Wireless World

ELECTRONICS, RADIO, TELEVISION

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In This Issue

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Transistor Stabilisation: Two-Battery Method

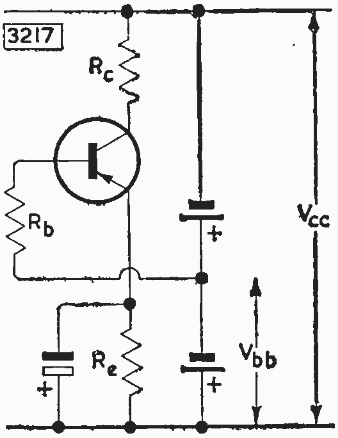
Transistor circuits are usually designed to operate from one battery. They should be stabilised as described in *Transistors for the Experimenter*. A two-battery system can be used instead (see figure). It is especially suitable for transformer coupling. The collector supply voltage V_{cc} is provided by two batteries in series, and the base supply voltage V_{bb} is obtained by connecting one resistor R_b from the base to the common point of the two batteries.

In transformer coupled two-battery circuits R_b can be very small and even zero. R_b draws base current only from V_{bb}, it does not bleed current from V_{cc}. Hence R_b can be small to obtain good stability, and in the limiting case when $R_b = 0$ the stability is the same as for a grounded base circuit.

In R-C coupled circuits a low R_b shunts the input and a value of the order of 10kΩ must be used. The main disadvantage of the circuit is that since V_{bb} is fixed, once the nominal collector current has been chosen, R_e is automatically decided, too. For example, if $I_c$nom. is 0.5mA and V_{bb} is 1.5V, then R_e can only be 2.7kΩ. There is therefore a fairly large voltage drop across R_e, hence R_c must be lower, and the gain is reduced. A small-signal R-C coupled circuit, in fact, cannot be operated with a collector supply voltage V_{cc} of less than 6V.

One general advantage of the two-battery circuit, which applies to both R-C coupling and transformer coupling, is that V_{cc} can be changed without having to re-design the circuit. If it is necessary to increase the size of the signal, one has only to increase V_{cc} while keeping V_{bb} the same, and the transistors operate at the same nominal collector currents. The stability is slightly worse because the junction temperature increases, but the signal is approximately the required size.

A further advantage of the two-battery system is that the effect of resistor tolerances is much smaller. First, the circuit contains few resistors, second, the tolerance on R_b exerts very little effect, a 10% spread in R_b giving only about 1% spread in I_c.



Preferred circuits for an OC71 operating with a collector supply voltage V_{cc} of 6V and a base supply voltage V_{bb} of 1.5V are given in the table for R-C coupling and transformer coupling. As when working with only one battery, the design of these circuits can be very much simplified by using graphs. For two batteries the graphs are always straight lines. Circuit values can also be calculated, without using graphs. The procedure is as follows. (1) Choose V_{cc}, V_{bb}, $I_c$nom., and R_b. (2) Then

$$R_e = (V_{bb} - V_{b\text{-}e} + I_{c(o)}R_b)/I_c - R_b/\alpha'.$$

(3) Calculate K and $I_{c(q)}$max., assuming $T_j = T_{amb}$, and allowing 5% for resistor tolerances if R_e and R_b are both ± 5%. (4) Find $V_{c(q)}$min. (5) Choose R_c less than the value given by

$$V_{c(q)}\text{min} = V_{cc} - I_{c(q)}\text{max.}(R_c + R_e).$$

(6) Find T_j, and if T_j is more than 1°C greater than T_{amb}, recalculate $I_{c(q)}$max. etc. accordingly.

PREFERRED CIRCUITS FOR OC71

	V_{cc}	V_{bb}	R_e	R_b	R_c	I_c nom.	$I_{c(q)}$ max.	$V_{c(q)}$min.	
								at nom. V_{cc}	at min. V_{cc}
R-C Coupling	6V	1.5V	2.7kΩ	10kΩ	3.9kΩ	0.5mA	0.81mA	0.5V	0.3V
	6V	1.5V	2.7kΩ	6.8kΩ	4.7kΩ	0.5mA	0.72mA	0.5V	0.3V
	6V	1.5V	1.2kΩ	10kΩ	2.2kΩ	1.0mA	1.6mA	0.5V	0.3V
Transformer Coupling	6V	1.5V	0.47kΩ	0	200Ω	2.85mA	3.05mA	3.9V	2.6V
	6V	1.5V	1.2kΩ	0	200Ω	1.1mA	1.2mA	4.2V	2.8V
	6V	1.5V	2.7kΩ	0	200Ω	0.5mA	0.57mA	4.2V	2.8V

Mullard

You can obtain your copy of 'Transistors for the Experimenter' from

T.S.D. DATA and PUBLICATIONS SECTION, MULLARD LTD., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

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F.M. Distortion

AT a time when the obvious advantages of v.h.f. broadcasting are being widely publicized it may seem churlish to draw attention to the obverse side of the picture. In the initial phases of the establishment of a nation-wide service there will be many fringe areas in which listeners who change from medium waves to v.h.f. will find that they have substituted a background of steam locomotive shunting noises (arising from aircraft reflections) for heterodyne whistles and monkey chatter. Even in areas of good signal strength there may be distortions arising from multi-path propagation and reflections from fixed objects which would not arise with amplitude modulation.

The problem of aircraft flutter in severe cases where the field strength periodically goes through zero can be solved only by the use of diversity reception with aerials spaced an odd number of quarter-wavelengths apart, but much can often be done with directional aerials to mitigate the lesser troubles by discriminating against the indirect or reflected signal.

Another approach is to improve the capture ratio of the receiver, and in this issue we publish an article which reflects the trend of thought in America and outlines the methods by which the ratio has been narrowed from the normal average of 20 dB to 1 dB or less.

It may well turn out that less drastic and expensive methods will suffice to combat the commoner forms of f.m. propagation distortion, as experienced in Britain, and we hope to deal more fully with these in a subsequent issue.

Domestic Equipment

LOOKING back at the Radio Show, it seems hardly an exaggeration to say that technical interest has shifted from television to v.h.f. sound broadcasting. In an appraisal of the exhibits printed elsewhere in this issue, the conclusion is reached that a condition of near-standardization has now been reached in television. For the first time it is possible to put forward a general description of a receiver which will apply with remarkable accuracy to the great majority of modern sets. There is even a measure of standardization in tube sizes. The 17-inch is apparently the most popular with viewers, but, incidentally, it was interesting to observe the favourable reactions of ordinary Show visitors to the picture quality offered by the 9-inch portables. That may be because such small pictures now have a novelty value.

Provision for v.h.f. reception is now practically universal in sound broadcast receivers. Though designs have been generally tidied up, there has been little development in circuitry. The ratio detector is chosen on economic grounds for the cheaper sets and the Foster-Seeley discriminator for the more expensive tuner units. Naturally enough, continuous tuning is used on v.h.f. in the combined a.m./f.m. receivers, but it is surprising to find that push-button (or three-position switch) selection of stations has not gained more ground in v.h.f.-only sets. It seems the natural thing for a three-programme service like ours. No doubt the reluctance to use switch tuning is partly connected with the difficulty in avoiding frequency drift; to fit an external trimmer would probably be considered an admission of defeat. In several new receiver designs advantage is taken of the wider frequency range obtainable from v.h.f. broadcasting by providing better audio sections and loudspeakers.

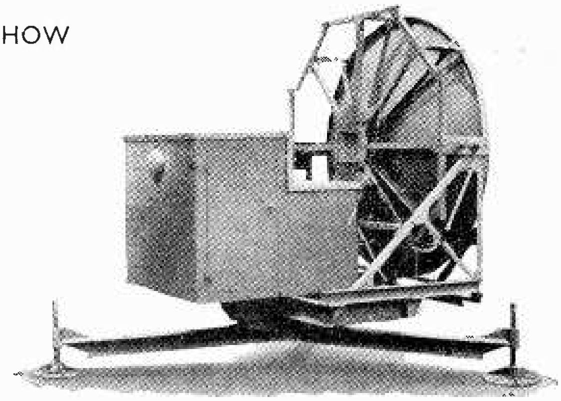
There are more v.h.f.-only receivers than last year, but their number is still small. According to some authorities, that is because the public generally is believed to insist on provision for reception of Radio Luxembourg.

With the spread of the transistor, the "personal" portable set has at last come into its own. No longer need the user be faced with heavy battery-replacement costs. Another solution to this problem may be provided by the "hybrid" receiver, which economizes battery current by using transistors in the output stage, with valves elsewhere. A similar technique is applied to a car radio receiver.

It will be interesting to see the long-term public reaction to two novelties in sound reproduction introduced at the Show. The first is a home recorder using a magnetic disc instead of tape; it has the advantage that, by substituting the appropriate pickup heads, it can be used for the reproduction of normal (non-magnetic) disc records. The second novelty is the "transistorized" portable record player, produced by several firms. This remarkable example of electro-mechanical ingenuity is run from a 6-volt dry battery which supplies the motor and transistors.

Aeronautical Radio Developments

NEW EQUIPMENT AT THE S.B.A.C. AIR SHOW



Decca "Wind-Finding" radar; the operators sit in the enclosed cabin behind the aerial "dish."

WHILST some new equipment made an appearance at the Farnborough Air Show, organized by the Society of British Aircraft Constructors, there was very little evidence that any strikingly new developments would emerge in the immediate future. Taking a long-term view, however, it seems that some changes are envisaged in channel spacing in the present air-to-ground communications band of 118 to 136 Mc/s. Evidence for this was the introduction by Marconi's of a new high-power aircraft v.h.f. transmitter designed for operation on channels 50-kc/s wide, which is just about half the current width; as a result double the number of operating channels are available, but not necessarily usable at present in this country. This set, Type AD305, gives 30 watts output, which is considerably more than customarily obtained from aircraft v.h.f. transmitters.

This increase in power of airborne transmitters is matched by a corresponding increase in some ground sets. Pye have a v.h.f. ground transmitter rated at 1 kW r.f. output, whereas the average output of such sets is in the 50- to 60-watt category. It appears that the higher-powered equipments are envisaged for use when the newest types of large jet aircraft come into service on the long-distance routes, as their higher speeds will necessitate v.h.f. communication over greater distances than hitherto.

Long-distance radio telephone communication on air routes has been envisaged for some time past and all the new aircraft communication equipment introduced over the past few years for use in the 2-to-20-Mc/s band has been designed with this possibility in view. The Marconi Type AD307 is a case in point and so is the Standard Telephones STR18 series. This year a new STR18D has appeared which provides 200 working spot frequencies selectable from either of two remote control units. Its outstanding features are, fully automatic control by motor operation of the tuning elements of circuits, 100 watts r.f. output on all bands on telephony and transmission on c.w. or i.c.w. for use when a wireless operator is included in the aircrew; otherwise it is operated entirely by remote control by the pilot on telephony.

Airborne Teleprinter

The tendency towards pilot operation of communication equipment adds considerably to the existing heavy burdens of pilots, but some relief from radio watch-keeping can now be provided by a new and compact selective calling attachment for aircraft receivers introduced by Marconi's. Known as "Secal" it operates on a two-pulse four-tone signal which is coded by combinations of the tones and only the aircraft decoder adjusted for a particular combination will respond and un-mute the receiver. A warning tone is generated and fed into the pilot's headphones, but visual warning can be employed instead if preferred.

An interesting development, which at present is only in the experimental stage, is an airborne teleprinter system. Examples of the equipment were shown by Marconi's and by Standard Telephones; the system operates on the comparatively low radio frequencies of 90 to 130 kc/s. It has been tried out quite successfully on the trans-atlantic air routes for passing meteorological and routine flight information.

Point-to-point communications along the principal air routes is usually effected now by teleprinter and high-speed radio telegraphy using the FSK (frequency shift keying) system. While no basic changes seem imminent a few new items of equipment have made an appearance. One is an electronic receiver muting unit (Type PV97A), developed by Plessey, which operates from the i.f. amplifier and mutes the receiver in the absence of a usable signal. However, in addition it provides a "cleaned up" signal as filters attenuate the noise while an amplifier enhances the signal. Plessey exhibited also a new high-stability version of their dual-diversity receiver (Type PV102B) which provides the correct form of output signal for direct operation of teleprinters.

A few new communications receivers were shown this year, principally by Amalgamated Wireless of Australia, by Cossor and by Redifon, the last-mentioned showing one designed for very accurate resetting to any previously logged signal, or to a desired frequency. It is known as the R145 and embodies a very massive coil turret allowing for fourteen frequency ranges in the 2-to-30-Mc/s band. Provision is made for double- or single-sideband reception with switch selection of either the upper or the lower sideband.

Improvements in radio navigational aids were exemplified by a sub-miniature version of the Standard Telephones f.m. radio altimeter and by a new automatic radio-direction finder for aircraft (AD712) introduced by Marconi's. This set is based on the Bellini-Tosi crossed-loop aerial system using flat, dust-iron cored, "dragless" loops in a fibre-glass housing; it covers the bands 100 to 415 kc/s and 490 to 1,779.5 kc/s with remote selection of any frequency in this range in steps of 0.5 kc/s.

Ekco have produced a new lightweight scanner for their TE120 airborne search radar which cuts 33 lb off the total weight. The addition of a small unit to this equipment now gives precise information on aircraft drift by utilizing the Doppler effect of modulation.

A new 3-cm aircraft radar was shown by Elliott. Based on a Bendix design, it gives warning of heavily charged storm clouds ahead and it can be used also for mapping the ground along the flight path. The working range is 150 nautical miles.

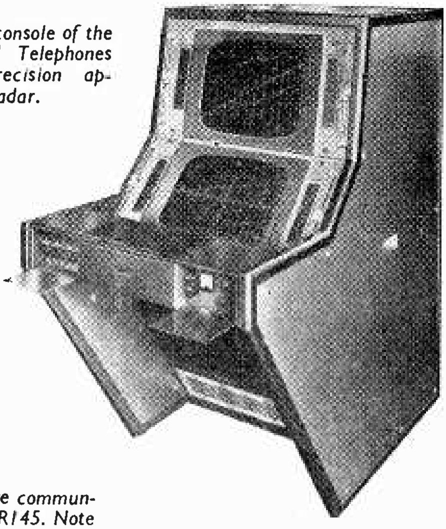
The Doppler effect is utilized in the design of a new Marconi aircraft navigational aid, Type AD2000. The airborne equipment radiates signals towards the ground and these are modulated by the movement of the aircraft over the ground at frequencies bearing a direct relationship to the aircraft's ground speed and drift angle. The reflected signals containing this data are fed to a computer, together with gyro-compass readings, and direct information is provided in the aircraft as continuous readings of latitude and longitude. Drift and ground speed are also available and all this information is obtained without the co-operation of ground stations.

Among the improvements to ground radar equipment is a fixed-coil assembly for use in place of the customary rotating coil assemblies employed for p.p.i. displays. This system enables much greater flexibility in the type of display to be provided solely by switching. It is a Decca development and the same firm have introduced a new 3-cm radar for plotting the tracks of meteorological balloons. They call it a "Wind-Finding" radar and it has an effective working height of 60,000 ft.

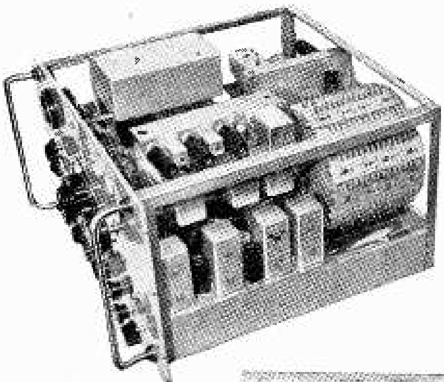
Standard Telephones have introduced a number of modifications into their precision approach radar, which in its present form (Type SLA3) is considerably smaller, has only four-fifths the former number of valves and is simpler to maintain. A new display console is employed which is fitted with two 17-in c.r. tubes arranged one above the other for easier interpretation of the azimuth, elevation and range information shown on the tubes.

Pye exhibited their latest ILS equipment, which is now in production form, and Cossor demonstrated a new method, using a special form of radio "lens," for cancelling the clutter on p.p.i. display tubes produced by heavy rain and storm clouds. The lens imparts a circular polarization to linearly polarized waves and is interposed between the horn and the aerial reflector. It was demonstrated in conjunction with their Type 21 airfield surveillance radar which operates on 10 cm. With the Decca Type 424 radar the operator can now select any type of polarization from linear through elliptical to circular as a means of cancelling rain and snow clutter without affecting the echoes from the aircraft, other than rendering them visible whereas they would otherwise be lost in the clutter.

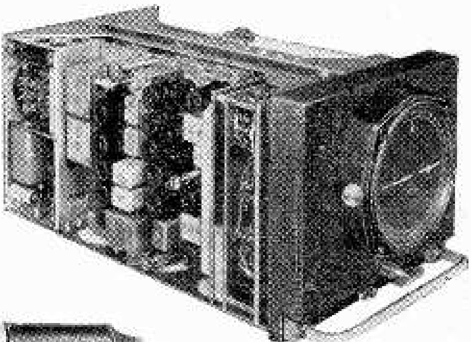
The two rescue beacons, Ultra "Sarah" and Burndept "Talbe," for aircrews forced down in the sea, were shown with various modifications. The most interesting of these is a transistor-type h.t. supply unit for "Sarah" which functions on the ringing-choke principle and derives its primary power from a 12-volt Kalium battery. Germanium diodes serve as rectifiers. It is for beacon operation only (not radio telephony) and the efficiency is said to be over 80%.



Display console of the Standard Telephones SLA3 precision approach radar.



Left: Redifon 14-range communications receiver Type R145. Note the massive coil turret.



Marconi AD712 receiver withdrawn from its case.

Transistor h.t. supply unit for Ultra "Sarah" rescue beacon.

WORLD OF WIRELESS

Organizational, Personal and Industrial Notes and News

Amateur Emergency Operation

THE LICENCE clause prohibiting British amateurs sending messages for a third party has been amended. Although limited to communication "during disaster relief operations or during any exercise relating to such operations conducted by the British Red Cross Society", it is a noteworthy move. It is, however, interesting to note that the lifting of the ban applies to all licensed radio amateurs and not only those linked with the Radio Amateur Emergency Network organized by the R.S.G.B., although the amendment has been made as a result of the efforts of that organization.

It is stressed that the primary duty of R.A.E.N. in an emergency is to transmit information to the nearest centre linked with the G.P.O. telephone—not to usurp the G.P.O.'s function.

Interference: More Recommendations

ABOUT 80 delegates, representing 17 countries and five international organizations, attended the fifth plenary session of the International Special Committee on Radio Interference (C.I.S.P.R.) held in Brussels a few weeks ago under the chairmanship of O. W. Humphreys (director, G.E.C. Research Laboratories). The United Kingdom delegation was led by E. L. E. Pawley (B.B.C.) and consisted of 14 members drawn from the G.P.O., R.I.C., B.E.A.M.A., I.E.E., Electrical Research Association, Society of Motor Manufacturers and Traders and the Radio Research Laboratory. The main considerations were (a) limits of interference and methods of control; (b) measurement of radio interference; and (c) safety aspects of suppression techniques.

It was recommended that the countries represented should set (within the frequency bands quoted) the following limits to the interfering voltage at the terminal of appliances.

150— 200 kc/s	500—1,500μV
200— 285 kc/s	500—1,000μV
525—1,605 kc/s	500—1,000μV

C. J. V. LAWSON

E. ALLARD

(See "Personalities")

Mobile Radio Changes

THE MAIN proposals in the Second Report of the Mobile Radio Committee*, which has been approved by the P.M.G., are narrower channelling and a revised sub-allocation plan. It is proposed that channels in the 165—173-Mc/s band should be reduced from 100 kc/s to 50 kc/s, as in the 71.5—88-Mc/s band. It is further recommended that the possibility of introducing 25-kc/s channelling in both bands should be examined.

The factors, both technical and operational, affecting channel spacing for mobile radio users are examined in an article on page 481.

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* H.M.S.O., price 1s 6d.

PERSONALITIES

J. A. Smale, C.B.E., A.F.C., B.Sc., M.I.E.E., engineer-in-chief of Cable and Wireless, Limited, since 1948, will be retiring in March. As, however, the deputy engineer-in-chief, **W. J. Knight,** M.B.E., will be retiring at the end of this year it has been necessary to appoint another deputy who will succeed Mr. Smale in April. The new deputy e.-in-c. is **C. J. V. Lawson,** M.I.E.E., aged 50, who since 1954 has been manager of the cable station and head of the school of telecommunication engineering at Porthcurno, near Land's End. He has had many years' service overseas since joining the Eastern Telegraph Company in 1923, and has been in charge of installation work at a number of wireless stations. Mr. Smale has been with C. & W. since 1929, having previously been on the staff of the Marconi W.T. Company for ten years. Last year he became part-time chairman of the Cyprus Inland Telecommunications Authority.

Five appointments are announced by English Electric Valve Company: E. Allard, assistant to the general manager; J. Dain, chief of microwave research; and R. G. Roach, Dr. F. C. Thompson and W. E. Turk as managers respectively of the valve, radar tube and photoelectric divisions. **E. Allard,** B.Sc., A.M.I.E.E., who joined the company a year ago, was with Edison Swan during the war as a valve development engineer and later engineer in charge of a shadow factory. In 1946 he joined Plessey and was with them as chief of physics research until 1951 when he went to the Ministry of Supply as engineer in charge of valve production. **J. Dain,** M.A., a Wrangler of St. John's College, Cambridge, joined the Telecommunications Research Establishment in 1942 working on pulse modulators. In 1946 he transferred to the Atomic Energy Research Establishment. Mr. Dain joined the English Electric Valve Company in 1954 where he has been engaged in research on, and design of, special types of microwave tube. **R. G. Roach,** B.Sc., joined the company in February, 1951, and has worked on the design and production of large transmitting valves. He was formerly in the valve division of Standard Telephones and Cables, which he joined in 1937. **F. C. Thompson,** Ph.D., A.M.I.E.E., has been with the company for seventeen years. During the war he was seconded to T.R.E. where he worked on airborne radar. **W. E. Turk,** B.Sc., A.M.I.E.E., joined the company in February, 1953, having previously been in the E.M.I. Research Laboratories where he was concerned with the design and development of photoelectric devices including television pick-up tubes.

Dr. D. Gabor, F.R.S., Mullard Reader in Electronics at Imperial College, has been elected a member of the council of the Physical Society. Dr. Gabor has been working for some time on the development of a flat, thin, neckless television tube, on which he will deliver a lecture at the meeting of the Television Society on October 25th.

