coding Letter	Would stand for
A	Detector-diode or double-diode with common cathode.
B	High AC-resistance triode.
C	Medium AC-resistance triode.
D	Low AC-resistance triode (power triode).
E	Variable-mu HF pentode (or critical-space tetrode).
F	Straight HF pentode (or critical-space tetrode).
G	High-slope television pentode (or critical-space tetrode).
H	Hexode or heptode (suppressor grid hexode).
K	Octode or pentagrid (mixer-osc. heptode).
L	Power pentode or beam tetrode.
M	Magic eye.
N	Neon stabiliser.
P	Gas (trigger) triode.
R	Barretter.
V	One-way vacuum rectifier.
W	Two-way vacuum rectifier.
Y	Three-way vacuum rectifier.
X	Two-way gas-filled rectifier.

Such a system is quite flexible. Valves with more than one electron path could be coded by two letters; for example:—

AA for split-cathode double-diodes.

AC for double-diode and medium AC-resistance triode.

BM for high AC-resistance triode and magic eye.

CH for triode + hexode or triode + heptode.

DD for double triode (class B).

VV for double one-way rectifier (voltage doubler),

and so on.

If colour-coding is adopted for heater-rating and letter-coding for functional groups the type number can be counted through quite irrespective of these.

It is obvious that even the most complex system cannot obviate occasional reference to data sheets. But what can be done to simplify recognition of types should be done.

K. E. MARCUS.

Uxbridge, Middx.

Radar Mechanics

THE story of radar (during 1940-42 particularly) is incomplete without mention of the radar mechanic. The work involved keeping radar equipment serviceable in aircraft and on the ground, especially during the night blitzes, was far from negligible. It not only necessitated brains, but fortitude, physical endurance and mechanical ability. Faults had to be diagnosed and rectified very quickly, and many modifications had to be effected in order to obtain first-class "airborne" serviceability. This work fell mainly on the shoulders of radar mechanics, at test-benches and in aircraft, and in many cases alternate 24-hour duties were carried out over a long period. Without exaggeration the aircrews concerned received invaluable help and advice on the operation of the radar equipment, and many voluntary flying hours were spent by the mechanics in testing apparatus and rectifying faults which were not evident on ground checks.

Experienced amateurs and pre-war radio mechanics composed the nucleus of this R.A.F. trade

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METAL RECTIFIERS, output 12 volts 1 amp., **17/6.**

50 VOLT MOTOR, D.C., input 4 amps., ¼ h.p., ball bearing, double ended shaft ½in. dia., slow speed, only 500 r.p.m., shunt wound, condition as new, also make good slow speed generator. Price **50/-.**

MOVING COIL METERS, all 2in. dia., flush mounting, 0-5 M/A, **40/-**; 0-20 M/A, **40/-**; 0-50 M/A, **37/6.**

LARGE PAXOLIN PANEL, size 14×7×½in., fitted massive switch arm, 12 large studs and contact blade, very smooth action, price **7/6** each.

BLOCK CONDENSERS, 2 MF, 1,500 v. D.C. working, **7/6** each.

X-RAY TRANSFORMER in oil, input 200 v., output 80,000 volts, rating 5 K.V.A., with Coolidge winding, **£50**; ditto, 2½ K.V.A. at 90,000 volts, **£45**; ditto, dental type, 45,000 volts, **£30.**

FLUORESCENT SCREENS, selt, 15×12, with lead glass, **£5.**

LARGE FAN MOTORS, all direct current, approx. ¼ h.p., 110 v. series wound, in first-class condition, **20/-** each; ditto, complete with stand, starter, cage and fan, **30/-.**

D.C. MOTORS, as above, only for 220 volts, in perfect order, **25/-**; ditto, complete with stand, starter, cage and fan, **35/-.**

ROTARY CONVERTER, input 230 v. D.C., output 230 v. A.C., 50 cycle, single phase, 1¼ kW., constant rating, a high-grade job of very solid construction, **£35.**