F. R. W. Strafford, M.I.E.E., has resigned from Belling and Lee, where he has served for many years as technical manager, to become a consulting radio and electronics engineer on his own account. He is well known to *Wireless World* readers for his many contributions on aerials and interference suppression and has been intimately associated with the technical side of the industry for 33 years. His work has included domestic radio, telecommunications, radar and general applications of electronics. While at Belling-Lee, Mr. Strafford originated G9AED, the pilot transmitter for the I.T.A. stations.

F. R. W. STRAFFORD

B. H. DOUTHWAITE

B. H. Douthwaite, A.M.I.E.E., rejoins Belling and Lee on October 1st as administrative head of the research and development activities of the company. He was previously with Belling-Lee from 1945-47 and was subsequently a divisional manager at the research laboratories of Elliott Bros. (London), Limited. During the war, as a member of the research staff of G.E.C., he was engaged on radio counter-measures.

G. A. Briggs, managing director of Wharfedale Wireless Works, Limited, is to address a New York meeting of the Audio Engineering Society on sound reproduction in concert halls on September 28th. He will also be giving a lecture-demonstration in Carnegie Hall, New York, on October 3rd for which he will be joined by H. J. Leak.

A. Whitaker, O.B.E., M.A., M.I.E.E., F.Inst.P., has been appointed a director on the board of Siemens-Ediswan, Limited. He is director of engineering, covering the Edison Swan interests of the company; his headquarters are at Cosmos Works, Brimsdown, Middlesex. Mr. Whitaker joined the Gramophone Company in 1927 to initiate a research department and subsequently took charge of product engineering for domestic appliances and cathode-ray tubes. Since leaving the Gramophone Company he has held various posts in industry.

B. G. H. Rowley, M.A.(Oxon), A.M.I.E.E., Marconi's new assistant commercial manager, joined the company in 1950 as their technical representative in the United States, returning to this country at the end of 1954 to become manager of the maritime division. Early in the war he was engaged on radar development at the Royal Naval Signal School. In 1942 he was attached to the United States Navy for radar liaison duties in the North Atlantic, and was later appointed to the staff of the British Admiralty Delegation in Washington.

J. P. Wykes, A.M.I.E.E., formerly works manager at Marconi's, Chelmsford, has been appointed manager of the company's maritime division. He joined the Marconi International Marine Communication Company as a sea-going radio officer in 1918, and subsequently served in various capacities ashore. In 1934 he transferred to the research and development staff of Marconi's W.T. Company and was engaged on the design and development of marine equipment. He became manager of the crystal department in 1942 and four years later was appointed assistant engineer-in-chief in charge of test at the Chelmsford works, of which he became manager in 1949.

OUR AUTHORS

Harold J. Leak, who, with A. B. Sarkar, writes on electrostatic loudspeaker design in this issue, needs little introduction to audio engineers. He founded the company bearing his name in 1934. For five years prior to 1934 he worked as an installation engineer of motion picture equipment. Mr. Leak is leaving London on September 25th on a seven-week tour of countries in the Western Hemisphere in which his company has agents. Whilst in Brazil he plans to conclude an agreement with the Feigenson Company, of Sao Paulo, under which it will manufacture Leak products under licence.

A. B. Sarkar, co-author of the article on page 486, joined H. J. Leak and Company for research on sound reproduction problems about a year ago, prior to which he was with Standard Telephones and Cables. Mr. Sarkar, who is 28, received an M.Sc. degree from London University for a thesis on measurement of acoustic impedance which he wrote following research in the physics department of Chelsea Polytechnic.

J. R. Humphreys, who discusses on page 481 the question of reduced band-width for mobile radio, has been with the Pye organization since 1948. He has been with Pye Telecommunications, of which he was appointed chief engineer in January, since 1950. For the past three years he has worked on the design and development of v.h.f. mobile equipment. Mr. Humphreys entered the radio industry in 1938 at the age of sixteen as a junior technical assistant at Marconi's, Chelmsford. From 1946 until he joined Pye he was senior design engineer with Denco, of Clacton.

Lawrence W. Johnson, author of the article on f.m. receiver design, is a development engineer in the laboratory of the Hewlett-Packard Company, Inc., of Palo Alto, California, which he joined earlier this year, and is at present concerned with the development of oscilloscopes. He obtained a B.S. degree in physics and an M.S. degree in electronic engineering from the Carnegie Institute of Technology, Pittsburgh. From 1948 until 1953 he was research assistant at the Institute's Nuclear Research Centre, where he was concerned with instrumentation for nuclear research, including the design of the f.m. oscillator for a 400-meV syncrocyclotron.

OBITUARY

George M. Wright, C.B.E., B.Eng., M.I.E.E., engineer-in-chief of Marconi's Wireless Telegraph Company until his retirement in 1954, died on August 26th in his sixty-sixth year. After obtaining his B.Eng. degree at Sheffield University he joined the Marconi Company's research department in 1912 where he assisted C. S. Franklin, pioneer of the beam system, and Captain H. J. Round, of valve fame. After service in the first World War, when he was closely associated with the establishment of the naval d.f. network, he returned to the company's research department, of which he subsequently became head. During the last war he was seconded to the Admiralty and became chief scientist at the Admiralty Research Establishment. Mr. Wright returned to

Marconi's as engineer-in-chief in 1946. He was a member of the Radio Research Board of D.S.I.R. from 1948 to 1950.

W. A. Ferguson, B.Sc.(Eng.), A.C.G.I., Grad.I.E.E., author of the articles on the design of a 20-watt high-quality amplifier which appeared in our May and June issues last year, died early in August at the age of thirty-two. He had been in Mullard's valve measurement and application laboratory since 1949 where he was initially concerned with the measurement of power output and distortion but latterly had concentrated on amplifier design. During the latter part of the war he was in the Royal Navy, having previously been at the National Physical Laboratory's Radio Division, Slough, from 1942 to 1944.

W. MacLanachan, who was well known in the radio industry as a technical writer, died at the end of August. "Mac," who was sixty, was for some years technical adviser to *The Observer* on radio and television matters. His book "Fighter Pilot" described his experiences in the first World War. In the last war he served for a time on the staff of Combined Operations Headquarters.

IN BRIEF

Broadcast receiving licences current in the United Kingdom at the end of July totalled 14,361,465, including 5,979,510 for television and 307,294 for car radio sets. Television licences increased by 57,490 during the month.

Audio Fairs, Limited, has been formed as a non-profit-making company "to assume responsibility for future **Audio Fairs** in Great Britain." The original organizing committee, consisting of representatives of audio manufacturers, "will continue to serve as members of this company on a purely voluntary basis." Enquiries regarding the 1957 Audio Fair (Waldorf Hotel, April 12th-15th) should be sent to the company at 21, Old Buildings, Lincoln's Inn, London, W.C.2.

Restoring "Top."—The filters recently installed by the B.B.C. at the Wrotham v.h.f. station to restrict upper modulation frequencies to 10 kc/s have now been removed. See our Editorial, August issue.

London Television Power.—We stated last month that both the Lichfield and Croydon I.T.A. stations had increased their power, whereas, in fact, the increased e.r.p. (120 kW) from Croydon was not finally introduced until September 8th. Two days later the e.r.p. of the B.B.C. station at Crystal Palace was also increased to 120 kW. This was made possible by the installation of a new aerial at a height of 400 feet on the support mast.

Scottish I.T.A. Station.—Work has begun on the transmitter building at the site for the I.T.A. station at Blackhill, Lanarkshire. The transmitting equipment, mast and aerial array will be supplied by Marconi's.

As might be expected, a television manufacturer was the first in this country to use **closed-circuit television** on a large scale for a national sales conference. Existing television links between London, Birmingham, Manchester, Glasgow, Bristol and Dorking were used by Pye for their conference in August.

"Too Old At—?"—In this article on age and hearing in the September issue, page 439, the curve in Fig. 2 labelled "9" should be "19."

"Cascode A.F. Amplifier."—In the first equation under Fig. 2, page 284, of the June issue, the last term on the right-hand side should be -E_{i}, to agree with the second equation, which is correct. The designation of V5 in the list of parts should be 5T4 (not 574). A British equivalent of this American rectifier is the Brimar 5U4.

PUBLICATION DATE

Owing to a temporary rearrangement of our printing schedule the publication date of the November issue of *Wireless World* will be advanced to October 16th.

Hearing Aid Show.—Twenty-five manufacturers of hearing aids, associated equipment, components and accessories are participating in a one-day exhibition and convention organized by the Society of Hearing Aid Audiologists. It will be held on October 6th (10.30 a.m. to 12.30 p.m. and 2.15 to 3.15 p.m.) in the Park Lane Hotel, Piccadilly, London, W.1. Details are obtainable from W. A. Cullen, 31, Highfield Avenue, Pinner, Middlesex.

Pulse Techniques.—A course of twenty-three lectures and a 12-week laboratory course under the general heading of pulse techniques, are being conducted by the Borough Polytechnic, Borough Road, London, S.E.1. The main course is on Monday evenings (beginning October 15th) and the laboratory course on Monday afternoons or Thursday evenings (beginning October 22nd). The fees are, respectively, £2 10s and £1.

A series of short lecture-demonstrations covering various aspects of **control engineering**—industrial instrumentation, automatic process control and servomechanisms—will be given at the Battersea Polytechnic, London, S.W.11, during the new session. The Polytechnic also provides a one-year evening course on linear servomechanisms which commences on October 3rd.

Among the **advanced lectures** in electrical and mechanical engineering listed in a booklet issued by the Manchester and District Advisory Council for Further Education are an eight-lecture course on transistor circuit techniques and a nine-lecture course on sound recording and reproduction. Both courses will be held at the Manchester College of Science and Technology, the first on Tuesday evenings, commencing October 16th, and the second on Mondays, commencing January 7th. Fees 30s per course.

Evening courses on transistors, servomechanisms, pulse techniques, radar and computers—varying from eight to twenty-four lectures—have been arranged for the new session by the Technical College, Beaconsfield Road, Southall, Middlesex. A course on colour television will begin in January.

Dr. G. N. Patchett, head of the department of electrical engineering at the **Bradford Technical College,** has sent us details of part-time day and evening courses in radio and allied subjects provided at the college. They include courses for the Higher National Certificate and professional qualifications in electrical, electronic, radio and television engineering and courses in radio and television servicing.

Those concerned with the **psycho-acoustic problems** involved in teaching deaf children to talk will be interested in a speech training hearing-aid amplifier introduced by Amplivox. The unit is a three-stage amplifier embodying volume compression.

FROM ABROAD

Audio in the U.S.—The eighth annual convention of the Audio Engineering Society, which now has a membership of nearly 2,000, will be held in New York from September 26th to 29th in conjunction with the High Fidelity Show (September 27th to 30th) sponsored by the Institute of High Fidelity Manufacturers. Both functions will be held in the New York Trade Show Building. It is understood that the Audio Fair fixed for October 4th to 7th in the Hotel New Yorker has been cancelled.

Broadcasting in India.—India's second five-year plan provides for expenditure of Rs.90M on broadcasting, including the installation of four new 100-kW transmitters at Delhi and 50-kW transmitters at Bombay, Calcutta and Madras. Provision is also made for spending Rs.4M on an experimental television service.

South African Broadcasting.—Later this year the new short-wave broadcasting centre of the South African Broadcasting Corporation at Paradys, near Bloemfontein, in the Orange Free State, will be officially brought into service. Marconi's have supplied nine 20-kW transmitters for the centre which is already in partial operation.

A sixty-foot diameter paraboloid, accurate to about 3/16ths of an inch, has been built by Bell Telephone Laboratories at Holmdel, New Jersey, for the study of **scatter propagation.** The 5½-ton paraboloid is intended for use at 460 and 4,000 Mc/s at which it has a gain of 37 and 54.6 dB respectively. It has also been tested at 9,400 Mc/s at which the gain was 61.1 dB.

BUSINESS NOTES

The Ministry of Supply has ordered from **Marconi's** a considerable quantity of equipment for ionospheric scatter transmission and reception. Some of the equipment, which is designed to operate in the 35-55 Mc/s band, will be used to establish a communications system between the United Kingdom and Malta, which will eventually be extended to Cyprus and the Middle East. Marconi's are undertaking the complete installation of the first section of the system. The company has also supplied a transmitter to the Admiralty. This has been set up in Gibraltar for experimental work on ionospheric scatter between the Rock and this country.

Anglo-American Company.—Ketay Limited has been formed jointly by the Plessey Company, of Ilford, and Norden-Ketay Corporation, of New York, to manufacture data transmission units. These include synchros, servo motors, computing synchros and tachometer generators. The new company's offices are at Eddes House, Eastern Avenue, West Romford, Essex.

Elliott-Swartwout Agreement.—Elliott Brothers (London), Limited, have concluded a licence and technical agreement with the Swartwout Company, of Cleveland, Ohio, by which they become the manufacturing licensees and sole agents in the British Commonwealth (except Canada) and Europe for the complete Swartwout range of electronic control equipment.

G.E.C. Laboratories.—Three laboratories of the General Electric Company, Limited, at Stanmore (Middlesex), Allesley (Coventry) and Salisbury (South Australia) have been renamed under a group title of Applied Electronics Laboratories. This change does not affect the Research Laboratories at Wembley.

Alma Components, Limited, was recently formed with premises at 165, Ossulston Street, Euston, London, N.W.1 (Tel.: Euston 2977) to manufacture precision wirewound fixed resistors. The maximum resistances in each of the three wattage ratings (¼, ½ and 1 watt) are respectively 600 kΩ, 800 kΩ and 2MΩ.

A feature of the radio equipment installed by **Marconi's** in the new 20 527-ton troopship *Nevasa* is the sound amplifying system. A total power of 420 watts is available to feed 214 loudspeakers. An aerial distribution system enabling 75 receiver points to be fed from a single aerial has also been fitted.

The laboratories and production departments of **Fortiphone, Limited,** manufacturers of hearing aids and miniature components, are now at the company's new head office at 92, Middlesex Street, London, E.1. (Tel.: Bishopsgate 0871.) A West End showroom and retail sales office for hearing aids is being maintained at 247, Regent Street, London, W.1. (Tel.: Langham 3773.)

Craven Electronic Instrument Company, of Bradford, will in future be known as Craven Electronics, Limited.

G. V. Planer, Limited, consultants with laboratories for research, development and experimental production of electronic components and materials, have moved to new premises at Windmill Road, Sunbury-on-Thames, Middlesex. (Tel.: Sunbury-on-Thames 2266.)

Multicore Solders (Australia) Pty., Ltd., formed just over a year ago as a sales organization, has acquired a factory at Alexandria, Sydney, where Ersin Multicore solder will be manufactured.

Kelvin and Hughes (Marine), Limited, have opened a depot at 4, Central Road, Docks, Southampton.

The head office, sales and service departments of **Runbaken Electrical Products** are now at 45, Oxford Road, Manchester 1.

Standard Telephones and Cables have established a regional office at Coronation House, 69/71, Market Street, Manchester 1.

EXPORT NEWS

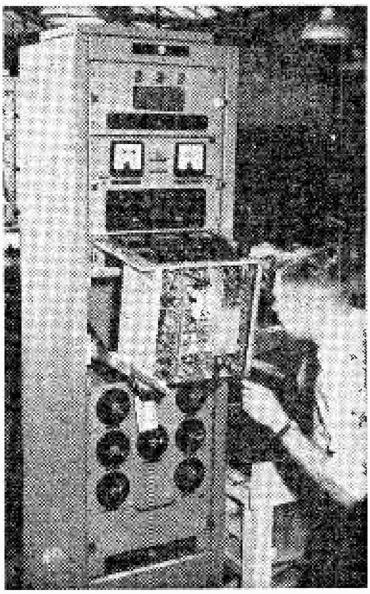
A mobile display of Garrard **record changers** and players has been touring the Continent giving demonstrations at various centres including exhibitions in Brussels, Leipzig, Vienna and Strasbourg.

Thirty-four member firms of the Scientific Instrument Manufacturers' Association participated in a display of **instruments** at the St. Eriks Fair held in Stockholm from September 1st to 16th.

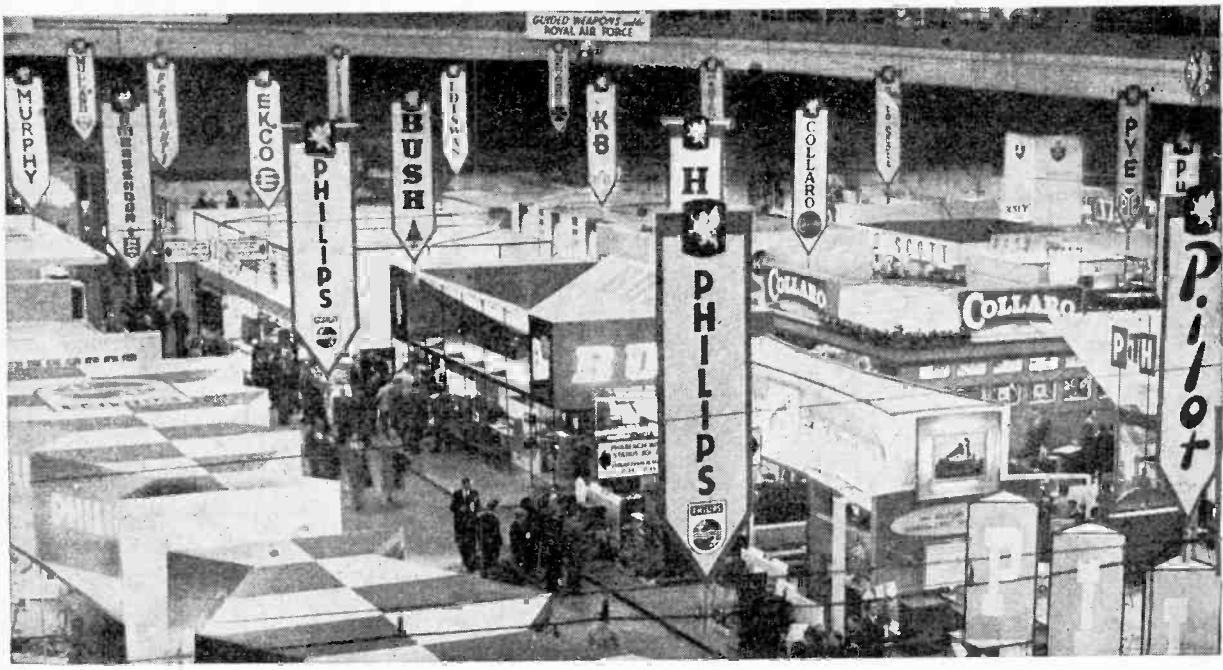
Television Receivers.—Seng Guan Hong Co., of 854/62 Talad Noi, New Road, Bangkok, are interested in securing the agency of a United Kingdom manufacturer of television receivers. Thailand has adopted the C.C.I.R. 625-line standard.

Tape Recorders.—A report on trade in Cyrenaica, Libya, states that there is a market for a small British tape recorder. The cheapest British equipment on sale at present costs about £70 c.i.f., whereas Italian tape recorders can be obtained for £27 c.i.f.

Record Changers.—K. F. Moseley, sales director of Birmingham Sound Reproducers, makers of the Monarch record changer, has been on a tour of the U.S.A. and Canada, during which he visited the new Broadway, New York, premises of the Discus Corporation (the B.S.R. sales and service office in America). Shipments to the States of Monarch record changers are now considerably in excess of the 4,500 units despatched weekly at the beginning of this year.



MONITOR for use at the B.B.C.'s frequency-modulation stations. Set up for operation on the three frequencies used at each station these monitors built by Marconi Instruments, provide for the measurement of carrier frequency drift, mean deviation, harmonic distortion at 60 c/s, 1 kc/s and 10 kc/s, and f.m. and a.m. noise.



Trends in Vision and Sound Broadcast Receivers—and Some Highlights

TELEVISION RECEIVERS

IT has been evident for some years that the trend of development in television receivers is towards a high degree of standardization between the products of different manufacturers. By this is meant a standardization of the kind of circuitry and not of mechanical form or external appearance. In this, television is merely following in the footsteps of sound broadcast receivers.

This uniformity of circuitry is not a result of the efforts of any standardization committee, but is a natural result of the fact that there is technically a best way of achieving a required performance. Sometimes there are equally good technical alternatives, of course, but then one is usually cheaper than another and the laws of economics dictate the choice.

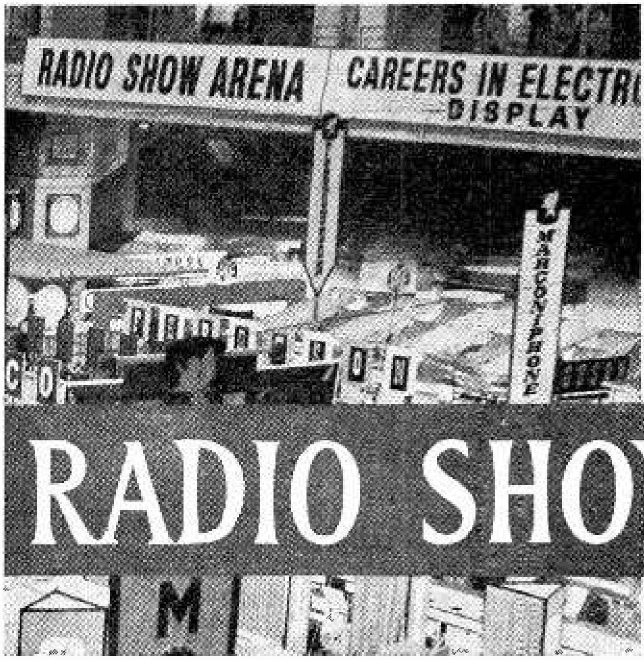
Complete identity of circuitry is not, of course, obtained. Probably no two receivers by different makers have exactly the same circuit, but the differences are more in biasing and decoupling arrangements than in the main general form of the circuits. In one thing, however, there is virtually complete standardization, and that is in picture sizes. This has been brought about by the c.r. tube manufacturers, who have adopted the range of 9-, 12-, 14-, 17- and 21-inch sizes, the dimensions referring to the screen diagonal or diameter. Of these, only the three largest sizes are in common use, the 9- and 12-inch tubes being normally reserved for portable apparatus. At the present time, the 17-inch tube appears to be the most popular, but there are still plenty of 14-inch and nearly all set makers are producing 21-inch models.

The effect of tube size upon the circuitry is very small. It actually affects only the timebases and e.h.t. supplies. Because of the large deflection angle and higher final-anode voltage a large tube needs more deflection power than a small one. In the main this is offset by the use of deflector coils and transformers of higher efficiency, and the net result is that there are negligible circuit differences.

It is now possible to attempt a general description of a television receiver which will apply with remarkable accuracy to the vast majority of modern sets. The general practice is to include a tuner covering Bands I and III which has a double-triode cascode r.f. amplifier and a triode-pentode frequency changer. There is a single-tuned input circuit coupling the aerial feeder to the grid of the r.f. stage, the first triode of which is neutralized by a capacitance bridge circuit. A coupled pair of circuits is used between the r.f. stage and the pentode mixer, and the oscillator is of the Colpitts form.

Four tuned circuits thus require alteration for station selection. There are three alternative methods of doing this. The usual one is the turret tuner, but the so-called incremental-inductance method with switch selection is still employed by a number of firms. Bush also retain the method by which a set of Band I and a set of Band III coils have their cores ganged to provide continuous tuning over the bands, but are provided with a cam-controlled mechanism and an automatic change-over switch, so that the user still has a multi-position selector control as in the other systems.

The standard intermediate frequencies of 34.65 Mc/s for vision and 38.15 Mc/s for sound are now used by nearly everyone. Coupled pairs of circuits are usual for the intervalve couplings of both sound and vision amplifiers, with three stages on vision and two on sound. Some makers, however, manage with a stage less, but there is a tendency for these



In the following pages the technical staff of "Wireless World" reports on tendencies in design in those branches of radio most fully represented at the National Radio Exhibition. As this review shows, television receivers have this year come much nearer to standardization in basic circuitry. Transistors appear for the first time in portable broadcast receivers and are widely used in sound reproducing equipment

RADIO SHOW REVIEW

to market also sets with the greater number of stages under the designation of fringe-area models. Such models may well have also other differences, such as flywheel sync.

Trap circuits are invariably included for the rejection of the sound channel, and one trap is often employed also to minimize any possibility of interference from the adjacent sound channel.

The detector is invariably a diode, either valve or crystal. Some variation exists in the video stage. The conventional single pentode stage is still used by many people but more and more are adding a triode cathode-follower after it. When this is done a single triode-pentode is generally employed for the two stages, as shown in Fig. 1, where the video amplifier V_1 is directly coupled to the cathode-follower V_2. There are two reasons for the use of the cathode-follower. One is to obtain a lower output impedance, for this assists certain forms of automatic gain control circuit. The other is to increase the video gain. This seems a little odd at first sight, for since the cathode-follower gives a voltage gain of less than unity, it would seem that its inclusion would reduce the total video gain. However, the cathode-follower has such a low input capacitance that when it is used the coupling resistance of the pentode stage can be so increased that the pentode stage gain is increased by more than the loss in the cathode-follower.

The video signal is normally fed to the cathode of the c.r. tube and to a sync separator which usually comprises a pentode, but is sometimes a triode, acting as a slicer. An ignition-interference limiter is invariably included. Generally, this is a biased diode across the video output, but sometimes it is put across the detector output. Sometimes, too, it is rather more elaborate and is known as a black-

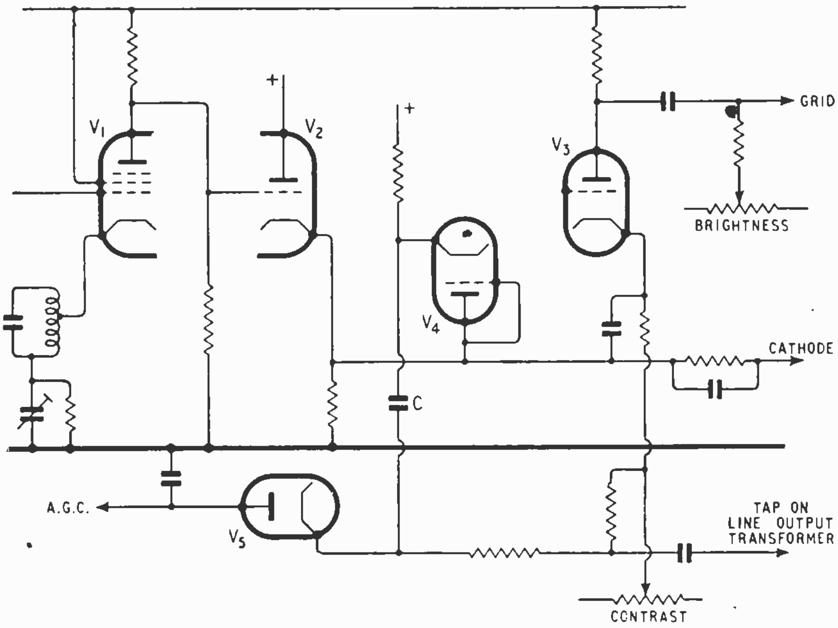


Fig. 1. Video circuit of Ekco T283 showing also the gated a.g.c. system and black spotter.

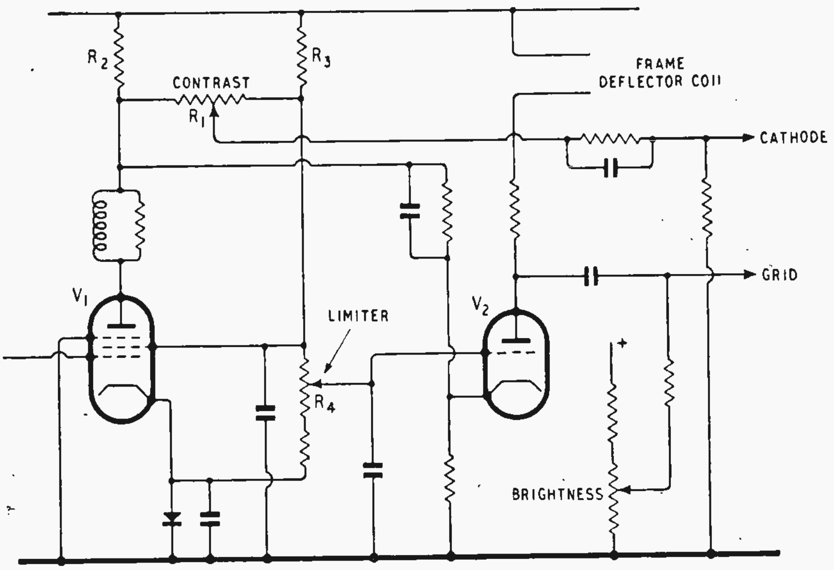


Fig. 2. H.M.V. receivers have a pentode video stage V_1 with a triode black-spotter V_2.

spotter or noise inverter. It is then usually a cathode-input triode connecting the video output to the tube *grid*. It is biased off over the video range of signals, but comes into operation on noise of greater amplitude than peak white and then provides on the grid a noise signal in the same phase as that applied in the normal way to the cathode. The two signals on grid and cathode thus tend to cancel in their effect on the tube.

Figs. 1 and 2 both show this type of black-spotter—in Fig. 1 fed from a cathode-follower and in Fig. 2 from the video stage itself. In the latter the complete video signal is fed through the contrast control to the cathode of the c.r. tube in more or less the usual way. It is also fed to the cathode of V_2 which is biased by R_4 so that it is non-conductive over the whole range of normal variations of the waveform. The signal is increasingly negative for increasing whiteness and a noise peak beyond peak white pulls down the cathode of V_2 sufficiently for it to conduct. An amplified noise pulse then appears on the anode in the same phase and is applied to the tube grid to nullify or overcome the noise pulse applied in the same phase to the tube cathode. Although some of the details of the circuit are different, the black-spotter V_3 of Fig. 1 operates in much the same manner.

The form of contrast control in Fig. 2 is an unusual one. The video-stage coupling resistor is R_2 and the required fraction of the voltage at this point is taken off the potentiometer R_1 to the c.r. tube. The "earthy" end of R_1 is returned to a point on the potential-divider chain R_3, R_4 to remove the standing voltage and so permit R_1 to be of low resistance without drawing excessive current.

Time-bases circuits have a somewhat less standardized appearance than elsewhere, but not very much. For the line scan there is invariably a pentode or beam tetrode output stage which is nearly always coupled to the deflector coils by an auto-transformer. A few people use the so-called direct-drive circuit; for example, Bush. The e.h.t. is a by-product of the flyback and is obtained from an over-wind on the transformer, a half-wave thermionic rectifier being used. In a few sets (e.g., Ekco) a Metrosil voltage-stabilizing element is added to the e.h.t. circuit. Linearity control is generally by means of a small coil having a core which is controllably saturated by a small permanent magnet. Width control is usually by a coil having a movable ferrite core.

The output stage is driven by either a blocking oscillator or a multivibrator; in a few cases, the output stage itself forms a part of the multivibrator. Last year there seemed to be a definite trend towards the use of flywheel sync, although the simpler direct-locking method was still quite widely used. This year the position is much the same, but one could hardly now call it a trend towards flywheel sync; the proportions of sets using the two methods appear to be much the same. There is, in fact, a feeling in some quarters that direct locking is to be preferred when interference is not such as to render flywheel sync a necessity. Murphy, for instance, use direct locking in all their ordinary models and include flywheel sync only in the fringe area types. In the frame sync circuits, considerable minor variations still exist. In the main, however, the waveform generator is a blocking oscillator or multivibrator, with a pentode output stage. For linearity, the well-known feedback circuit is still a favourite.

On sound, a diode detector and a simple, but effective, diode ignition-interference limiter are always used. A pentode output stage, often preceded by a triode a.f. amplifier, is employed. A.G.C. on the sound channel is obtained in a conventional manner. On vision, however, a.g.c. is a good deal more complex and there is no great uniformity of methods. It is not always included at all, of course, but when it is the mean level system still has its adherents. In this the grid voltage of the sync separator is smoothed and applied via a delay diode to one or more i.f. stages and to the r.f. stage. This is the simplest arrangement, but it is one in which the mean brightness of the picture is necessarily affected by the control, for the a.g.c. voltage depends on the mean brightness as well as upon signal strength *per se*.

Gated a.g.c. systems, in which the signal is sampled during the back porch, are free from this effect. The level of signal during the back porch is independent of the mean brightness of the picture. Such systems are a good deal more complicated for they require the production of a gating pulse at some time during the back porch. This is usually developed from the pulse which occurs in the line timebase during line flyback, and quite often a simple RC network will provide the requisite delay. The methods used, however, vary a good deal. One is illustrated in Fig. 1. The diode V_4 is normally non-conductive but is rendered conductive during the back porch by a pulse which is derived from a tap on the output auto-transformer of the line timebase. The capacitor C then becomes charged to a value dependent upon the various voltages involved of which only the back-porch signal level is a variable; the total charge thus varies according to the black level of the signal and so to signal strength. The voltage across C is applied through the delay diode V_5 to the a.g.c. line. The diode also prevents any possibility of the a.g.c. line becoming positive.

Power supplies are almost invariably of the a.c./d.c. type with series heaters, while the h.t. is derived through a half-wave rectifier, either valve or metal. Auxiliary supplies are few, for the electromagnetic focus coil vanished some years ago. However, the permanent magnet focus unit is now showing signs of disappearing also. Some of the new c.r. tubes have electrostatic focus. The voltages needed are fairly low and can be obtained from the h.t. supply or, when this is too low, from an extra rectifier connected to a tapping on the line-scan transformer.

Electrostatic focus means that the focus control can once again be conveniently placed instead of being an inaccessible lever projecting through the back of the cabinet. However, this does not mean that it is always so fitted; there is a tendency to operate under fixed focus conditions or, if not this, to regard it as a pre-set and not a user control.

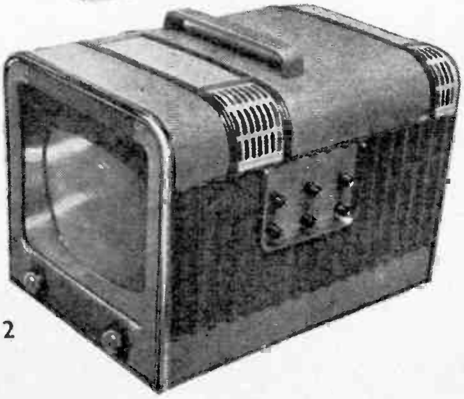
Remote control for television sets is coming somewhat to the fore. Ekco have a remote-control unit for some models which contains contrast and volume controls. It is connected by a multi-core cable and the connector plugs into the set. Philco have a more elaborate arrangement in which a pecking motor is used to operate the turret tuner so that station selection can also be effected remotely.

It was evident last year that manufacturers were not slow to realize that the television set lends itself to Band II f.m. reception and quite a few models with provision for this were shown. This year there are, if anything, more of them. In such sets, Band II coils are fitted to the turret tuner and the sound i.f. amplifier is arranged to feed a discriminator and ratio detector. Some switching is involved in the audio circuits, but mainly in the power supply, since the tube and vision circuits are put out of action on Band II. This switching is mechanically linked to the turret.

Although the combination of Band II sound with the television receiver seems fairly popular the inclusion of a medium and long-wave receiver with it has never been common and of recent years such models have become very rare. A new one this year is produced by Pye and includes also a record-player and four loudspeakers.

In the bigger television sets, like this one, there is certainly a tendency to improve the sound side. The H.M.V. 1847 table model with a 21-inch tube, for example, has two loudspeakers of which one is a high-frequency tweeter. A very unusual point is that provision is made for fitting the bass speaker on either side of the cabinet so that it may be placed on the better side from the point of view of room acoustics.

1. Pye portable with a 14-inch tube. 2. Spencer-West portable. A 9-inch tube is used and the controls are on the side. 3. One of the panels in the Pam printed circuit television receiver. The upper view shows the "connection" side of the panel and the lower the component side.



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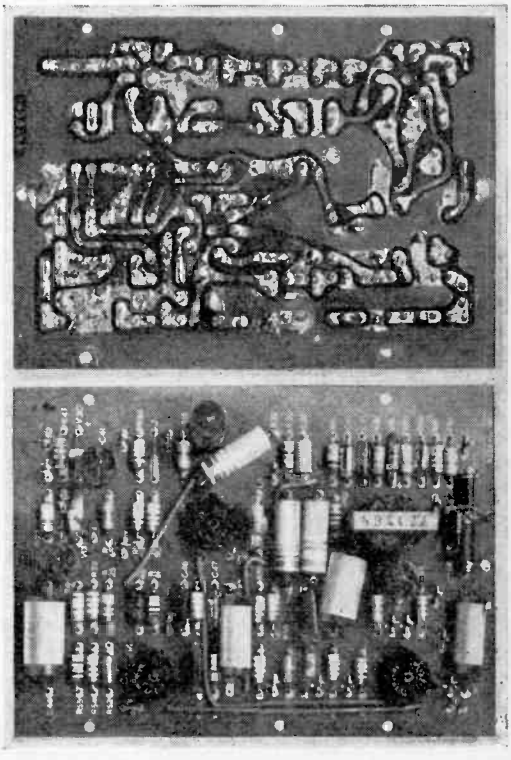

Last year a new trend in television appeared; the portable set. Ekco produced a 9-inch tube model with a vibrator h.t. supply and Murphy a 12-inch with a.c. supply; both are continued this year. There are now several newcomers. Pye have one with a 14-inch tube for a.c. mains only. Spencer-West have a 9-inch tube model.

It is characteristic of these portable models that they have no true cabinet, but light cases of purely functional character. They are, however, of extremely attractive appearance.

TELEVISION AERIALS

A FEW new television aerials made an appearance this year but the general impression given by close examination of the exhibits in this category was that most aerial makers have been busy consolidating the position created last year. Then, the approach of commercial television brought about a spate of dual-band and Band-III aerials, all of which had had to be designed before actual transmissions commenced; Band III was unmapped territory so far as television was concerned in this country.

A year's experience has shown that very few changes in the design of these aerials has been necessary. Mostly they concern the mechanical design rather than the electrical, as, for example, the practice of assembling aerials in the factory in such a way that they can be sent out with all elements correctly assembled, but with the aerial collapsed rather like an umbrella. This simplifies the work of erection as the assembly merely consists of opening out the aerial and possibly tightening a few wing nuts. In some cases even this is not necessary. Generally a locating clip or pin, as used on the Belling-Lee collapsible Band-III aerials, is used to ensure that the elements take up their correct positions and do not become displaced under the stress of vibration after erection. The collapsible technique is not restricted to the smaller Band-III aerials, but is adopted also for some of the dual-band models made by Aerialite, Antiference, Labgear and Telerection.

There is a tendency to replace seamless, drawn tube by rolled tube for aerial elements, it being said that the rolled variety is tougher than the drawn and less liable to fracture in high winds. Wolsey have gone over to rolled stainless steel tube for their elements, but retain aluminium for cross-arms and the supporting pole. In all cases where rolled tube is used for the elements drawn tube seems to be retained for cross-arms and supporting poles.

As rolled tube is not watertight, its adoption has led to a re-design, in some cases, of the centre insulator on the aerial in order to prevent water getting into the cable compartment *via* the aerial rods. This might not have any serious consequences when solid dielectric cable is fitted, apart from the general undesirableness of dampness anywhere in electrical circuits, but it can be quite disastrous with semi-air spaced cables, used extensively on Band-III aerials and often on Band-I models in fringe areas.

Of the new developments an interesting one is the Telerection "phase-corrected" dual-band aerial. The one shown had two Band-I dipoles combined with the reflector and director elements of two Band-III Yagis. The Band-I dipoles function also as the driven elements (to use a transmitting term for easier explanation) on Band III and the complete aerial behaves as a broadside array on both bands. The "delta" matching system, for which this firm is noted, is employed, and, owing to the proportioning of the number of the elements, the matching holds good on both bands.

The unique feature of this aerial is that the Band-I dipoles are broken up into three collinear half-wave Band-III sections by what appear to be insulators, but which are actually housings for small LC circuits resonating in Band III. These confine the out-of-phase r.f. currents along the long dipoles when used on Band III to these non-radiating parts of the system and each thus behaves as three

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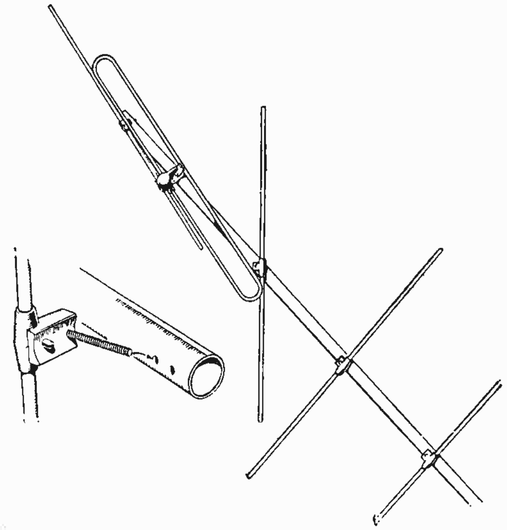
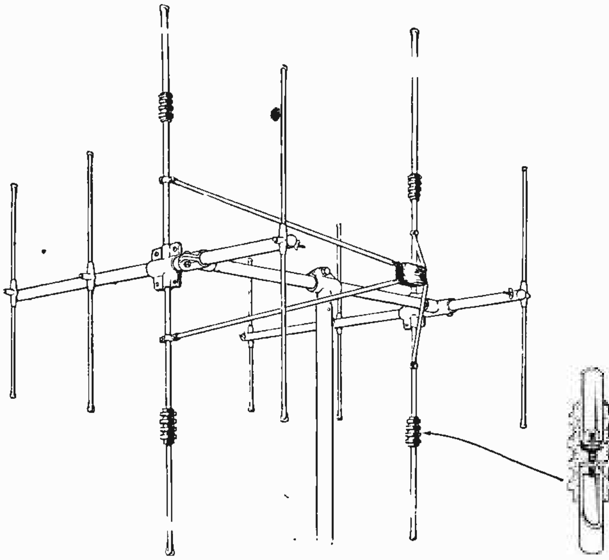


Belling-Lee collapsible Band-III aerial embodying a locating device for the elements.



Left: Telerection "Double Delta Four" combined aerial showing phasing sections inserted in the Band-I dipoles.

collinear half-wave dipoles operated in phase. The principle of operation is similar to that of some of the American wide-band television aerials, but in those the makers use either folded or open stubs resonating in their "high" band. The principle was explained in "Wide-Band Television Aerials" in *Wireless World* of June, 1956.

Without these "phase correctors," as Telerection call them, the vertical polar diagram on Band III would have two principal lobes, one above and one below the horizontal, with very poor response at the normal angles of reception. The phase correctors cause the two lobes to merge into one.

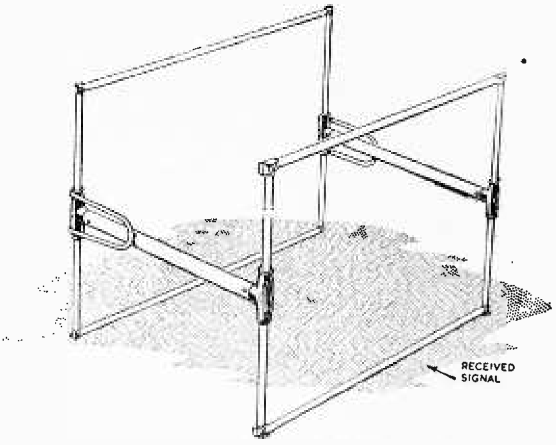
The addition of reflectors and directors for Band III reinforces the forward gain and cancels all or most of the back responses. As shown, with only two Band-I phase-corrected dipoles, the aerial is bi-directional on Band I and uni-directional on Band III, but with the addition of Band-I reflectors the array would be uni-directional on both bands.

Another new aerial of unorthodox construction was shown by Labgear. It is described as the "Bi-Square" and lends itself admirably for erection in a loft, as the space occupied is much less than that of an aerial of more orthodox construction and equivalent gain. Basically it consists of two full-wave dipoles each bent to form a square and mounted about λ/4 apart. The front one, to which is connected the feeder (75Ω), is the "live," or driven, element and the other behaves as a parasitic reflector and occupies the rear position (in relation to the station being received). In order for the rear element to function as a reflector it must be made slightly longer, physically, than the driven element and this is achieved by inserting folded stubs in the centre of each half-wave section.