TRANSFORMER CORE to suit 2½ kW. transformer, complete with clamps and bolts, **25/-.**

LARGE OUTDOOR BELLS, 110 v. D.C. working, 6 in. gong, **17/6.**

D.C. MOTOR, totally enclosed, shunt wound, 220 v. D.C. 1/10 b.h.p., large size, high-grade, **45/-.**

AUTO TRANSFORMERS, tapped 0-110-200-220-240 step up or down, 500 watts, **£3/10 0**; 2,000 watts, **£9.**

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World Radio History

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WALTER F. BALL.

Sutton, Surrey.

Telepathy or Radio-Telepathy ?

WHAT is *Wireless World* up to?

"Telepathy" and "astral phenomena"! What next? Presumably, we shall soon be reading serious attempts to explain "what the stars foretell" in terms of some ultra-electronic energy. It is to be hoped a serious radio periodical will not lend scientific colour to such beliefs.

But granting there is good evidence for telepathy: it is the height of fantasy to look to radio for the explanation. No doubt there are still mechanists who would say "thought" is an "electronic phenomenon," though they would probably think it a little far-fetched to talk of *ideas* being "radiated."

We had better stick to things concrete, and cease joining the hopeful behaviourists who devote their days to finding the explanation for what they think in "brain currents."

"DUALIST."

"Channel Hogging"

IT might have been added to the interesting letter in your June issue that quite a number of commercial morse stations seem to find it necessary to work on top of broadcast stations. Yet other parts of the dial are often, if not always, clear of transmissions. But, in spite of this, there is a movement afoot — notably in America—to stop international short-wave broadcasting on the grounds of lack of space.

Coupled with the emphasis being laid on wired broadcasting in certain quarters, it makes one wonder whether some political reason(s) exists for the above state of affairs. Perhaps international short-wave broadcasting does not lend itself to censorship so easily as the Press or wired broadcasting systems.

The opinion has been expressed that all fixed points should be connected by land or submarine cable, so surely the commercial stations should surrender frequencies, if any need to be surrendered for new services.

D. O. FRENCH.

Norwich.

"EI" Amateurs

IN the November issue of *Wireless World* you state that amateur transmitters are again allowed to operate in Eire. This is not correct; our amateurs are *not* back on the "air." It is true that the Emergency Order under which our apparatus was seized and our licences cancelled has been revoked. The impounded apparatus held by the authorities has also been returned; but on condition that it is dismantled, and not used for transmitting purposes. No licences are being reissued until the international position regarding amateur radio is clarified.

ANDREW C. WOODS,
Hon. Secretary, The Irish Radio Transmitters' Society.

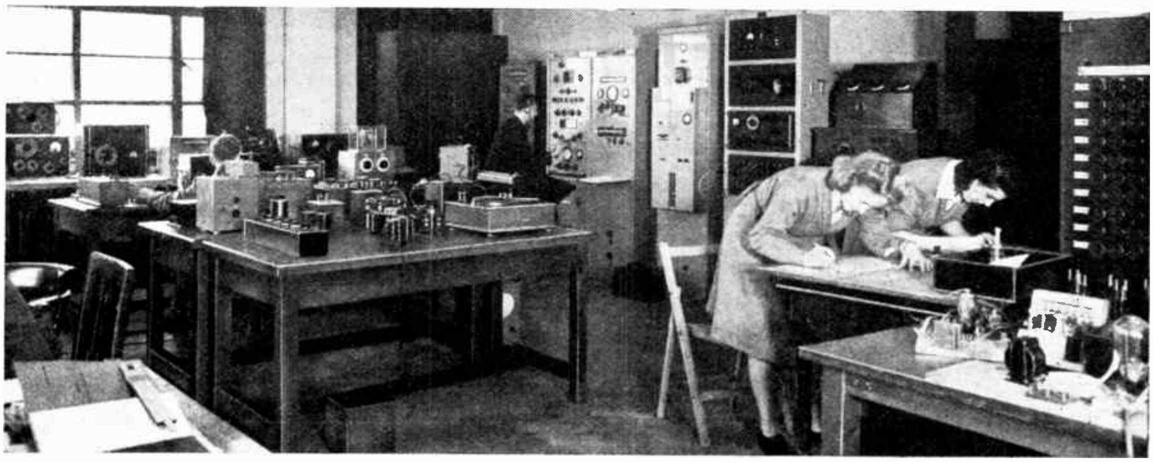
Dublin.