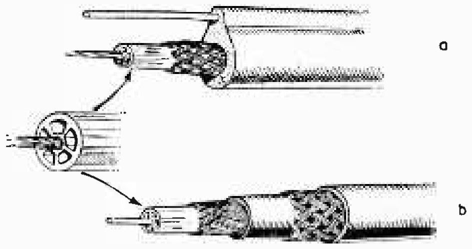
With the aerial rotated so that the "insulators" (the only real insulator is where the feeder is connected) are in the vertical sides, the aerial responds to vertically polarized waves and if turned through 90° so that the insulators are in top and bottom sides the polarization then becomes horizontal. As implied by the mention of a reflector, the aerial is uni-directional and this is at right-angles to the plane of the "loops." The elements may be referred to as loops as the reflector, for example, is continuous electrically, while the only discontinuity in the "live" element is at the feeder connection.

The "Bi-Square" is for use on Band I and is said to give a gain of 12 dB compared with a plain dipole. For Channel I the overall size is approximately 5 ft square and 4 ft from back to front, so the earlier statement that it is well suited for loft mounting is quite justified. For other Band-I channels the aerial will be smaller; a separate model is supplied for each. It is claimed that when erected in a loft, and despite the reduction in efficiency usually encountered under these conditions, its performance is comparable to that of a 3- or 4-element outdoor aerial and good reception can generally be provided out to 50 or 60 miles from a high-power television station. The aerial can be used, of course, out of doors, when it should be equivalent to a 7- or 8-element Yagi, or to two 3- or 4-element Yagis in broadside, so far as gain is concerned.

A novel dual-band aerial, also of unorthodox design, is the new J-Beam "Hornbeam." The Band-III portion, which is called a "skeleton horn," consists of a square frame erected vertically with a horizontal "V" part behind it, the open ends of the "V" being joined to the centres of the top and bottom sides of the square. All parts, such as the sides of the square and the arms of the "V," are very approximately λ/2 long on Band III.



Labgear "Bi-Square" aerial, note the tuning stubs in the reflector element.



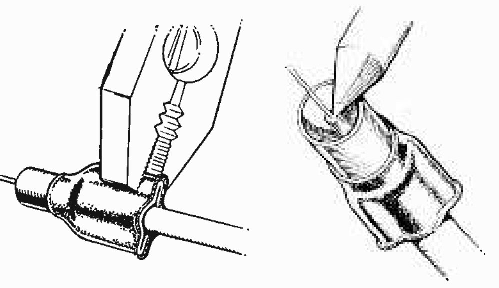
Two new Aerialite coaxial cables: (a) with catenary suspension wire (b) with double screening.

Two vertical elements are joined to the top and bottom sides of the square at the junctions of the ends of the "V." These vertical rods are telescopic and have to be adjusted in length for each Band-I channel. The square plus "V" comprise the Band-III aerial and the vertical rods, in conjunction with the two halves of the square in parallel, form a plain dipole on Band I. In this form the aerial is known as the "Hornbeam I."

The precise method of operation of this aerial on Band III is not very clear, but it appears to behave as two inclined vertical collinear λ/2 dipoles (the "V" portion) with the vertical sides of the square reinforcing the forward response by behaving as two vertical λ/2 dipoles connected in phase by the horizontal sides. This assumes it is orientated for vertical polarization as illustrated in last month's *Wireless World* (page 419).

Now a 4-element Yagi gives a gain of about 9 dB and the 7 to 9 dB claimed for the "Hornbeam" on Band III agrees with what might be expected from an aerial having four effective λ/2 elements. A Band-I reflector can be added thereby making the aerial uni-directional on both bands; in this form it is described as the "Hornbeam II."

Apart from its unique construction the "Hornbeam" is characterized by having a very wide bandwidth; it is said to cover 170 to 230 Mc/s giving a



Antiference one-piece coaxial plug showing method of fitting the cable.

gain of 7 dB at the lower frequency and 9 dB at the higher.

Only infrequently does anything interesting in the shape of coaxial cables appear at the Show. This year Aerialite had two new types which have been produced primarily for use in television relay installations, in blocks of flats wired for television and wherever television is "piped" to a number of receiving points from a central position. One new cable takes the form of a double-screened version of the Super Aeraxial, the additional copper-braid sheath being separated by polythene insulation from the normal outer conductor.

The other cable, which has characteristics similar to the Standard Aeraxial, includes a 0.048-in (No. 18 s.w.g.) galvanized steel catenary wire embedded in the outer PVC covering. This cable is intended for use where long overhead runs are required, or wherever frequent anchorage points cannot be provided. It is a single-screened variety and, in common with the double-screened cable, has a nominal impedance of 73Ω.

Coaxial plugs and sockets used on television receivers, v.h.f. sets, audio equipment at times and some test gear are now more or less standardized and few changes are encountered as a rule. This year, however, Antiference has introduced a new one-piece cable plug for which certain advantages are claimed. There are no loose parts to get lost; it has polystyrene insulation and is completely insulated by a Neoprene sleeve. Assembling (or loading, as it is often called) the cable in the plug merely consists of stripping back sufficient inner and outer insulation on the cable, threading the centre conductor through the hollow pin on the plug, and tip soldering it, then squeezing the skirt of the plug on to the outer braid of the cable. Ordinary flat-nosed pliers can be used.

SOUND RECEIVERS AND REPRODUCERS

UNDOUBTEDLY the predominant development in sound receivers is the establishment of the v.h.f. range as an essential alternative to the short-, medium- and long-wave bands. The success of the early transmissions from Wrotham, the now rapid expansion of the v.h.f. service to the provinces and the renaissance of public interest in sound broadcasting freed from interference and improved in quality have convinced the industry of the wisdom of the B.B.C.'s policy. Two years ago some, last year many and this year all domestic sound receivers are equipped for reception on Band II.

No significant developments in circuitry are evident; the neutralized double-triode mixer-oscillator and the ratio type discriminator continue to provide the economic answer for most manufacturers. The Foster-Seeley discriminator is to be found in high-quality tuner units and a fresh example was noted in the Whiteley Electrical tuner.

The improved quality of reproduction on v.h.f. is due primarily to the removal of restrictions on the bandwidth of the i.f. amplifier which must of necessity be narrow to exclude adjacent-channel interference on medium waves. To exploit the widened frequency response permissible on Band II several manufacturers have revised their designs to provide better sound reproduction. In the Murphy A272C, for example, a return has been made to large baffle mounting for a loudspeaker of better quality. The tuning scale, too, implies that the v.h.f. is the principal waveband. Ekco have gone the whole hog and produced three sets, for v.h.f. only, in which a combination of two speakers is used to improve quality.

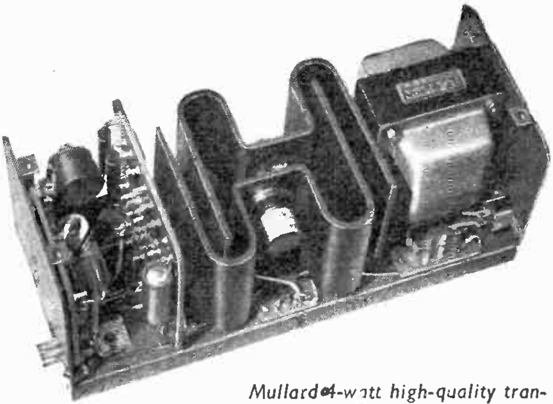
Multiple speakers are also being more widely used for omni-directional (3D) sound distribution in the manner popularized by Continental manufacturers, and the Continental influence is to be seen in many cabinets with dark polished finish and gilt ornamentation.

Two portable receivers made by the printed-circuit technique and employing transistors in all stages were shown. The Pam Model 710 which employs eight transistors (oscillator, mixer, two i.f., detector, a.f. amplifier and push-pull output) has an intermediate frequency of 315 kc/s. In the Cossor set there are six transistors, the first is an oscillator-mixer and is followed by a single i.f stage (460 kc/s), detector, two drivers and the customary push-pull output stage.

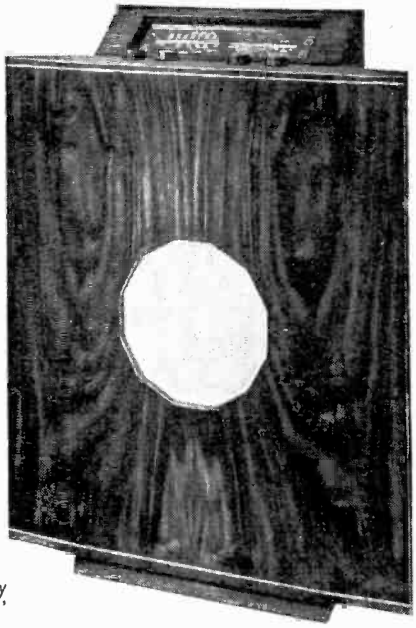
Transistors have virtually ousted valves in small portable record reproducers, which are now available with a battery-driven turntable for 45-r.p.m. records. Four U2 dry cells (6 volts) serve to run the motor and energize the transistor amplifier. Examples of this new trend were to be seen on the stands of Cossor, Philco, Philips, Pye, Roberts and Vidor. In the Philips AG2130 and the Philco Model 3755 three-speed battery-driven turntables are provided.

The transistor has also invaded the car radio field and is used in the latest Pye receiver not only for the output stage but also as a switching device in place of the more usual mechanical vibrator for h.t. generation.

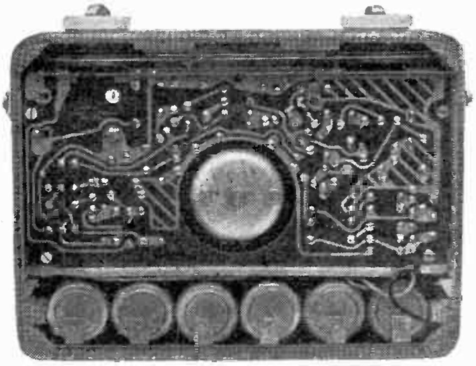
The widely held opinion that transistors, while being all very well for hearing aids and small portables, are unlikely for a long time to come to displace valves in high-quality power amplifiers may have to be revised sooner than most people think. Last year we saw their use in a low-distortion tape pre-amplifier (Reflectograph) and this year Mullard demonstrated an experimental high-quality amplifier with less than 0.4% total distortion at a rated maximum output of 4 watts (at 1 watt the distortion is 0.13% a 1000 c/s). Push-pull OC16 transistors are used in the output stage and there are two feedback loops, the inner from the OC16 collectors to the bases of the driver transistors and the outer from the output transformer secondary to the base of the input stage. Stability problems with large degrees of feedback are eased by the fact that direct couplings can be used between the driver and output stages, and



Mullard 4-watt high-quality transistor amplifier showing " heat sinks " for power transistors.

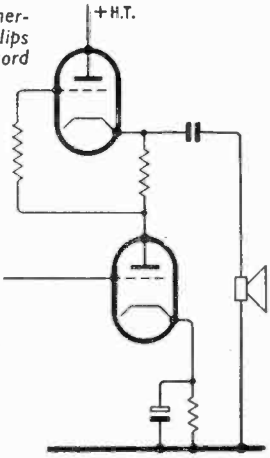


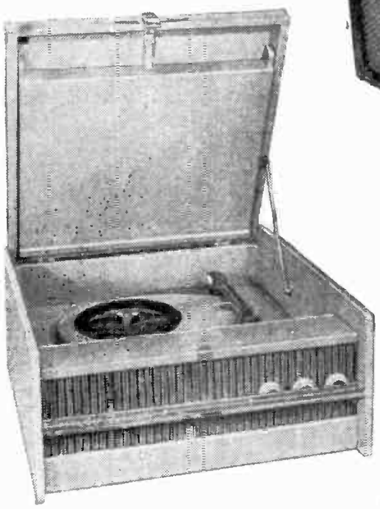
Right: Murphy A272C "baffle" type console.



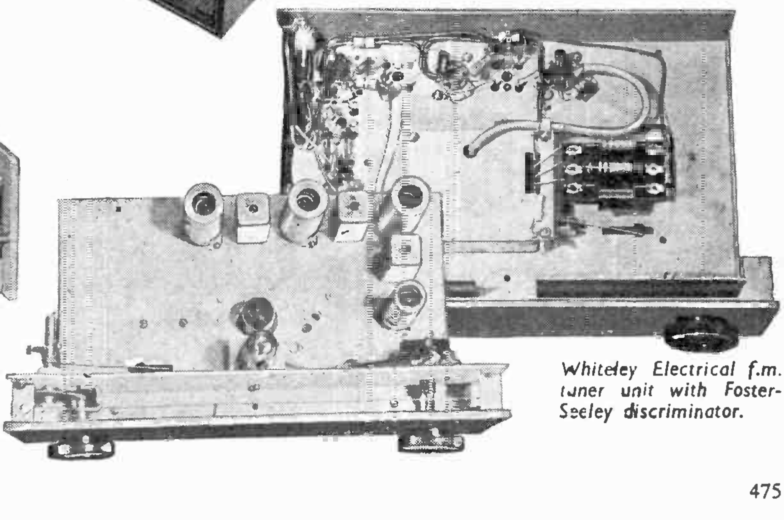
Cossor portable receiver using transistors throughout in a printed circuit.

Right: Connections of transformerless output stage in the Philips AG2126 "Magic Box" record player (below).





Philco "Transistor" 3-speed portable record player.



Whiteley Electrical f.m. tuner unit with Foster-Seeley discriminator.

by the use of an OC45 to give a wide-band, high-gain input stage. Heater hum problems are non-existent and supply voltages are low.

Although an output transformer is used in the Mullard amplifier it is often dispensed with in transistor push-pull output stages, which then feed a centre-tapped high-impedance moving-coil loudspeaker directly. A move in another direction to eliminate the output transformer was noted in the Philips AG2126 "Magic Box" record reproducer. This is for a.c. operation and uses valves throughout. The interesting point is that the two output valves are operated in series with feedback applied in the upper valve. The result is a useful increase in the current gain of the stage as a whole and an equivalent output impedence low enough to feed a high-impedence moving coil directly.

Electrostatic loudspeakers are still subsidiary to the moving coil as far as most receivers and reproducers are concerned. Two are used in conjunction with a 12-in moving coil in the McMichael 1555 radio-gramophone and Pye have added an electrostatic unit to extend the frequency range of their "Super Black Box" record reproducer. An interesting combination of the moving-coil and electrostatic principles is under development by Whiteley Electrical who showed one of their 12-in "Duplex" models in which three of the mid-frequency stabilizing patches in the main diaphragm were replaced by small circular electrostatic "wafers" connected in parallel.

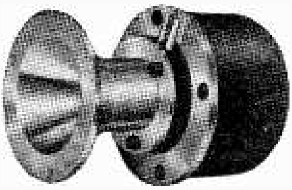
An unexpected development by Goodmans is a return to pressure units and horn loading for middle as well as high frequencies, and a three-unit system employing a large direct-radiating "woofer" for the bass showed itself capable of handling the high power outputs which are now called for by many American buyers of "hi-fi" equipment.

Tape recording activities are centred chiefly on the reproduction of "Stereosonic" twin-channel records and H.M.V. can now supply their tape deck (Model 3035), with equalized amplifiers and a control unit for incorporation in existing high-quality installations.

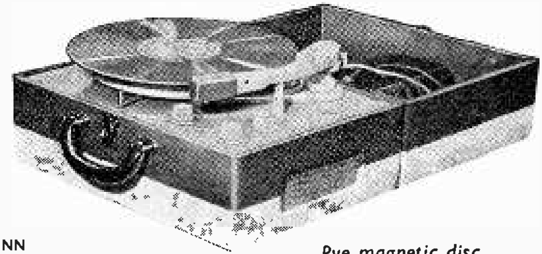
G.E.C. have gone into production with a complete stereophonic sound reproducing system incorporating standard G.E.C quality amplifiers and metal-cone loudspeaker units and using a Truvox Mark IV tape deck with a special dual playback head.

A disc-type magnetic recorder has been developed by Pye for home entertainment. The record/playback head is mounted in a tone arm, and the discs, which are impregnated with magnetic oxide, have an unmodulated spiral groove impressed on both sides which serves to track the head. The turntable has four speeds and playing times up to 12 minutes per side at 16⅔ r.p.m. are obtained. Recording is made with a.c. bias and erasure by separate magnetic "wiper" blade. Accessories include a two-station radio tuner unit, and normal gramophone pickup heads can be purchased separately to convert the instrument to a record player. The amplifier has an output of 4 watts and enough gain for use with a microphone.

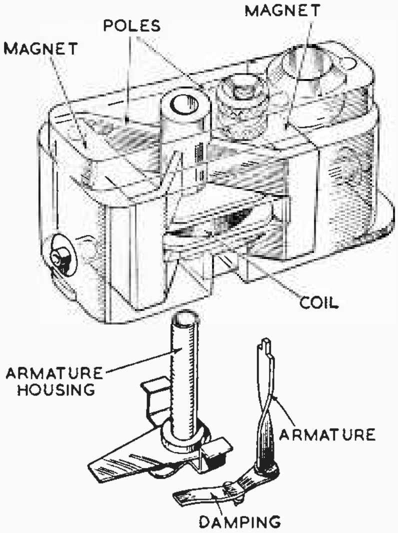
Normal disc reproducing techniques, as exempli-

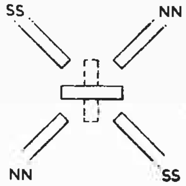


Goodmans "Trebax" horn-loaded high-frequency unit.

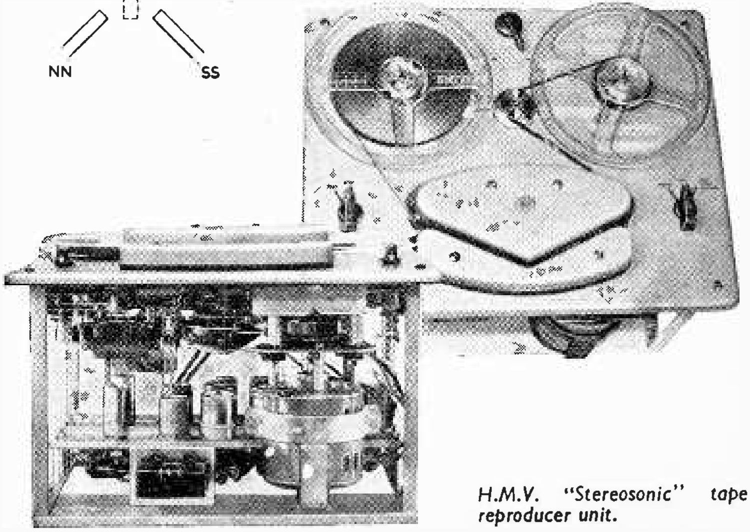


Pye magnetic disc "Record Maker."





R.C.A. eight-pole "New Orthophonic" pickup.



H.M.V. "Stereosonic" tape reproducer unit.

fied at the Show, have not changed fundamentally, but the pickup marketed by R.C.A. (Great Britain) Ltd. is of interest. It serves to underline the dictum that method of execution is often more important than principle of operation in electro-acoustic transducers. The moving-iron (variable reluctance) principle has had more detractors than most, yet it was shown many years ago that distortion could be reduced to negligible proportions by the use of wide air gaps and proper siting of the pickup coil. In the R.C.A. design no fewer than eight poles are used and the armature has a 90° twist above and below the pickup coil. This results in what might be termed double differential cancellation of any residual non-linearities near the neutral positions of the two halves of the armature.

VALVES AND SEMICONDUCTORS

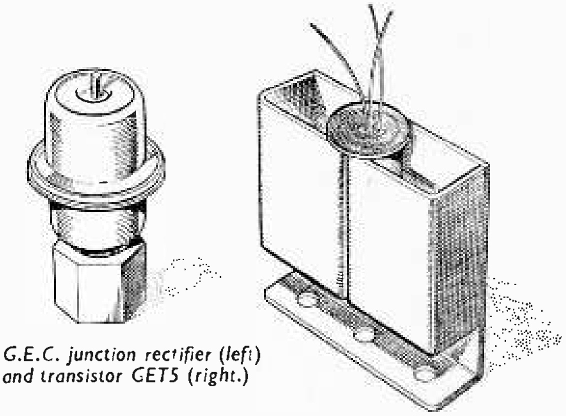
JUNCTION transistors, at one time only available for low-power amplification at audio frequencies, are now branching out in two directions—towards higher powers and higher frequencies. This puts us in the pleasant position of having several categories of transistors from which to choose. The groups are fairly well defined by the limiting values of the transistors concerned, and they correspond roughly to the various departments of a sound broadcast receiver.

First of all there are the low-power, low-frequency types primarily intended for audio input and driver stages. They have collector dissipations in the region of 25-50 mW and alpha cut-off frequencies of about 500-800 kc/s. Some of them have rather higher cut-off frequencies, of the order of 1-2 Mc/s, and these, particularly, can be used for i.f. amplifier stages working at 200-500 kc/s when their internal feedback is neutralized by suitable circuit design. A wide range of types by various manufacturers is already on the market.

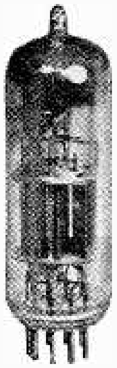
Going up in frequency brings us to the next category—r.f. transistors. These are low-power devices (collector dissipations of 10-25 mW) with cut-off frequencies in the region of 3-10 Mc/s. They can be used as r.f. amplifiers, oscillators and frequency changers for the medium- and long-wave bands and also, of course, as i.f. amplifiers. At the moment they are not readily available on the general market, but should be in quantity production at the beginning of next year.

In roughly the same stage of development are the transistors in the high-power category. These are mainly intended for audio output stages and are often used in Class B push-pull circuits. The smaller types, which are easily obtainable, have collector dissipations of about 50 mW and in push-pull circuits will give outputs of approximately 200 mW. The larger ones, which are still to some extent experimental, will dissipate 2-8 watts when suitably cooled and provide outputs (push-pull) in the range 3-10 watts.

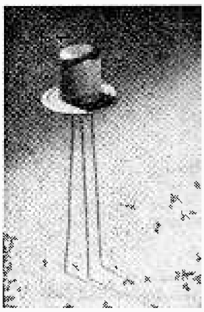
At the Show a complete range of transistors representing each of these categories was offered by Ediswan, who have just entered the field. Their XA101, for example, with a cut-off frequency of 4.5 Mc/s, is suitable for i.f. amplification at 250-500 kc/s, while the XA102, with 7 Mc/s cut-off, can be used as a frequency changer or local oscillator. Types XB102 and XB103 are for a.f. amplifier or driver stages, while the XC101 comes in the small-size power category (220 mW push-pull output). All of them are hermetically sealed in welded metal cases.



G.E.C. junction rectifier (left) and transistor GET5 (right.)



Mullard u.h.f. transmitting double tetrode QQVO2-6.

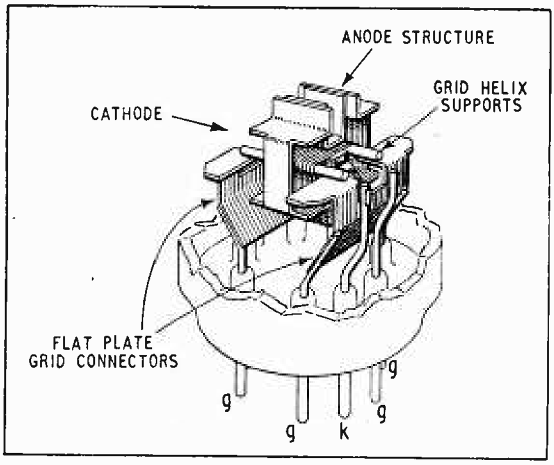


Ediswan transistor of metal construction.

Pye Industrial Electronics also have a complete range, with three audio and i.f. types, prefixed V10; three r.f. types, prefixed V6, having cut-off frequencies between 3 and 10 Mc/s; and six large-size power types, prefixed V15 and V30, with collector dissipations of up to 4 watts.

One of the earliest power transistors, the Mullard OC15, has now been superseded by a new experimental type, the OC16. This operates with collector voltages up to 16 V and has a maximum dissipation of 8 watts at 25°C. Another new experimental type from the same firm is the OC45 r.f. transistor, which is of all-glass construction and has a cut-off frequency of 6 Mc/s The equivalent-circuit collector capacitance is 12.5 pF.

The range of G.E.C. junction transistors hitherto known by the prefix EW are now being changed to GET type numbers. The GET3, GET4 and GET6 are all primarily intended for low-power a.f. and i.f. applications, but the GET6 is notable for its low-noise performance, while the GET4 characteristics are such that it can be used for Class B push-pull output stages of up to 200 mW. A transistor specifically designed for output stages is the GET5. This is similar internally to the GET4 (both have f_α at about 1.4 Mc/s) but has a nickel-plated copper mounting arrangement designed to give low thermal resistance (see sketch), which allows the collector dissipation to be as high as 200 mW at 45°C. Moreover, the variation of current gain factor with emitter current is quite small. In a push-pull output stage



Electrode structure of Brimar 6AM4. The grid (normally earthed) is connected to five pins by flat metal sheets.

working from 20 V a pair of GET5s will give 800 mW.

As for the rest of the semi-conductor field, the more recent developments were represented as follows: avalanche transistors for high-speed pulse circuits (Mullard); silicon junction diodes for high temperature operation (Ferranti, G.E.C. and S.T.C.); silicon junction power rectifiers (Ferranti); germanium junction photocells (S.T.C.); and photo-transistors (Mullard). Two new silicon junction diodes, SX641 and SX642, for operation up to 150°C were shown by G.E.C. At 100°C they have reverse currents as low as 5 μA with peak inverse voltages of 60 and 120 respectively.

Amongst metal rectifiers the most interesting exhibit was a rectifier/stabilizer for the 1.4-V valve filament supplies of mains/battery portable receivers. It consists of two small selenium rectifiers mounted on the same insulated spindle. The first is used for obtaining the d.c. low-tension voltage from the mains transformer and comprises two units which can be connected for either half- or full-wave rectification. The second rectifier, also in two sections but joined permanently in series, is shunted across the valve filaments, and it acts as a voltage stabilizer—with the aid of a series resistor—by virtue of the non-linear voltage/current properties of the forward characteristic.

There were no really outstanding developments in valves to be seen this year, except perhaps the introduction by G.E.C. of a "big brother" for the well-known KT66 audio output pentode. Known as KT88, it has the increased anode dissipation of 35 W (as against 25 W), a slope of 11 mA/V (compared with 6.3 mA/V), and in a push-pull stage with fixed bias will give twice the output power of an equivalent KT66 stage.

If a trend in valves is to be detected at all, it is perhaps the gradual introduction of u.h.f. types for operation in Bands IV and V. This is made necessary by the possibility of colour television and mobile radio moving into these bands. The rather surprising thing about the new valves is that they look like ordinary miniature receiving types on B7G and B9A bases, but in fact their internal electrode structures are somewhat different, being mostly constructed on the planar-electrode principle. In a sense they represent a half-way house between conventional electrode structures and the expensive disc-seal techniques.

S.T.C. rectifier/stabilizer for mains battery portables.

Examples at the Show were the G.E.C. type A2521 low-noise receiver input valve, the Brimar 6AF4A oscillator triode, the Brimar 6AM4 r.f. amplifier or mixer triode, and the Mullard QQVO2-6 power-amplifier double tetrode. The last-mentioned, which is intended for mobile radio transmitters, uses a new type of control grid to give the high slope (for u.h.f.) of 7 mA/V, and in a power amplifier circuit working at 490 Mc/s will deliver 3.5 watts to the aerial.

The trend in television cathode-ray tubes towards bigger and bigger screens has now largely stabilized at the 21-inch rectangular type with a 90° deflection angle. Ediswan, however, were showing a 24-inch rectangular tube. Will this be the next stage—or are we beginning to stretch our 405 lines beyond the limit?

OTHER EXHIBITS

IN addition to ERNIE, the random number generator described in our last issue, the G.P.O. demonstrated several other unusual electronic devices. Perhaps the most impressive was an electronic letter-sorting machine, which enables a single operator to divide mail into 144 groups at one sorting as against the 48 groups in ordinary hand sorting. The letters are actually distributed by a "conveyor belt" system made up of small rollers with receiving compartments underneath, and it is the function of the electronic circuits to select and open the lids of the compartments for the travelling letters to fall into.

First, the letters are automatically passed in front of the operator, who observes the town of destination and then, in accordance with a memorized code, presses two buttons simultaneously. There are 12 buttons for each hand, so that a total of 144 combinations is available. The buttons switch on voltages, which are applied to a 12 × 12 matrix of 144 cold-cathode tubes, so that for each combination a particular tube is triggered. The output signal from the tube is then used to actuate electromechanical control gear, which opens the appropriate receiving compartment after a delay to allow for the travelling of the letter.

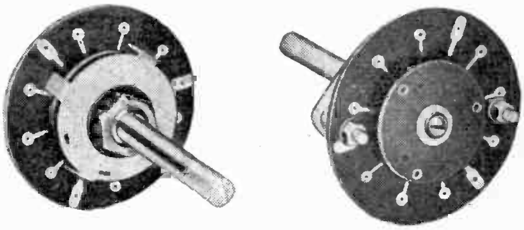
The process of selection by electronic means was also to be seen in a demonstration of electronic switching for automatic telephone exchanges. Here the method of communication between any two subscribers, over a circuit common to many subscribers, was based on the time-division multiplex principle. The connection of any two subscribers is achieved when coincident pulses are applied to germanium rectifiers in each of their circuits, and at these instants speech currents held as charges in capacitors are transferred from one end to the other. The switching pulses themselves are prevented from coming on the line by arrangements of transformers. Ringing is achieved by transmitting a 2-kc/s tone broken at 17-c/s intervals. At the receiving end this is amplified by a transistor, which allows a capacitor to charge and so produce a 17-c/s pulsating voltage for operating the bell.

Precise timing was also the essence of another demonstration, in the "Careers in Electronics" section, showing the electronic method used for calculating the speed of the Fairey Delta II aircraft on its record-breaking 1,132-m.p.h. run. Special cameras were set up at each end of a 9-mile course. When the aircraft came in the field of view of the first camera an operator exposed the film, and the shutter mechanism started an electronic timer counting pulses from a crystal-controlled source. At the far end of the course the second camera was operated as the aircraft came in view and here the shutter was used to stop the timer. Thus, from the number of pulses counted (representing a period of time), the known length of the course, and the position of the aircraft relative to the graticule of each camera when actually photographed, it was possible to calculate the speed. An overall accuracy of 1 in 2 or 3 thousand was said to be obtained.

An unusual type of display seen on a cathode-ray tube on the Mullard stand was the spot tracing out a word in the form of handwriting. The tube was a 12-inch p.p.i. radar type with a long-persistence screen. The necessary X and Y deflection wave-

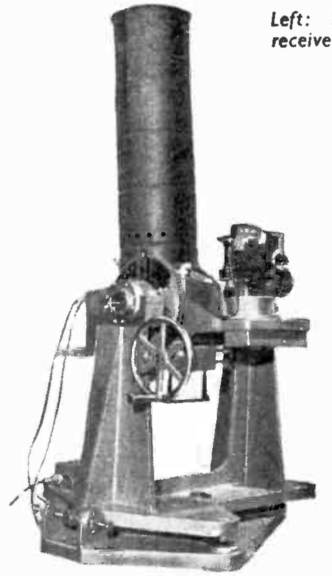
Display version of G.P.O. electronic random number generator for providing two digits.

Pye transistorized loud-hailer with trigger switch.



T.C.C. printed-circuit wafer switches with flush contacts to reduce wear and prevent contact bounce.

Left: Special camera used for electronic timing of Fairey Delta II aircraft. Right: Midget receivers being soldered with Multicore "Savbit" alloy containing copper to reduce bit wear.



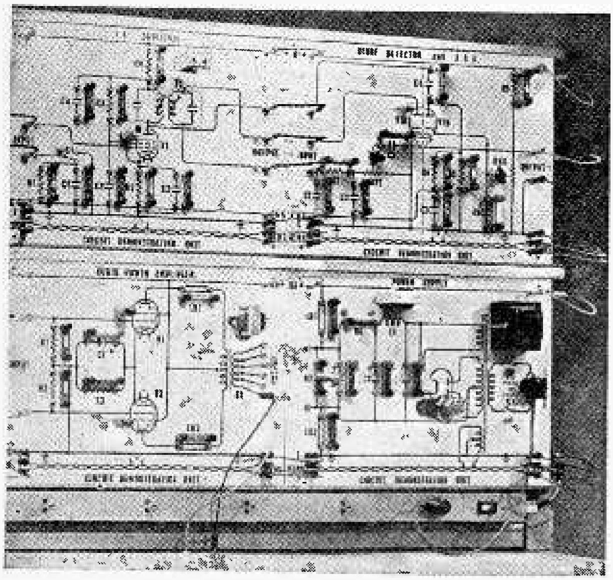
forms for doing this were obtained from photocells scanning rotating masks, which were shaped to represent graphs of the waveforms in polar co-ordinates. By adjusting the X and Y gain controls it was possible to alter the character of the handwriting.

As one might expect, transistors were to be seen in a good deal of apparatus, especially where small size, light weight and economical operation were the desirable features. A good example was the Pye transistorized loud-hailer, which incorporates a folded-horn loudspeaker, a 3-watt transistor amplifier, an electromagnetic microphone and batteries, all in a single hand unit weighing only 5lb. The speaking range is up to 500 yards, while the average consumption from the 12-V battery is 120 mA, giving a battery life of about 20,000 ten-second operations, or up to about six months on normal use. The amplifier consists of a Class A driver transistor in a common-emitter circuit coupled by a phase-splitting transformer to a pair of 3-W dissipation power transistors in a Class B push-pull stage, which drives the 15-Ω loudspeaker through an output transformer. The frequency response is flat within 3 dB from 200 c/s to 4 kc/s.

An example of how transistors can be used to advantage in test gear was to be seen on the Labgear stand in the shape of a portable crystal-controlled r.f. oscillator not much bigger than a matchbox. It is intended for servicing radio equipment in the field when mains supplies and normal test gear are not available. An r.f. junction transistor is used in the oscillator circuit, operating in the range 2-6 Mc/s (as ordered) and giving an output (unloaded) of at least 1.5 V r.m.s. with a frequency stability of 0.01%. The current drain from the built-in miniature battery is 1 mA, giving an average battery life of 40 hours.

Wolsey "balun" 75-300-ohm coupling unit.

Below: Circuit display boards used in Philco training equipment.



Several experimental transistor receivers for medium and long waves were shown by Mullard, but perhaps the most interesting example of transistorization here was an unorthodox approach to the problem of v.h.f. reception. Obviously, even the latest r.f. transistors could not be used for r.f. amplification at 90 Mc/s, so the aerial was connected straight to a diode mixer. The local v.h.f. oscillation was obtained by using an avalanche transistor to generate very sharp pulses and then selecting the appropriate harmonic from them by filters. Another interesting circuit was a television sync separator using two OC71 transistors. This gave line and frame sync pulses of about 10 V amplitude suitable for all normal types of timebase oscillator. Approximately 1 volt of composite video signal was required at the input.

An excellent aid to practical training in radio and electronics was demonstrated for the first time by a new department of Philco (Overseas). This consisted of a series of displayed circuit panels, 34 in all, each of which carried a circuit diagram, painted in black on a yellow background, and an actual working circuit laid out correspondingly. The components and valves are on the front of the panels and are plugged in alongside their appropriate circuit symbols. Up to eight panels can be mounted on a large display rack, which has wiring facilities for interconnecting the units. Accompanying this demonstration equipment is an equivalent set of 34 small standardized chassis for actual laboratory work. These duplicate the circuits on the demonstration panels and can be connected together in the same way in racks but are constructed on more orthodox lines.

On the same general principle of building up one's own apparatus—though not entirely for educational purposes—were the two instrument kits for home construction shown by Cossor Instruments. One of these was for a single-beam 4-inch oscilloscope with a timebase variable in frequency from 20 c/s to 250 kc/s and a Y amplifier having a useful response up to 10 Mc/s and giving a maximum sensitivity of 50 mV per cm. The other kit was for a valve voltmeter covering 40 c/s-1 Mc/s and having r.m.s. ranges up to 1.5 kV, peak-to-peak ranges up to 4 kV, and also ranges for ohms and d.c. volts.

Among the various accessories to be seen this year was a small "balun" for matching a 75-Ω coaxial cable to a 300-Ω balanced input circuit of the kind found in some f.m. receivers and tuners. It is made by Wolsey and has a coaxial socket at one end and a short length of 300-Ω ribbon feeder at the other. An interesting aerial development is a new Belling-Lee "Skyrod" for commercial rather than "domestic" use which is fitted with a precipitation static discharger at the top. The specimen shown was about 15ft long and made of 1½in-diameter tube.

A wide range of printed circuits for various applications was to be seen on the T.C.C. stand, including small panels for mounting sub-assemblies and wafer switches with flush contacts.

Mobile Radio Development

V.H.F. Operation with Reduced Channel Spacing

By *J. R. HUMPHREYS**

THE need to reduce channel spacing as a means of providing more channels within the frequency bands used by v.h.f. mobile radio in this country is not disputed by anyone. It is a factor of great importance to those actively concerned with finding sufficient channels to allocate, and those who wish to operate in these bands with freedom from undue interference.

The success of our efforts to reduce channel spacing, however, depends to a great extent on our ability to solve a number of important problems. Not the least of these is that of introducing new equipment to new standards into a field of operation now occupied by a variety of equipment, some of which is not always capable of providing interference-free operation with the present channel spacing.

It is with this in view that the author intends to start with a brief examination of the history, method of operation, and channelling standard of equipment currently in use in the two v.h.f. bands; then pass to a more detailed examination of operational and technical factors affecting channel spacing in particular.

Present Practice and Standards in the U.K.—Over the period of the last ten years a very considerable quantity of v.h.f. equipment has been installed and is operating in the bands 71.5 to 88 Mc/s (called the low band) and 156 to 184 Mc/s (called the high band).

The low band, which was the first to be used, has been allocated on a 50-kc/s channel separation basis, and schemes using this band have tended in the main to be those wishing to cover as wide an area of operation as possible.

The high band, which has at present a channel spacing of 100 kc/s, is more suitable, by reason of its shorter range propagation characteristics, for use in highly industrialized areas and for schemes not requiring a large area of operation.

There is considerable need for more channels in both bands, but the problem in the high band has assumed a higher degree of priority, because of a recent decision to reduce its upper limit to 174 Mc/s.

The bulk of equipment in these two bands operates on a two-frequency simplex system, with a frequency spacing of the order of 10 Mc/s, which permits a close geographical spacing between base stations

When the existing equipment specifications were drawn up by the General Post Office, in conjunction with the radio industry in 1948, the accent lay on what it would be reasonably possible to produce rather than what was actually necessary to give a certain desirable system performance. Inevitable though this was at the time, it has produced a specification which has three important shortcomings from a channel separation point of view. These are:—

(a) When the maximum frequency errors occur, two adjacent channels may be as close as 64 kc/s at 180 Mc/s, or 33 kc/s at 85 Mc/s.

(b) The specified minimum selectivity of receivers is such that, even if the maximum errors in (a) do not occur, unrestricted and interference-free use of a number of adjacent channels cannot be guaranteed in the same area. This is particularly true of low band equipment where 50-kc/s channelling makes the selectivity requirements more arduous.

(c) There is no limitation placed upon the amount of energy radiated by a transmitter in channels adjacent to its own carrier frequency. This unwanted radiation becomes important for spacings of 50 kc/s or less when a high degree of adjacent channel protection is needed.

These factors have an important bearing upon the present allocation as well as on future plans.

Frequency Allocation.—This is a complicated subject upon which it is only too easy to generalize and it must be borne in mind here that the problem of allocation is often very difficult. Even so, the following two questions may fairly be asked:—

First, is the best use being made of the existing frequency bands, with the channel spacing currently employed, and the equipment at present in use? Secondly, with new equipment becoming available, what channel spacing should be adopted in the high and the low band and how can this best be introduced?

First, let us examine some of the methods which are at present in use, or could be introduced in these bands, to increase the use of the spectrum.

A well-known method, that of frequency sharing or co-channel operation, has obvious advantages particularly when applied to areas sufficiently spaced in distance to prevent interference. It also has limited use for "same area" users who may operate on a time-sharing basis. This latter type of sharing has obvious limitations, but applied intelligently is a useful example of frequency economy.

Another method often advocated, but not in use in this country, is that of allocating split channels in areas sufficiently separated in distance to enable existing equipment to be used. This would appear at first sight to offer considerable advantage and would allow 50-kc/s channels to be used in the high band and 25-kc/s in the low band. If this could be successfully applied over the country, the economy effected would enable more channels with the present spacing to be used in those areas already congested.

These advantages cannot be realized with present equipment, however, due mainly to the fact, already mentioned, that owing to frequency errors and lack of selectivity the geographical separation necessary would not be appreciably less than that for co-channel working. For example, a typical 50-kc/s channel equipment meeting existing specifications, but having maximum frequency errors, might well give only

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* Pye Telecommunications, Ltd.

10-dB rejection of a signal in an adjacent channel of only 25 kc/s separation.

Even when new and technically superior equipment is used this form of allocation does impose a greater burden of responsibiity upon those concerned with planning and frequency allocation. They might be expected to favour what at first sight would appear to be a simpler course of allocation which avoids this type of geographical and technical consideration.

Apart, therefore, from the other advantages to be gained, the introduction of equipment which will operate satisfactorily on adjacent channels in the same area, with reduced channel spacing, appears to offer planners a simpler solution to their problems.

Coming now to the second question, it seems a logical step to aim at the minimum achievable spacing that can be introduced in both bands. This has the very great advantage of avoiding the need for more than one change and one type of equipment and will ensure a very long period of operational stability.

Bearing in mind the present spacings of 50 and 100 kc/s, the obvious reduction is to a spacing of 25 kc/s throughout, which will allow double the number of low-band channels, provide four times the number of high-band channels and at the same time will require no alteration of the frequencies at present in use.

There is considerable evidence to show, taking into account all foreseeable technical advances, that a separation of much less than 25 kc/s would not permit the satisfactory operation of adjacent channel schemes in the same area. There is, however, good reason to believe that equipment operating satisfactorily in the same area with a spacing of 25 kc/s, could be used on split channels of 12.5 kc/s for operation in areas with suitable geographical spacing.

A very similar proposal has been made by the American F.C.C. authority who are splitting their present 60-kc/s channels into 30-kc/s and then 15-kc/s channels with a geographical safeguard.

Introducing New Equipment.—The method of introduction of new equipment is obviously of great importance as it raises the problem of compatibility with, and interference to and from, old equipment. Let us examine briefly the question of introducing two frequency simplex equipment in the high and the low bands which will: (a) operate satisfactorily in the same area on adjacent 50-kc/s channels, and (b) on adjacent 25-kc/s channels.

The introduction of equipment described in (a) into existing schemes presents a compatibility problem in the high band but not the low band.

If (a) equipment is added to existing high-band schemes, then existing base transmitters will need to have improved frequency stability. Base receivers must remain "wide band" unless all old mobile transmitters are improved in stability or until they become obsolete.

If (a) equipment is used in the high band and new 50-kc/s channels are interleaved between the old 100-kc/s channels, then it will not be possible to allocate them in the same area as existing 100-kc/s schemes, because of adjacent channel interference to old and new equipment.

The geographical separation between schemes which will allow an interleaving policy, is not easy to estimate owing to the uncertainty of the errors of existing equipment. A rough estimate would be approximately half the co-channel spacing distance.

The introduction of equipment described in (b) into existing schemes presents a compatibility problem in the low and the high band, and existing base transmitters will need to have a much higher degree of frequency stability to work into the narrow bandwidths of mobile receivers. Similarly, base receivers will have to remain wide band until all old mobiles become obsolete or can be stabilized.

The interleaving of (b) equipment on new 50-kc/s channels in the high band will produce the same sort of result as for (a) equipment with rather less interference to the new services from the old.

The allocation of (a) equipment to new 25-kc/s channels, can be made in those areas where old equipment is not in use, or is at least 100 kc/s away in frequency.

Operational Limitations.—With the reduction of channel spacing and the consequent increase in the number of channels and users in any particular area, there will arise a number of operational factors not all of which are directly related to channel width.

The first, and perhaps the most important of these, is the effect of inter-modulation in receivers from a combination of unwanted transmitters spaced close in frequency to the wanted transmission. The subject has been examined in detail by Bullington[1] and Babcock[2] who, writing from their experience of American mobile v.h.f., had to consider the twin effects of congestion of operation, as well as the use of a single-frequency simplex system.

Because v.h.f. mobile systems in this country are operated mainly on a two-frequency basis, the problem is simplified considerably. This is because combinations of base transmitters, which might cause harmful interference in base receivers in the same area, tend not to occur. Also, if interference does arise, it is comparatively simple to eliminate.