A.I.D. TEST HOUSE

Production Testing of Aircraft Equipment

SITUATED at Harefield, some 20 miles N.W. of London, are the central testing laboratories of the Aeronautical Inspection Directorate of the Ministry of Aircraft Production. The main purpose of this establishment is to provide facilities for check testing the products of firms engaged in the manufacture of materials, parts, sub-assemblies and accessories used in the construction of aircraft. Considerable time is also devoted to the investigation of methods of testing in order that hidden flaws and imperfections may be the more readily detected during production testing at the factory. There is quite a large section devoted to the radio industry.

One piece of apparatus in the



General view of the A.I.D. Electrical Standards Laboratory showing in the background (left) the standard frequency RF generator, with a beat frequency AF oscillator and harmonic analyser on its right.

World Radio History

Electrical Standards Laboratory illustrates the care taken to ensure a high order of accuracy. This consists of a master radio-frequency oscillator from which is derived harmonics and sub-divisions of the frequency for check-testing standard frequency generators. A fundamental frequency of 50 kc/s is generated by a crystal-controlled oscillator contained in a temperature-controlled oven. The output from the oscillator is fed to a series of multi-vibrators, some of which operate at a higher frequency and some at a lower frequency than the master oscillator. These are locked either to its harmonics, or to others in the chain that are so locked, and together they provide a number of spot frequencies up to 1 Mc/s.

The subdivision of frequency is carried down to 100 c/s and this is used to drive an electric clock which is periodically checked against Greenwich time signals. By a system of recording, differences of a minute fraction of a second can be determined and converted back as a check on the frequency of the master oscillator. Further checks are made by using the standard frequency transmissions rediated by WWV, Maryland, U.S.A.

Radio technique often plays a part in testing materials which are not themselves being used in the construction of radio apparatus. For example, use is made of a method similar to that described in our May, 1945, issue (p. 157) of testing by examination of echoes of super-sonic pulses propagated through metal objects. The system, of which the previously described application was for the measurement of thickness, is used for the detection of flaws, which, due to change of density, cause secondary reflections.

SELF-SOLDERING

AN apparently incongruous partnership between the Ministry of Supply, Bryant and May and the firm of Multicore Solders resulted in the production during the war of a novel soldering device. The "self-soldering sleeve," as it was called, was used for jointing field telephone cables, and not for wireless purposes, though the principle employed might well have applications in that field. The sleeve consists of a length of copper tube, partly filled with fluxed Multicore solder and coated externally with igniting material.

To make a joint, the bared ends of the cables are inserted in the sleeve and the covering is ignited by striking it with the edge of the packing box. Cable ends, sleeve and solder are heated to over 375 deg. C. and an excellent joint is made.

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RANDOM RADIATIONS

By "DIALLIST"

What is Radar?