The problem nevertheless exists to the same degree in respect of combinations of base transmitters causing interference in mobile receivers. It will also be caused, though less frequently, by a number of mobile transmitters interfering with base receivers.

To give some idea of the magnitude of these effects, the following example taken from recent field measurements using equipment of new design may be of interest:—

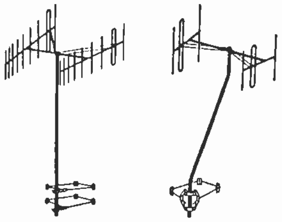
Three co-sited base transmitters, A, B and C, were operated in the 150-Mc/s band with powers of approximately 15 watts, with heights above the ground of approximately 100 ft and at a frequency spacing between each of 25 kc/s.

It was observed that a mobile receiver operating on the frequency of transmitter A received interference from the combination of B and C (in the absence of a transmission from A) when it operated in an area around the site of between 200 yds and 800 yds radius. It is interesting to compare this figure with the radius of adjacent-channel interference which was confined to a distance of between 50 and 100 yds. Whilst it is true that with co-sited schemes the wanted transmission will generally "capture," this will not occur in the majority of cases. The planning, therefore, of numerous v.h.f. schemes in a small area and using closely spaced channels must take increasing note of this problem which rapidly becomes more difficult as the number of channels increases. Inter-modulation can, of course,

(*Continued on page* 483)

"BELLING-LEE" NOTES

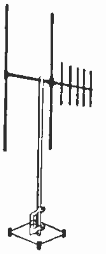
New Band III Broadsides from Enfield



We can announce several new band III designs which we were able to finalise after the last issue of the "Wireless World" went to press, and before the Radio Show opened its doors to the public. By the time you are reading this, we will be delivering all these new types—they are in production.

The great success of the "Belling-Lee" "double-six" broadside array has resulted in our producing a "double-three" and a "double-nine." These new designs are particularly useful for the reduction of "ghost" images in "difficult" towns such as Sheffield, where the town is surrounded by hills.

In localities not far enough away to warrant a "double-six" the "double-three" will be found a boon. Both of these new designs are available for channels 8, 9 or 10. The "double-three" has either a cranked mast and single lashings, or a nine foot mast and double lashings. But the "double-nine" is provided with a 14 foot mast and double lashings only, and is probably the most efficient commercial aerial available from production lines at the moment.

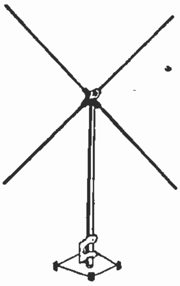


Band I "H" with 5 Band III elements

This aerial is the logical development from our band III adaptor kit, which consists of two add-on elements alongside a band I dipole (L.924 Patent Application No. 17696/54). The patent will be seen to be two years old. This combination results in an aerial which will give good results in the secondary areas of both B.B.C. and I.T.A. services.

It was originally designed for channels 1 and 9 only, but is now available in channels 2 and 10, so they will soon be seen on the skyline in Yorkshire. It is supplied with a 9 foot mast and lashings, and has an array only suitable for fixing to customers own tubular mast with 1½in. bore.

The Announcement of a Long-Life Collapsible Band I "X" Aerial

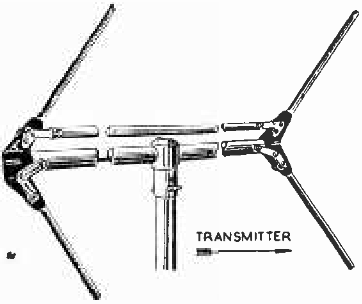


Ever since "Belling-Lee" invented the "V" type array first produced in September 1946, we have toyed with the idea of setting up two of them "back to back" to make a band I "X."

Such an aerial is obviously cheaper to manufacture than an "H" as there is no crossarm. But no "X" is as efficient as a good "H" although there are many sites where maximum efficiency is not required, and it must be admitted that the "X" has "caught on." So, as a result of repeated requests from the public and trade alike here is a "Belling-Lee" "X."

The mechanical design is very interesting, it almost "springs to attention." It is definitely a long life array, easily erected, with particular care taken to ensure easy and quick connection of the feeder.

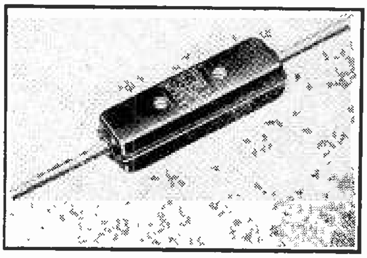
An improved "Double V" for the Midlands



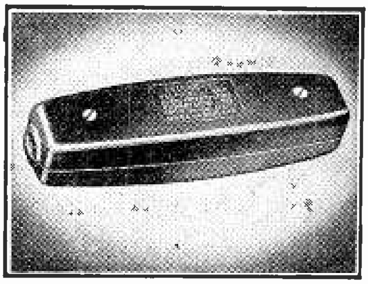
We have been able to improve both the appearance and performance of the "Double V" array for use with Lichfield and Sutton Coldfield. The new list number is L.920 and it should be noted that L.927 ceases to be shown in our catalogue and lists.

Advertisement of
BELLING & LEE LTD.
Great Cambridge Rd., Enfield, Middx.
Written 20th August 1956

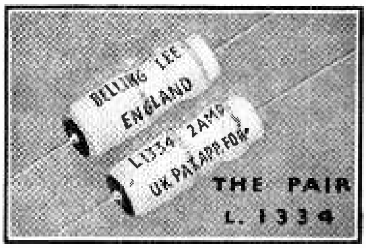
"BELLING-LEE" INTERFERENCE FILTER



L.1314 For 2-core cables, 2 amp. 250 v. A.C./D.C. This new small flex lead filter is designed for the suppression of interference at band I television frequencies only, and is for insertion in the flex lead *within* 6 *in.* of the motor of an appliance. This is the most convenient form of filter which can be readily installed and is complete with terminals, cord grips, etc.



L.199. (2 or 3-core) 2 amp. 250 v. A.C./D.C. Inductor and capacitor filter effective at band I television frequencies and short and medium wavebands. This is an inductor and capacitor filter designed for connection in the lead of domestic electrical equipment such as hair dryers, vacuum cleaners, sewing machine motors, electric fans, etc., and to be truly effective must be fitted *within* 6 *in.* of the connections of the motor in the appliance.



L.1334. 2 Amp. This very small inductor is essential for the filtering of interference on band III, and is individually tuned for use on band I. It must be fitted inside the casing of the appliance. When dealing with these very high frequencies, it is generally quite useless to attempt filtering in the flex lead, as the odd 6in. of lead together with the overall dimensions of the appliance is an appreciable factor of the wavelengths and the whole acts as a radiator of interference.

BELLING & LEE LTD
GREAT CAMBRIDGE RD., ENFIELD, MIDDX., ENGLAND

Telephone: Enfield 2322 Telegrams: Radiobel, Enfield

COMBINED COUPLING

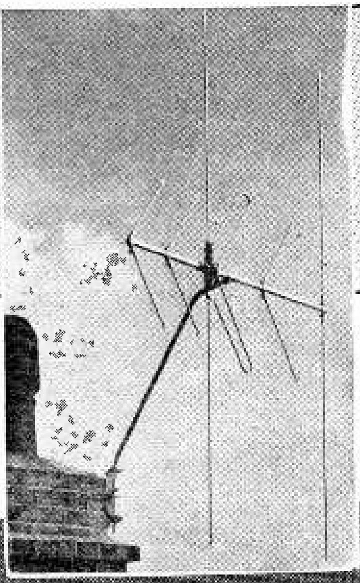
IS THE SUBJECT OF A PATENT APPLICATION FOR

(Patent Application 37189/1954)

WOLSEY IN-LINE AERIALS

ONE JUNCTION BOX

NO CROSSOVER NET WORK



ONE AERIAL

FOR ALL CHANNELS

AND ONLY ONE DOWN LEAD

Maximum energy transfer is gained by supplementing the direct coupling of the system *with additional electrical coupling*. The "arrow" formation of the Band III elements is designed so as to correspond exactly with the lobes obtained when taking Polar Diagrams of the larger elements during Band III reception.

In short, the Band I elements boost the Band III system during Band III reception.

The design also allows the full use of reflectors and the consequent advantage of high directivity.

Plus these other positive features:

- Folded Dipole for accurate matching
- Unbreakable, fully waterproof junction box
- Models for all channels
- Models for all future transmissions
- Alternative mounting—chimney lashed, mast mounting—wall mounting
- Square cross bar assembly
- Can be supplied with stainless steel elements at **£6/-/-**, or close-butt aluminium alloy elements, at **£5/-/-**.

WOLSEY

WOLSEY TELEVISION LIMITED

PACEMAKERS TO THE AERIAL INDUSTRY

CRAY AVENUE, ST. MARY CRAY, KENT   TELEPHONE: ORPINGTON 26661/2/3/4

W26

occur between transmitters but this is not a serious problem with transmitters of small power rating.

Equipment Design.—The technical factors which set limits to the reduction of channel width, and which primarily concern equipment design, are as follows:—

I. Bandwidth of transmission and reception.
II. Frequency stability of transmitters and receivers.
III. Inter-modulation effects in receivers.
IV. Susceptibility of narrow band receivers to noise interference.

I—Transmission Bandwidth.—Consideration of the "intelligence bandwidth" necessary for amplitude modulation, frequency modulation and single sideband systems, is in favour of the s.s.b. system. But it is only proposed in this article to consider the use of a.m. and f.m. systems as it is considered that sufficient technical progress has not yet been made to permit s.s.b. systems to be used for v.h.f. mobile radio.

The comparison of intelligence bandwidth of transmission between a.m. and f.m. is in favour of the a.m. system which in the ideal case only occupies a total spectrum of twice the highest modulating frequency in use. The f.m. system occupies a spectrum total of twice the highest audio frequency, plus twice the peak frequency deviation. Of more practical significance, however, is the attenuation of the unwanted sideband energy as this becomes an important and limiting factor in the ultimate reduction of channel spacing.

Measurements made by the author on a.m. and f.m. systems indicate that, from the point of view of modulation sidebands, a low-deviation f.m. transmitter is very similar to a carefully designed a.m. transmitter. The noise sidebands from f.m. transmitters, however, occupy a very much wider frequency spectrum, which becomes a limiting factor not present with an a.m. transmission.

The modulation and noise sideband spectra of an f.m. transmitter are shown in Fig. 1 together with measurements of an a.m. transmitter designed for narrow-channel operation. This illustrates the very wide noise spectrum of a frequency modulated transmitter.

It seems probable also that in order to achieve channel spacings as low as 20 kc/s, f.m. systems will need to restrict peak deviation to 5 kc/s. In both a.m. and f.m. systems modulation limiting must be employed and followed by low-pass filters to prevent frequencies in excess of 3,000 c/s from entering the modulated stage.

Receiver Bandwidth.—The effective bandwidth, or "nose" bandwidth, of a receiver must allow for the modulation width, plus the frequency error of the wanted transmitter as well as its own frequency error and i.f. drift.

In the case of f.m. the minimum "nose" bandwidth (6 dB bandwidth) can be made equal to twice the r.m.s. frequency deviation plus twice the system frequency error.

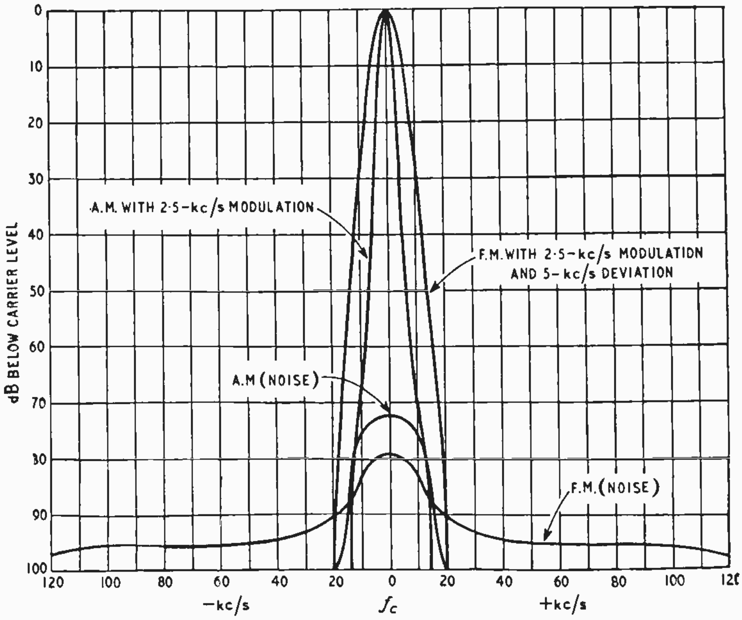


Fig. 1. Comparison of modulation and noise spectra of a.m. and f.m. transmitters designed for narrow-channel operation.

In the case of a.m. the minimum "nose" bandwidth can be either twice the highest modulation frequency or twice the r.m.s. system frequency error, whichever is the greater.

The required slope response, or "bandwidth factor," of the main selectivity determining elements of receivers is not easy to specify accurately. This is because of the wide variations which are possible between the response of the filters used and the "true" selectivity when measured by "two signal" methods (i.e., the level needed from an interfering signal to degrade a certain level of wanted signal by a fixed amount). This is particularly true of f.m. receivers and was adequately described by Nicholson.[3] The attenuation characteristics of filters must also allow for the frequency errors of the receiver itself and of the adjacent interfering transmitter.

Some conclusions drawn by the author are:—

1. A smaller bandwidth factor (i.e. a better filter) will be necessary for an f.m. system for the same end result as an a.m. system.
2. In general, up to 20 dB more attenuation is necessary from the filter characteristics than can be expected from a two-signal measurement on a.m. and probably nearer 40 dB for f.m.
3. With due allowance made for system frequency errors, there is no great operational virtue in making the true selectivity of receivers significantly better than the degree to which adjacent channel transmitter sideband energy can be attenuated.

II—Frequency Stability Considerations.—The degree of frequency stability obviously becomes greater as the channel spacing is decreased and if both fixed and mobile equipments were produced regardless of cost then even the most stringent of requirements could be met. Even if this were the case, however, it would not produce a proportional reward in terms of channel width reduction, as the present limitation (ignoring inter-modulation effects) is the frequency spectrum occupied by both a.m. and f.m. transmitters.

This being so, the requirements of frequency stability are as follows:—

(a) The frequency stability of transmitters and receivers must be such that, under the worst conditions, the channel spacing is not reduced to less than a figure which will be determined by the onset of interference in receivers due to transmitter sideband radiation. For instance, in a 25-kc/s system this might well be not less than 20 kc/s.

(b) The transmitter and receiver stability must be such that under conditions of maximum frequency error the degradation of "on-channel" performance is not unreasonable.

These two factors are, of course, related to the receiver "nose" bandwidth and bandwidth factor, and a compromise is necessary bearing in mind that a greater frequency error may be tolerated in an a.m. system for a given degree of distortion. In any event, the less the frequency errors the greater may be the permissible b.w.f. and the smaller the "nose" width. In this last connection it should be noted that the reduction of "nose" bandwidth is beneficial because it will reduce the degree of energy received from a transmitter's unwanted sidebands.

The implications of tighter frequency tolerance are of great practical importance in relation to the design, production and maintenance of equipment. In respect of frequency stability the important difference to be expected between present equipment and equipment for considerably narrower channel operation, i.e. 30 kc/s or less, are as follows:—

1. All equipment will have to be adjusted with a high degree of accuracy to their assigned frequency.
2. The use of crystal-oven control, to maintain the required degree of stability, will be important on base station equipment, and in the case of f.m. probably on mobile equipment also.
3. Facilities must exist for periodically checking the frequency of base station and mobile equipment which must be provided with sufficient adjustment to correct any frequency error.

One method, which has much to recommend it, is to periodically check the base equipment frequency and provide a simple means of checking the relative error of the mobiles. This may be accomplished by the use of a stable oscillator on the centre frequency of the receiver's i.f. amplifier which in the presence of the wanted transmission will give a beat note equal to the prevailing system error. An illustration of a miniature portable oscillator which has been specially designed for this purpose is shown in Fig. 2. This oscillator is crystal controlled and employs one transistor.

III—Inter-modulation.—The operational effect of inter-modulation in receivers has already been stressed and therefore all measures to reduce this factor will be of great benefit. Three approaches are possible:—

1. Provide sufficient r.f. selectivity to attenuate the unwanted adjacent channels.
2. Use r.f. amplifiers and mixers which have a high degree of linearity.
3. Keeping the voltage gain of r.f. stages to a minimum, consistent with good noise factor.

It is clearly uneconomical to provide a sufficient degree of r.f. selectivity before non-linear valves which produce these harmful distortion products, and therefore it is not of practical importance.

The last two solutions are immediately applicable but only (3) is entirely in the hands of the equipment designer.

IV—Noise Considerations.—The increase in susceptibility of receivers to impulsive noise as the passband is reduced is both an unfortunate fact and a very complex problem, which presents difficulty for the engineer both in respect of calculation and measurement.

Analysis and measurements which have been conducted on f.m. systems[4] tend to show that, dependent upon the deviation employed, the level of input and the degree of frequency error, a 25-kc/s receiver will be on the average 3-dB (but could be 6-dB) worse than a 50-kc/s receiver as far as impulsive noise is concerned.

Where fluctuation noise is considered, this average figure is not measurably different, but for small input levels the narrow-band receiver can be slightly superior.

For a.m. receivers fluctuation noise is less in direct proportion to the bandwidth, a fact which renders this narrow-band type of receiver much quieter, in the absence of any impulsive type of interference, than its wide-band counterpart.

Narrow-band a.m. receivers are more susceptible to impulse noise and this has been adequately discussed by Toth[5] and many others. Measurements made by the author show that, depending upon the input level, but not to any great extent the frequency error, there is an inferiority of approximately 3 dB compared with a 50-kc/s receiver.

Trends in Equipment Design and Measurement Technique.—It is interesting to examine what has made possible the solution of many of the problems just enumerated, problems that it was not possible to solve economically as late as 1950. Taking the technical parameters one by one, we come first to the big advantage to be gained in frequency stability by the use of close tolerance AT-type crystals. These can be produced economically with as little as ±0.0015% change in frequency for a temperature variation of some 80°C. Coupled with this is the use in base or mobile equipment of the miniature type crystal oven (illustrated in Fig. 3). This type of unit has long been in use in the U.S.A. and Canada and for a relatively small cost will reduce crystal frequency drift to less than ±0.0005%.

With the use of ferrites, small highly stable capacitors and methods of encapsulation, it is no longer a formidable problem to produce the necessary receiver selectivity in a small size and with the required stability. As an example of what may be

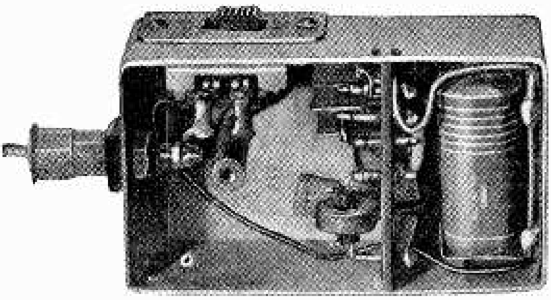


Fig. 2. Miniature crystal controlled transistor oscillator for testing v.h.f. mobile equipment (Labgear).

Fig. 3. Miniature crystal oven for use in mobile v.h.f. equipment.

achieved, an i.f. amplifier using six i.f. transformers and employing ferrite coils can be made with a "nose" width of 12 kc/s, a bandwidth factor of 3, and a frequency drift not exceeding 1 kc/s.

Conclusions.—In conclusion it is intended to describe and comment in brief upon a number of the most important factors affecting the introduction and operational success of narrow-channel spacing in the v.h.f. bands.

1. The technical specifications to which this type of equipment must be designed and operate, can and are being written in a manner which permits satisfactory operation on adjacent channels in the same area. In this respect it will be possible to give a considerable measure of improvement with narrow-channel spacing, compared with current apparatus complying with existing specifications at the present channel spacing.

2. Consideration should be given to the use of "same area" 25-kc/s channel-spaced equipment, and frequency separation of, say, 12.5 kc/s with geographical spacing.

3. Everything else being equal, some small degradation must be expected in the performance of narrow-channel equipment under conditions of impulsive interference but this should be more than compensated by the availability of more channels.

4. There is no reason to think that narrow-channel equipment will be less reliable, indeed it is likely that in view of the more stringent requirements in design, reliability will be improved.

5. There will inevitably be problems of compatibility between existing and new equipment and old and new frequency allocations. Careful attention to a comparatively small number of essential technical considerations, however, should ensure a smooth period during the introduction of new equipment.

6. There should be only a small increase in maintenance cost as compared with a properly maintained wide-band system. It must be borne in mind, however, that satisfactory maintenance will demand accurate test equipment and well trained personnel.

7. The maximum use of the extra channels, made possible by narrower channel spacing, will not be obtained in areas using a large number of channels, unless there is a reasonably co-operative approach to the problems of the transmitter location, radiation pattern, and other means for reducing the effects of inter-modulation.

8. There is an obvious advantage to be gained by the immediate introduction of equipment which will operate satisfactorily on the very minimum of channel spacing. This will ensure a long period of technical and operational stability and at the same time offer the very maximum of channels to the user.

Finally, the way in which our limited frequency spectrum is to be divided between the various classes of users is a factor which will have a considerable bearing on the best use of the extra channels which technical achievement has made possible. The maximum benefit to be gained will, in the end, be dependent on the good sense of administrators, manufacturers and users.

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[4] Joint Technical Advisory Committee, May 28th, 1953.

[5] "Noise and Output Limiters" by E. Toth. *Electronics*, Nov. & Dec., 1946.

COMMERCIAL LITERATURE

Square Pulse Generator giving a main pulse, variable in width from 0.2 μsec to 2 secs, from one output and a 0.2 μsec "pre-pulse", preceding it by an interval variable between 0.2 μsec and 2 secs, from another output. Main pulse has rise time of 0.01 μsec and can be triggered at frequencies up to 3 Mc/s. Specification from Nagard, 18, Avenue Road, Belmont, Surrey.

The Narda Corporation, of Mineola, New York, ask us to state (with reference to the item **Waveguide Attenuators** in the August issue) that their British representatives are now B and K Laboratories, 57, Union Street, London, S.E.1.

Optical Lenses and hand magnifiers made from synthetic resins, suitable for laboratories and inspection departments. Illustrated leaflet of types available from Combined Optical Industries, Plasta Works, Bath Road, Slough, Bucks.

Anchoring Devices for circuit wiring. Technical bulletin (No. 4) with drawings of recent introductions from Harwin Engineers, 101-105. Nibthwaite Road, Harrow, Middlesex.

Aerials and Accessories for sound and television, indoor and outdoor, twin-band, v.h.f. and cars. Convertors and pre-amplifiers are included. A 1956-57 catalogue of the complete range made by Aerialite, Castle Works, Stalybridge, Cheshire.

Contact Bi-Metal consisting of an inlay or facing of contact material integrally bonded to a base metal backing. Suitable for manufacture of contact parts, and will withstand shearing, punching and bending. Also finished bi-metal contacts. Electrical Engineering Data Sheet 1300:345 from Johnson, Matthey and Co., 73-83, Hatton Garden, London, E.C.1.

Pillar Signal Lamp, like a miniature lighthouse, suitable for illuminating baseboards, etc. Also a 3-position jack switch, signal-lamp lenses, micro-switches with toggle (lever) operation and rubber-covered crocodile clips. Leaflet of new products from A. F. Bulgin and Co., Bye Pass Road, Barking, Essex.

Aerial Masts for rhombic, turnstile, delta match, v.h.f., u.h.f. microwave and scatter propagation arrays. Also transmission lines and other accessories. Illustrated catalogue from the Tower Construction Company, Sioux City, Iowa, U.S.A., whose installation services include survey and layout of site, computation of stress analysis and construction of feeders.

Full-Range Electrostatic

By **H. J. LEAK**, M. Brit. I.R.E., and **A. B. SARKAR**, M.Sc. (Cal.), M.Sc. (Lond.), Grad. Inst. P., Grad. Brit. I.R.E.

IT is now well known that the push-pull electrostatic loudspeaker is capable of a quality of reproduction far in advance of that obtainable from the moving-coil system. So far as the authors are aware previous literature on the push-pull condition and practical attempts at the construction of push-pull loudspeakers[1,2] have been on the assumption that construction will be as shown in Fig. 1. Hunt[3] (pp. 167-212) has given a detailed analysis of this transducer system and further contributions have been made by Walker[4], Cocking[5] and Nuttall[6].

In the course of research and development on full-range electrostatic loudspeakers the authors have discovered that an alternative method of construction has theoretical and practical advantages.

It will first be necessary to consider briefly the construction of Fig. 1. The active element consists of a very thin film of plastic material (D) stretched midway between two insulated and perforated metal plates (P_1 and P_2). The gaps P_1D and P_2D allow movement of the diaphragm, which *must* have high resistivity in ohms per sq. centimetre. The alternative arrangement of inserting a very high resistance (such as R in Fig. 1) has been shown in previous literature, the stated purpose being to prevent the electrostatic charge on the moving diaphragm from varying during the lowest audio-frequency cycle to be reproduced. This is an impracticable solution in a *full-range* electrostatic loudspeaker, the reason being that the capacitances will be small enough to necessitate R being of the order of thousands of megohms. If the full d.c. potential is to be applied to the diaphragm then the insulation must be in the region of many thousands of megohms, and this is impracticable with normal humidity variations.

Let us examine some aspects of the mounting of the diaphragm of Fig. 1. The diaphragm must be tensioned to give a positive stiffness sufficient to counteract the negative stiffness or force resulting from the constant charge. The acoustical loading on either side of the diaphragm is low at low frequencies. With the thin, light plastic materials at present available for use, the elastic restoring force may not be sufficiently stable with respect to time to prevent eventual collapse. Of course, greater stability can be obtained by sub-dividing the diaphragm into smaller areas bounded by supports, and better acoustic impedance matching and directivity may be obtained by making the diaphragm vibrate in the end of a long tube[7-10], and in this case the radiation impedance for the loudspeaker will be approximately the same as if it were mounted in an infinite baffle. The directivity pattern can also be altered by mechanical and acoustical treatment in the long tube. At first glance it appears that by these means one can avoid the use of the type of cabinet so essential for dynamic loudspeakers, but the work involved in production is complicated and little less expensive than a cabinet.

The foregoing considerations led the authors to the new method of construction shown in Fig. 2. The loudspeaker consists of an insulated and perforated metal plate fixed rigidly between two stretched thin and light diaphragms, with air backing. Thus, the a.c. signal will be applied on the membranes (D1, D2) and the d.c. potential on the fixed plate (P).

The transformation of electrical energy into mechanical energy involves the interactions between magnetic (in the case of the moving coil transducer) or electric (in the case of electrostatic, electrostrictive and piezoelectric transducers) fields and matter. The present theoretical concept is based on any of these physical effects since all types of electro-acoustic transducer follow the reciprocity law. Table 4.8 of ref. 11 shows the general relationships for these electro-mechanical transducer principles. It must be remembered that in the case of the moving-coil transducer the force per unit current is a function of the inductance and of the negative stiffness resulting from the steady magnetic field, and the solution therefore entails the concept of "motional impedance." But, in the case of the electrostatic transducer the force per unit voltage is a function of the capacitance and of the negative stiffness resulting from the steady electrostatic field, and hence the analysis can best be carried out using the concept of "motional admittance"[3] (p. 202), particularly when considering light plastic diaphragm materials comparable to the density of air.

We know that a mechanical force f produces a particle velocity u when applied over a transducer surface S. If we consider plane compressional waves in a medium of low viscosity, then we have $pS/u = \rho_a c_a S = Z_R$ = mechanical radiation resistance (for lossless medium), where $\rho_a c_a$ is the impedance of the medium (air), and p is the pressure.

We can draw now the equivalent circuit of an air-backed transducer which may take the form of Fig. 3, in which L = equivalent inductance = $M/4t_r^2$, where M = motional mass and t_r = transformation factor; C = equivalent capacitance, where K = motional stiffness; $R_m = Z_R/4t_r^2$, and C_0 = clamped electrical capacitance.

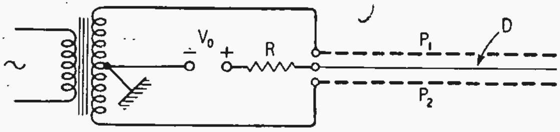

Fig. 1. In the majority of push-pull electrostatic loudspeakers a central diaphragm vibrates between perforated fixed outer electrodes.

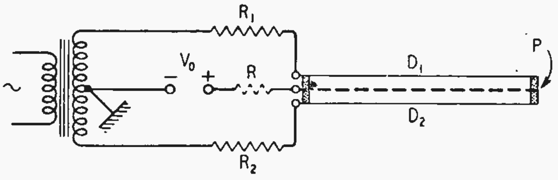

Fig. 2. Alternative arrangement of electrodes offering many advantages both in design and manufacture.

SEE CORRECTION
P. 528

Loudspeakers

A New Approach to Practical Design

We know that the mechanical Q of the transducer plays an important part in controlling the frequency response of the radiated power. The calculated value of the mechanical Q is generally lowered owing to the mounting loss of the transducer. Thus mounting is very important, since this additional damping reduces the intensity of the sound radiation. We know that it is possible to represent mechano-electric networks either by the sum of admittance or by the sum of impedance components (velocity and current as independent variables), and this so-called " duality " behaviour[3, 12] plays an important part in the analysis of complex electro-acoustic systems. An example is the operation of a spring[11] (a simple harmonic motion device).

Let us now study the vibration of a stressed membrane which will be applicable to the motion of our diaphragms in Fig. 2. Morse[13] has dealt in detail with the vibration of a stretched membrane, and he has shown that the shape of the boundary line on which the diaphragm is stretched has considerable effect on the solution of the equation, which is beyond the scope of this paper. One of his classic examples is a kettledrum, which we will consider briefly as it is applicable to our loudspeaker design. Striking one of the stretched membranes causes alternating compression and expansion of the enclosed air, which exerts force on both membranes and modifies their modes of vibration. When the velocity of transverse waves in the membranes is low compared with the velocity of sound in air, then the effect of the motion of one part of the membrane transmits very rapidly through the air to affect the other parts, and so, on the whole, the reaction of the air is uniform over the membrane's surface. When the membrane vibrates, due to the adiabatic pressure-volume variations the excess pressure is represented with a negative sign, since this pressure always opposes the displacement of the diaphragm. The load offered to the diaphragm is expressible as a resistive term (additional reactive load is added when the mass of the diaphragm is not negligible). The resistive term varies with frequency, except when the speed of sound in the medium is less than that in the membrane, in which case the resistance is constant ($= \rho_a c_a$, ρ_a being the density of the air and c_a sound velocity in air).

The foregoing physical phenomena can be applied to the design of a modern condenser microphone and, remembering Rayleigh's and Helmholtz' reciprocity theorems and also the acoustical principle of similarity[9], we know that these phenomena will be equally applicable to the construction of our full-range electrostatic loudspeaker. Considering the microphone, we must know the driving force due to the incident wave (uniform, approximately, over the diaphragm), and the reaction force per unit area of the medium (both sides of the membrane), the latter being proportional to the average displacement. The proportionality factor contains the specific acoustic impedance term of the medium. The resistive part of this impedance consists of (1) the radiation resistance of the air next to the outer part of the membrane, and (2) the resistance due to reaction offered to the side facing the inside of the microphone case containing small holes (viscous friction is produced with the motion of air through these holes). The reactive part of the impedance due to the outer air is masslike (i.e., positive reaction) and that due to the air inside is stiffness controlled. The motion of the diaphragm is stiffness controlled when the frequency of mechanical resonance lies near the upper limit of the frequency range. To achieve this a metallic diaphragm must be tensioned, limited by the tensile strength of the metal. In the case of a non-metallic diaphragm of low tensile strength, resonance will occur too low in the frequency range unless means can be found to bolster up the stiffness of the material. This can be done[14, 15] by a construction similar to Fig. 2, but omitting an electrical connection to one diaphragm. Assuming that the boundaries are air-tight, the trapped air serves the acoustic purpose of providing the necessary stiffness to the working diaphragm.

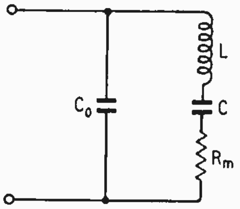

Fig. 3. Electrical analogue of a loudspeaker with the electrode arrangement of Fig. 2.

We have applied the foregoing principles to the construction of a full-range electrostatic loudspeaker,* which takes the form of Fig. 2. Consider the static condition: when the polarizing potential is applied the charge is constant over the entire surface of the central conducting electrode, because it is effectively infinitely rigid. Both diaphragms move small equal distances towards the central electrode, and there is no unbalancing of the two capacitances; therefore the balanced push-pull condition is maintained. One important advantage of our construction is that we can dispense with R (shown dotted) altogether, without altering the operation of the loudspeaker; because the charged plate is not moving, there is no necessity for a large RC constant. The problem of achieving resistance and insulation values of thousands of megohms is thereby eliminated. Of course, a low, practical value of R can be inserted as a protective device.

The plastic diaphragms in our design are given outside resistive coatings, the values of these being designated R_1 and R_2 in Fig. 2; therefore they are not external physical resistors. This construction prevents migration of charge, and also gives us a built-in RC transmission line offering a partial solution to the variable-area requirement necessary in a full-range loudspeaker.

On applying the polarizing potential, in the absence of a signal, the behaviour of the diaphragms can be studied under two conditions: (1) when the interior air cavity is perfectly air-tight, which (if it can be practically realized over a long period) necessitates calculations based on innumerable

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* Patent applied for.

atmospheric variations; and (2) when a pinhole duct is deliberately introduced to allow for atmospheric pressure equalization. We will deal here only with condition 2. The force of attraction between the perforated plate and one diaphragm can be represented by: $F = \xi V_0^2$ where ξ is a constant.

Consider now the dynamic conditions when a signal voltage is applied, comprehending that the pinhole introduced to allow for atmospheric pressure equalization will have negligible effect at any audio-frequency on the stiffness of the enclosed air, and therefore on the damping effect of the resonant modes of vibration of the diaphragm. It is to be noted here that the displacement of the diaphragms will be due only to the magnitude of the constant charge on the fixed plate and the a.c. field resulting from the signal voltage between the diaphragms. Assuming e and e' to be the maximum values of the signal and ω and ω' their respective angular velocities, we can write the Fourier series (for the force between direct and alternating voltages) as:

$$\begin{aligned} f &= \xi(V_0 + e\cos\omega t + e'\cos\omega' t)^2 \\ &= \xi[(V_0 + \tfrac{1}{2}e^2 + \tfrac{1}{2}e'^2) + \\ &\qquad \tfrac{1}{2}(e^2\cos 2\omega t + e'^2\cos 2\omega' t) \\ &\quad + ee'\{\cos(\omega + \omega')t + \cos(\omega - \omega')t\} \\ &\quad + (2V_0(e\cos\omega t + e'\cos\omega' t)] \\ &\qquad\text{(on expansion)} \quad .. \quad .. \quad .. \end{aligned} \tag{1}$$

The first term of equation (1) is a steady component whose function is to displace the diaphragm from its stationary position; hence it does not contribute to the reproduction of sound. The second term will produce second harmonic distortion, for we can see that it contains terms with frequencies double those of our applied frequencies. Similar distortion in the sound output will occur with the third term containing the sum and differences of the applied frequencies, so it is only the fourth term, which contains the applied frequencies, that we desire to be reproduced. Obviously, for low acoustic distortion we must make $V_0 \gg e$ and e', so that $2V_0e$ and $2V_0e' \gg e$, e', $\tfrac{1}{2}e^2$ and $\tfrac{1}{2}e'^2$. The same argument regarding the force can then be applied to the other diaphragm, remembering that the displacement and the a.c. signal change sign on passing from one side to the other. Thus not only the efficiency, but also the quality of sound output is dependent on a high polarizing potential, particularly at low frequencies, since amplitude and sound energy is directly proportional to V_0 and V_0^2 respectively. Note that this loudspeaker acts as a doublet. Note also that we have not taken into account, for the sake of simplicity, the non-planar shape of the vibrating diaphragms and the corresponding variation of electrostatic force on different parts of the diaphragms.

As previously stated, the air enclosed by the diaphragms acts to stiffen them, and this helps towards an extended low-frequency response because the need for highly tensioning the diaphragms is reduced. The stiffness behind the diaphragms is dependent to some extent on the dimensions of the perforations in the central electrode. Changing the dimensions, and hence the air resistance, will alter the displacement and response curves, as shown by Morse (ref. 13, p. 197).

The advantages of this system are considerable. Harmonic distortion, transient distortion and frequency deviations are all *very* much lower than on moving coil systems. The construction is simple, and reliable; the dimensions need not be unreasonably large; the diaphragms need not be very tightly stretched; they are visible for inspection, and they form a dust-proof barrier protecting the highly-charged central electrode.

In the previous convention of Fig. 1 the single diaphragm can be properly tensioned in the first instance on one of the perforated plates, but when the second plate is applied it is difficult to ensure exact coincidence of the spacers, and also the diaphragm is not accessible for inspection or adjustment. There is also the serious practical difficulty of holding the spacers on the two plates in intimate contact with the diaphragm.

The authors hope that the wide application of their ideas will speed the availability of better and cheaper high-fidelity loudspeakers, for it can be stated that the cost will be considerably lower than the best moving-coil systems, whilst the overall improvement in listening quality is demonstrably beyond question.

Thanks are due to our colleagues E. H. Ashley and P. H. Biggs for their practical help in constructing many development models.

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Solid "Electrolytic" Capacitor

A METHOD of eliminating the electrolyte in tantalum oxide capacitors is reported by Bell Telephone Laboratories. After formation of the oxide film on the surface of the sintered tantalum anode in the usual way, the electrolyte is removed and replaced by successive deposited layers of manganese dioxide, carbon and lead alloy. The barrier layer established by tantalum, tantalum oxide and manganese dioxide is said to have high stability with time and temperature and gives a capacitance of 500 μF per cubic inch for a voltage rating of 35.

Arrangements for manufacture are in the hands of the Western Electric Company.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

Echoes of the Show

HAVING heard several "high-quality" demonstrations at this year's Radio Show it has struck me how unsatisfactory the set-up is. There are no standards of comparison. One demonstrator was frank enough to say the tone controls were set to suit himself and he could only hope it suited his audience. On another stand I was told that a speaker cabinet had been designed for another room, hence its admitted rather poor performance. The recordings were chosen either to show good points or conceal the bad ones.

I would suggest in future all the demonstration rooms should be made to a standard design and part of the demonstration should include standard records of widely varying character, all played with tone controls set level. Of course, other recordings and settings could be used for other parts of the demonstration. And dare I ask for "independent" rooms for comparing different makers' products?

London, N.8. C. STREATFIELD.

AT the Radio Show a great deal of time was given to demonstrating the reproduction of gramophone records of popular music played on an electronic organ with a rhythmic accompaniment.

In a type of instrument commonly used for this sort of entertainment, harmonics generated by rotating electromagnetic tone-wheels are synthesized into complex sounds; but only harmonics up to the eighth are used and the highest frequency generated is about 6,000 cycles per second. Moreover—and this applies to any electronic instrument—the final complex sound itself issues from a loudspeaker which may be incapable of reproducing the highest audio frequencies.

I do not suggest that the instruments in question are defective; on the contrary, the limitations I quote are largely the result of careful and ingenious design in a practical instrument. It is clear, however, that electronic organs, whatever their merits otherwise, are of limited value as test material for wide-range sound equipment. In the demonstration I heard this fact was concealed by the drums accompanying the organ which naturally stood out in startling fashion when an efficient tweeter was brought into use. Unfortunately, the ability of a loudspeaker to reproduce toneless percussion instruments is no guarantee of a clean upper register; and many reproducers able to recreate vividly the snare drum, castanet and tambourine fail miserably in the reproduction of sustained complex tones at the top of the musical scale. Records of electronic organ and drums may therefore be positively misleading as a guide to the capabilities of a wide-range reproducer.

Sawbridgeworth, Herts. H. GLOVER.

Receiver Radiation

"DIALLIST," in your August issue, is a bit belated in suggesting that U.K. manufacturers should emulate the F.C.C. and establish limits for line timebase and other radiation from television receivers. My Association has had limits (evolved in collaboration with the G.P.O.) for line timebase radiation and tentative limits for oscillator radiation for about four years. In due course these limits will be published as part of BS905.

We claim that, in the field of receiver measurement and interference radiation measurement and suppression techniques, the U.K. radio manufacturing industry is well ahead of its counterparts in other countries. In fact, many of the B.R.E.M.A. proposals to the B.S.I. were submitted in unabridged form as British proposals to International Standards conferences and have since been incorporated, basically unaltered, as standards.

The only criticism of British manufacturers in this respect which we feel "Diallist" could legitimately make is that the industry has been too overloaded to publicize the work it has completed in collaboration with the G.P.O. However, it is to be hoped that this will be remedied by the publication of the British Standard. S. E. ALLCHURCH.

Secretary, The British Radio Equipment Manufacturers' Association.

Headphone Portables

WHY does no manufacturer or kit supplier provide a cheap light portable or mains transportable for headphone use? The solution of the difficulties and domestic ill-feeling that arise when different members of a family want different programmes is not going to be solved by the production of small loudspeaker receivers for alternative use. Each loudspeaker programme needs a separate room, but the average English home in winter has only one warm habitable room; also there are times when some of us prefer silence.

It is simple enough, I know, if one has the time and facilities, to modify existing sets and circuits for headphone use, but why should it be necessary? Besides, a manufacturer has the resources to design such a set so as to achieve the greatest compactness. A mains headphone set is what is wanted.

Reading, Berks. THOMAS ASHBY.

"Economy in Receiver Design"

I SHOULD like to comment on the use of negative feedback into a diode load, as in the circuit of the simple superheterodyne described in your August issue. In order to be negative, the feedback voltage must oppose the audio voltage on the diode due to demodulation, causing the diode to "see" an impedance lower than the load resistance. As the following amplifier does not pass d.c. the result is a deterioration of the a.c./d.c. load ratio, bound up with the well-known clipping at high modulation.

There is also another way of looking at this. Assume at the diode a carrier of, say, 1 volt nearly fully modulated with a sine wave, and the volume control set so as to get, say, 2 volts appearing across the speaker terminals (about 1.5 watts). Then at the instant of the centre of the modulation trough the negative diode voltage due to r.f. (or i.f.) will be at its minimum (a.f. positive going), but a negative peak of 2.8 volts appears at the other end of the diode load. It is clear from this that the diode is cut off, at least during an appreciable part of the modulation trough. Admittedly this is about the worst possible case, but some clipping must occur, especially with weak carriers and at high volume.

Negative feedback into a diode-triode stage seems a tricky business. The feedback signal can be fed either (*a*) into the grid circuit, or (*b*) into the cathode circuit, but in both cases the same problem arises, unless in case (*b*) the entire grid and diode circuit is also returned to the feedback point, having the disadvantage of losing all the gain of the triode stage, so far as the feedback loop is concerned. It would seem better to combine the diode (or diodes) with the i.f. stage (6B8G, EBF80, etc.), and feed back into the audio triode cathode. The ensuing loss of maximum gain (feedback being constant now) is probably not so serious, as the maximum possible gain would hardly be wanted in connection with the then rather high hiss level, especially with good quality i.f. coils and a ferrite rod aerial.

London, N.W.2. G. N. E. PASCH

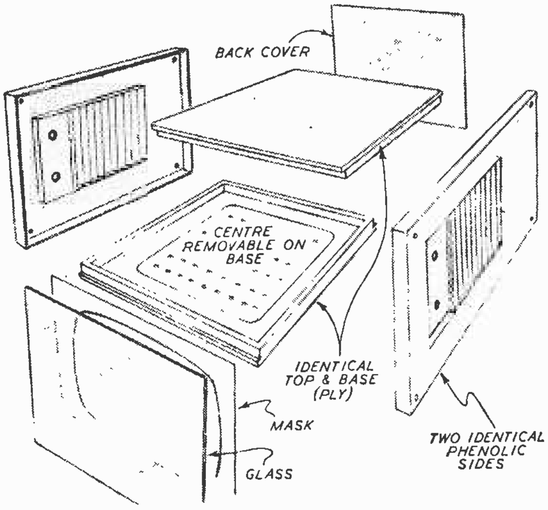
Flexibility in Cabinet Design

THE CASE FOR PLASTICS, ALONE OR IN COMBINATION WITH WOOD

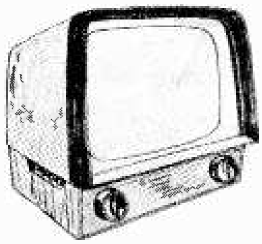
IN these days of constant change in cabinet fashions radio manufacturers are often reluctant to make use of the many advantages of plastics when faced with high initial tool cost and the possibility of a "fixed" design. With a wooden cabinet, although more expensive in itself, there are no tool costs and alterations can be accomplished with relative ease to give the model a "face lift" at a later date.