THE controversy on the subject of what is and is not radar still continues and doesn't seem to be getting very much forrader. When the beans were first spilled both Smith Rose and Appleton laid it down that the characteristic which distinguished radar from all other systems of position finding and course plotting was that it required no co-operation on the part of the target. Systems such as "Gee," "Oboe" and "Rebecca-Eureka" do require such co-operation; in each of them, in fact, the target must be fitted with apparatus which, on receiving pulses from a questing transmitter is triggered off and emits pulses which a suitable receiver picks up. In other words, the return pulse is not an echo, as it must be in true radar. It isn't difficult to see how systems using triggered instead of true echo pulses came originally to be classed as radar equipment. So far as I know the first application of the triggered pulse principle was IFF, the system by means of which a friendly aircraft or ship automatically sends out an identifying signal when "hit" by radar pulses. IFF was designed by the men who specialised in designing radar equipment, fitted to radar apparatus and worked by radar operators. Hence it fell in the Services under the general classification of radar, and one doesn't quite see where else it could have fallen. Gee, Oboe and the rest followed in due course and were again, quite naturally, regarded for similar reasons as members of the radar family. But that is no reason why they should continue to occupy a place which does not rightly belong to them. I am all for avoiding confusion by making classification as rigid as possible. My own suggestion is that radar should be used to describe only such systems as rely on true echoes and that the triggering systems should be known as radio position finding (RPF), radio course control (RCC) or something of that kind.

□ □ □

A Connector Tip

DO you make any use in your wireless hook-ups of those handy little connectors which electricians often employ for joining up lighting leads inside junction boxes? In case you don't know them, they are made of porcelain, shaped like small thimbles and provided inside with a tapering screw thread. You bare half an inch or so of the leads to be joined and twist the ends together; then you apply one of the little thimbles and simply screw it on. Its thread bites the wires with a bull-dog grip, and when the connector is right home the bared ends are completely covered up and well insulated. They can be used, naturally, only for joining up fairly stout wires—fine wires would simply break as you tightened up and the joint would "come to pieces in yer 'and." But when you are dealing with wires of suitable gauge they certainly save a deal of time and trouble in the making up of experimental circuits. The joints they make are probably as sound electrically as any unsoldered joints can be and they have the special virtue (*not* possessed by crocodile clips) that no exposed "hot" points can be left ready to cause spectacular "shorts," or to cause the experimenter to leap high and profanely when in an absent-minded moment his hand strays on to them.

Buying It

Speaking of the stimulus, both physical and linguistic, that a "live" scrap of metal can provide when over-trustingly caressed by the careless hand reminds me of a real fourpenny one in the way of shocks that came my way a few days before this was written. I should perhaps mention that I am one of those luckless thin-skinned beings who are particularly susceptible to the effects of electric shocks. Nature, I always feel, fails singularly to do her stuff in the case of the electrical engineer. She helps the blacksmith to develop such toughness of hide that he airily lights his pipe with a glowing coal picked up by his bare fingers; professional gardeners grow backs that do not know what a crick is; a special muscle burgeons in the tinsmith's hand to enable him to use his shears effectively and without nipping bits out of himself with those horrible hooks at the ends of the handles; and there are countless other examples of the way in which she adapts the physique of the worker to the job which she assigns to him. But, having infected a man with a desire to follow electricity as a calling, does she help him to grow shockproof? She does not. Here and there you find the kind of human neon tube who smilingly detects the presence of real high-tension stuff (I have seen it done with sparking plugs) by licking a finger and placing it where the volts should be. But taking them by and large the votaries of electricity do not become nearly as pachydermatous as they would if Nature played the game as well by them as she does by those in other walks of life. But to return to my shock.

Save Us from Our Friends

For some days I had been engaged with one whom I then regarded as a trusted friend in an interesting series of experiments. In these a metal chassis was involved and I had taken particular care to see that this was effectively earthed. The apparatus was connected to the mains by means of a three-pin plug and a switch-controlled socket, and I had taken equally good care to see that the switch broke the "line" and not the "neutral." Having to go away for a day or two, I left the conduct of experiments trustfully in the hands of the alleged friend. On my return I found a note from him saying that he had had to go away on the day after I left. He had, though, had time to make some interesting tests and left an account of these. I was just reading what he had written when another friend came in and at once cast inquiring eyes on the chassis. Of course, I began at once to show him what it was all about. Having explained its top side, I switched off, turned it over and, holding it firmly with my right hand, began to introduce him to what was beneath it. "That," I said, touching a metal tag with my left forefinger, "that is the . . ." It was at that moment that I leapt and spake winged words. The best part of two hours passed before I ceased to be all of a twitter, for it was one of those thorough and shattering shocks that leave you in no two minds as to whether or not you have bought it. Next day friend No. 1 returned and I asked if he'd done anything not mentioned in his notes. "Only one thing that I can think of," he said. "I didn't like the look of that lead-covered lead to the switch-socket. It went over the skirting board, if you remember. To tidy it up I took it behind the skirting and rewired the socket. I was specially careful over the earth connection." I could testify personally, I answered him, to the efficacy of the earth connection and after a brief discussion he agreed that you must always make sure that switches are inserted in the "live" lead.

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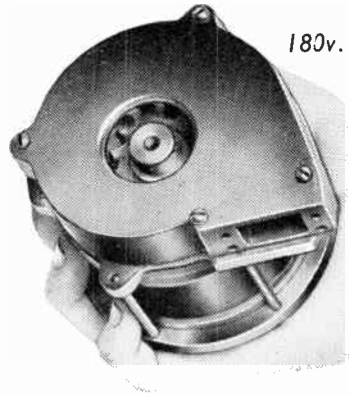

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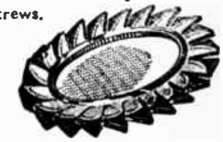

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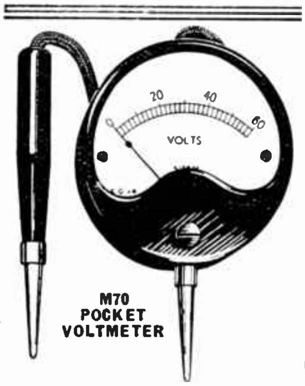

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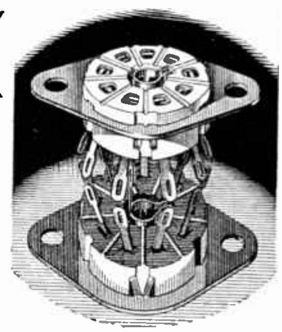

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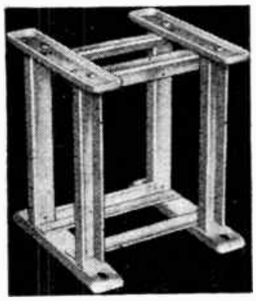

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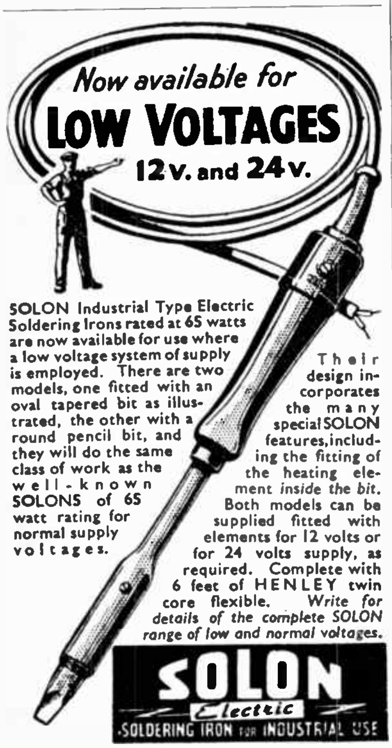

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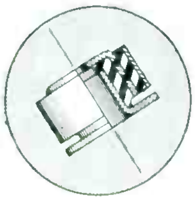

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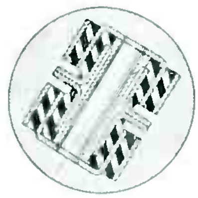

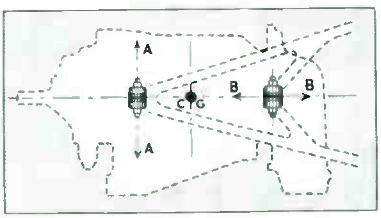

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