In spite of this, I hope to show by the accompanying examples that plastics can give the designer much more scope than is perhaps realized. The combined use of plastics and wood can often give strength and enhance the appeal of the design as a whole. The sketches are put forward simply as basic ideas to start trends of thought and they will have served their purpose if they lead to something new or help people to view plastics in a different light.

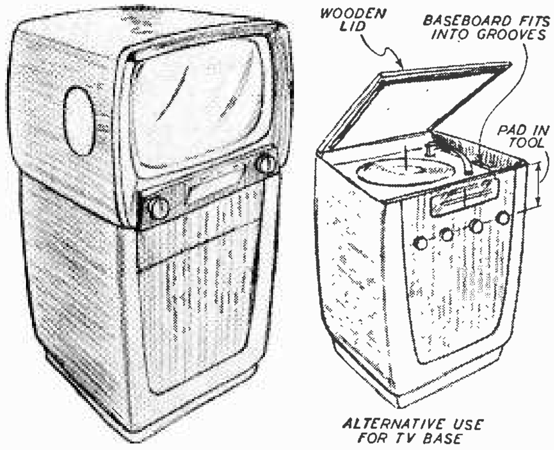
Application has been made for registration of the designs presented in this article.



"Knock-down" or "pack-flat" television cabinet which utilizes two identical moulded side cheeks. The loudspeaker louvers point forward, guiding the sound toward the front of the set; the controls may be easily recessed. Decorative schemes could be changed by pads in the moulding tools, and the glass could be silk-screened around the edges to mask internal fixings. For 14-in and 27-in television sets, the top, base, back, mask and glass could be altered dimensionally, still leaving the mouldings intact. The top panel could be veneered ply or leathercloth-covered hardboard. With this arrangement, cabinet storage and transport difficulties are overcome. All the complex shape is taken by the plastic moulding, while the other parts are comparatively plain.



Complex curved sides, top and back in phenolic; chassis sits in virtually a plain wooden box with a fancy front. The moulding is used as a dust cover and holds the glass and mask, the glass being detachable via the wooden trim across the front. Plain colours, stoved enamel or the patented "Oxvar" finish could be used on the phenolic cover.



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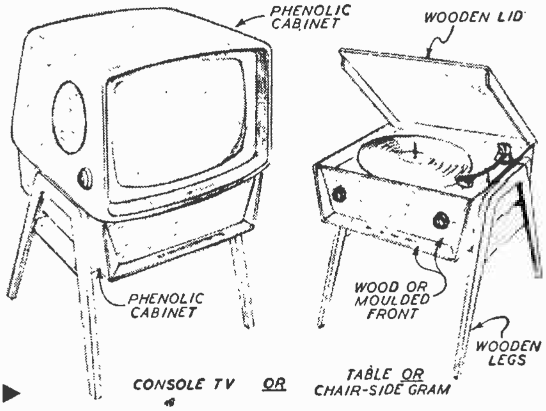
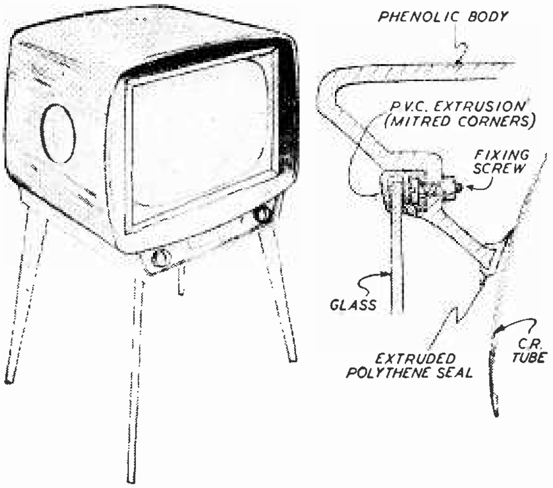
A different approach to the television console or the radio equivalent to the furniture manufacturer's "G" plan.

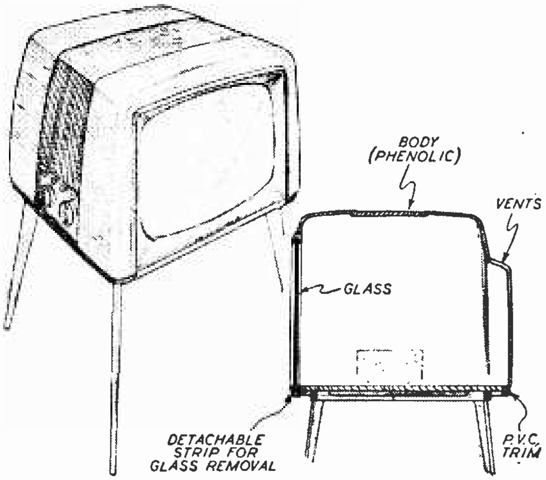
Carries things a stage further. Here are three alternatives; a pull-out drawer type gramophone makes a fourth. ►



By **JOHN W. MOORE,** M.S.I.A.
(Formerly Chief Designer, British Moulded Plastics, Ltd.)



A method of sealing the air space between the glass and the tube face and moulding the mask as an integral part of the cabinet. As an alternative, the front portion alone could be moulded and attached to a simple wrapped-ply cabinet.



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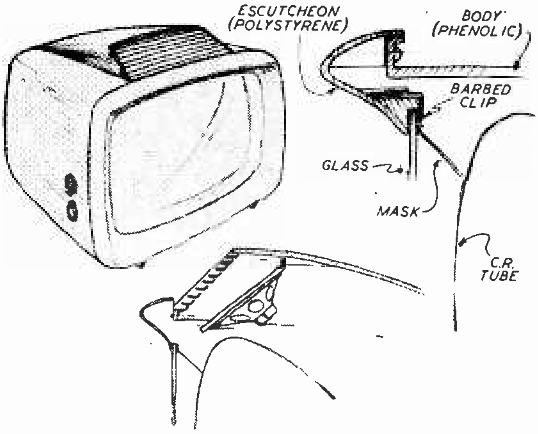
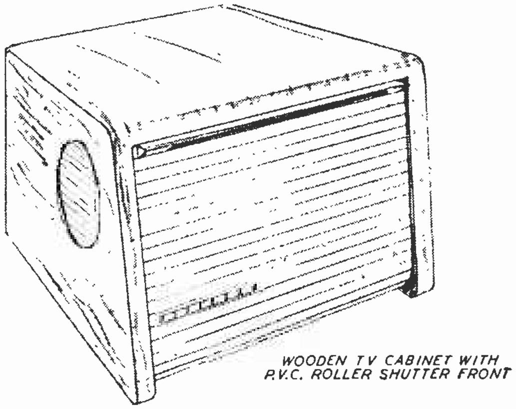
One-piece phenolic cover. Everything is there in one moulding: loudspeaker apertures, vented back, rabbet for glass with simple removal. Chassis, tube and controls mounted on plywood base. A separate centre pad in the tool could give variety in the speaker openings which could also be covered or painted to give colour changes. An extruded flexible p.v.c. trim provides a non-scratch, non-skid buffer for a polished table top and allows yet another possible colour change.

The cabinet body should be of relatively simple shape with a plain frontal area. The tuning scale could be applied as a transparent disc, or moulded-in and paint filled. The frontal covering could be virtually anything with enough holes in to pass the sound. Metal or plastic trim strips could be trapped between the cabinet and front cover.

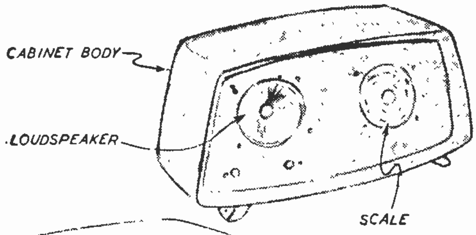


A shot at the future. If it makes you shudder, I hope it will also make you think. In effect it is an ideal moulding form with its sweeping curves and compound radii.



WOODEN TV CABINET WITH P.V.C. ROLLER SHUTTER FRONT

The main objective is to cover the vacant stare of the cathode-ray tube when not in use. This is achieved on more expensive models by hinged doors or wooden shutters. Plastic shuttering achieves cheapness, colour and durability in one go.



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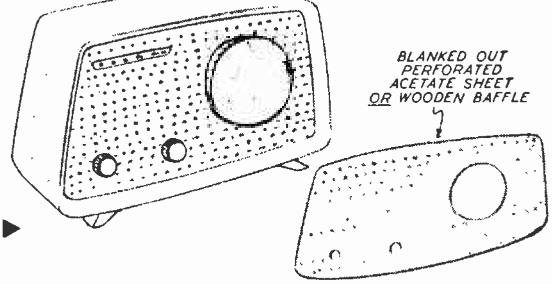
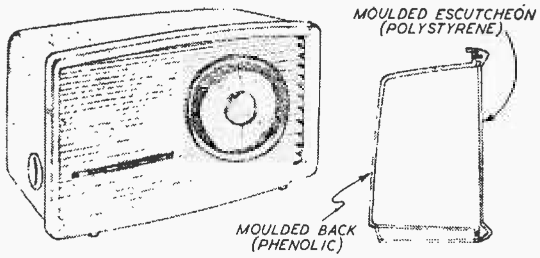
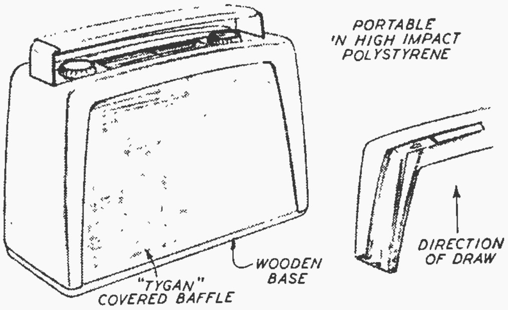
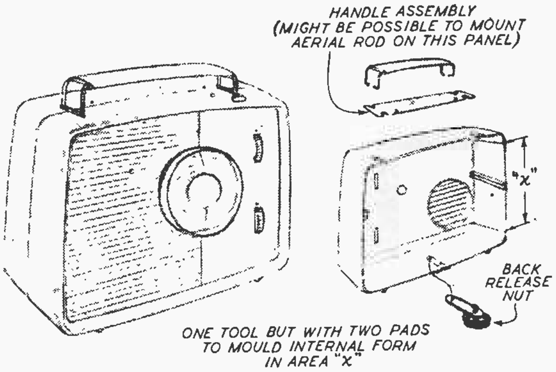




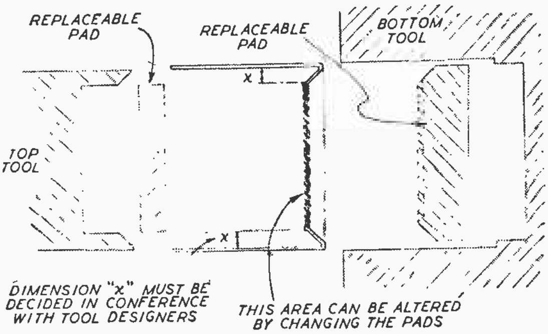
An alternative treatment of the two-piece cabinet in which the front escutcheon is constant. Either a moulded or a wrapped-ply back cover with internal fittings could be used.



Possibly the best shape from the portable point of view. The long handle is designed to take the pull of the set's weight at the proper points and could be made to pivot to one side to disclose the scale and knobs. These would fit neatly into a dished form or could be attached to the chassis and pushed into the top part of the recess that takes the baffle, thereby giving a frontal instead of top scale presentation. The moulding itself would be inexpensive and strong and could be either colourful or unobtrusive.

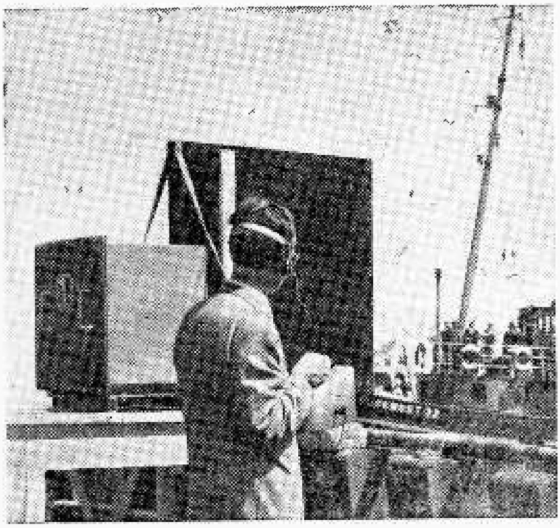


Method of achieving maximum internal flexibility in a portable with the minimum of tool cost using "identical" back and front forms, but with a slight amendment to the top tool. For example, if we require holes in the front of the cabinet we mould, say, 5,000 off. The pad is then changed to seal off those holes and 5,000 backs are moulded.



Method of changing the "face" of a cabinet. Not new, but could be more widely known. Although the body remains basically unaltered the part that really matters may be subjected to innumerable alterations.

Centimetre-wave Beacon



Microwave harbour beacon equipment, with portable receiver in the foreground.

A COMMERCIAL version of the microwave harbour beacon described in *Wireless World*, November, 1955, by A. L. P. Milwright (Admiralty Signal and Radar Establishment) has now been produced by Elliott Brothers. The equipment, though basically unchanged, has been modified in external form, particularly as regards the receiver. It works on an adaptation of the Lorenz system of overlapping signal sectors with an equi-signal path between them.

In its present form the gear provides a simple and relatively inexpensive navigational aid for small craft, such as fishing vessels, when entering harbours. The transmitter, installed on shore, costs £550 and receivers, one of which is needed for each vessel using the beacon service, cost £55 each.

The receivers, which are extremely light and easily portable, employ transistors; they can also be used as simple direction-finders as an aid to finding the beam-path. Agents for installation and maintenance are Coastal Radio, Ltd., Hope Crescent, Edinburgh, 7.

Designing Decade Units

By C. D. LINDSAY, B.Sc.

Simple Method of making useful items of test gear

TRIAL and error is often the method by which the optimum value of a component for a particular circuit function is found. This is a simple matter in the case of resistors, but capacitors or inductors are more difficult to deal with. In most cases the usual way is to use a decade box. It is often thought that such a box is large and costly, but it need not be so, as it is now proposed to explain.

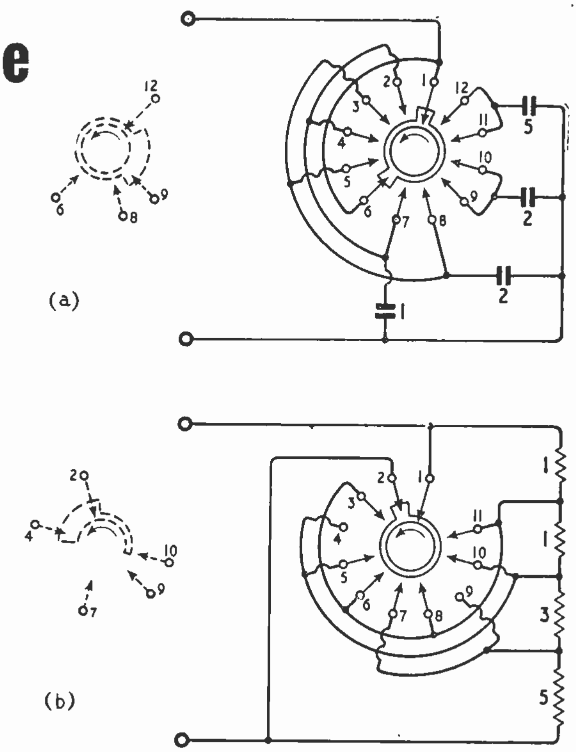
It is well known that if one has units of capacitance of 1, 2, 2, and 5, by suitable choice, any value from zero to 10 in steps of 1 may be formed. At first sight the switch to make this choice may appear to be somewhat complicated, but in point of fact it is possible to do this with a single wafer-type switch, actually much simpler than the wavechange switch in the average radio set. Moreover, no insulated contacts are used, as this would seriously increase the stray capacitances. In an actual decade the error caused by the switch amounted to only 13 pF.

For most practical purposes 10% tolerance components are satisfactory, but 5% selected capacitors are normally available at slightly increased cost from at least one well-known manufacturer (T.C.C.). Naturally a box using a number of decades of these components would be correct only to one significant figure.

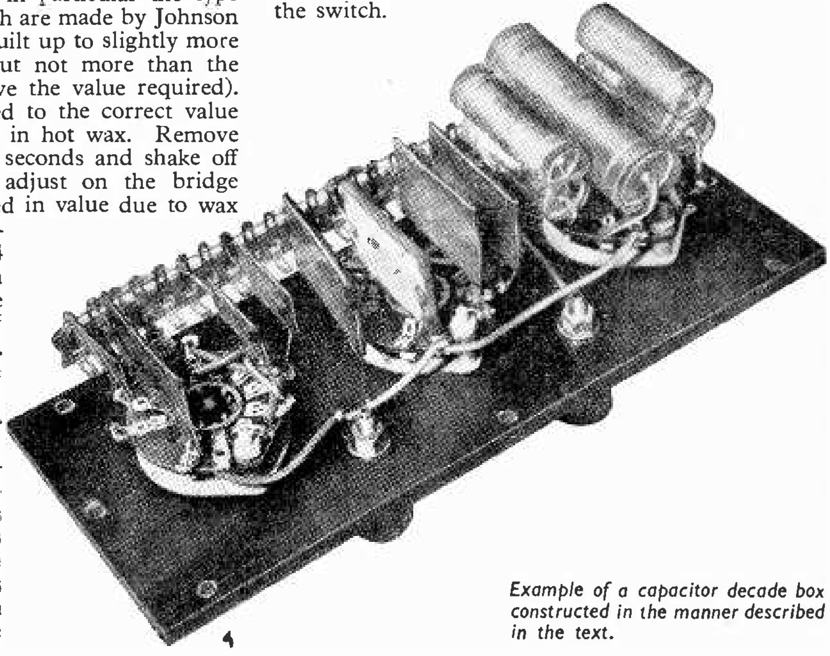
Those who wish to construct a closer tolerance box, and have available a good quality bridge, may use silvered mica capacitors, in particular the type one eyelets together, and which are made by Johnson Matthey. These should be built up to slightly more capacitance than required (but not more than the capacitance of one plate above the value required). They should then be adjusted to the correct value by scraping and then dipped in hot wax. Remove from the wax after about 15 seconds and shake off excess wax. After cooling, adjust on the bridge again (they will have increased in value due to wax dipping). After final adjustment dip in wax for 3 to 4 seconds which will build up a thick protective coating. The value of the capacitor may, if it will show through the wax, be written in ink on the plate remote from the one on which any capacitance adjustment is to be made.

A single wafer switch intended for inductors or resistors (or anything that adds when joined in series) is shown here. Again it uses no insulated contacts. As it was not found possible to design such a switch using the more conventional values of 1, 2, 2, and 5, the choice of 1, 1, 3, and 5 was adopted instead and in practice has been found to be just as good.

The series resistance of the contacts is below 5 milliohms so that even low values of resistance are practical, the limit being set by the current rating of the switch.



Arrangement of contacts and "wiper" rings on switch plates for (a) capacitors and (b) resistors, viewed from the rear. The knob is assumed turned fully anti-clockwise. Dotted sketches on left show the contacts on the front surface of the wafer as viewed from the back.



Example of a capacitor decade box constructed in the manner described in the text.

Transistor R.F. Amplifiers

I.—Available Junction Types as High Frequency Circuit Elements

By D. D. JONES,* M.Sc., D.I.C.

JUNCTION transistors will probably find one of their main markets in battery-operated broadcast radio receivers such as the "personal" portable and car types. The reason for there being only a few of such receivers on the British market at present is that transistors for handling large output powers and for use in high-frequency circuits are not yet in large-scale production. Transistors suitable for the high-frequency stages of receivers for the medium waveband are now in an advanced stage of development but it is unlikely that all the requirements of a v.h.f. f.m. receiver will be met for a considerable time.

Difficulties in obtaining high-frequency transistors inevitably mean that the existing types are used at higher frequencies than are intended by their designers. Since this state of affairs may last for some time, it is important to realize what parameters set a limit to the frequency at which the transistor can be used. It is equally important to consider the effect of these parameters on circuit design, in order that as good performance as possible can be obtained.

In one respect junction transistors differ very considerably from thermionic valves. Whilst the valve is substantially free from internal feedback effects up to comparatively high frequencies, the transistor suffers from feedback at all frequencies. Because of this, the input and output circuits of a transistor amplifier are not isolated from each other as are the grid and anode circuits of a "common cathode" thermionic valve amplifier. At high frequencies this internal feedback, coupled with phase changes due to transit time effects in the transistor, can be very serious and can easily lead to an amplifier becoming unstable.

This part of the article discusses how to represent a transistor as a high-frequency circuit element, while Part 2 will show how the effects of internal feedback can be neutralized. As an example, the use of a p-n-p transistor, type GET4, in a 465-kc/s i.f. amplifier is considered. This transistor is really intended for use in amplifiers at much lower frequencies, but its use at 465 kc/s is fairly typical of the "marginal" application of transistors that is inevitable until newer types are readily available. The problem of automatic gain control will also be discussed in Part 2.

Probably the most suitable, if not the only, tool for studying the behaviour of transistors at high frequency is the a.c. equivalent network. This is a network used to represent the a.c. characteristics of a transistor under the chosen d.c. operating conditions; it is assumed that the d.c. bias circuit does not shunt or otherwise upset the a.c. circuit. Although many different networks have been suggested, it is found that the T type is as simple and convenient as any.

At low frequencies a junction transistor operated in a common-base amplifier arrangement can be represented as shown in Fig. 1. The current generator αi_e means that a voltage $\alpha r_c i_e$ is developed across the collector resistance r_c when a current i_e flows in the input circuit. The arrows indicate positive directions of currents and voltages.

At high frequencies it is necessary to change this network in a number of ways:—

(a) Because of transit time effects the value of the current gain factor, α, decreases as the frequency increases. It is found that this can be expressed as

$\alpha = \dfrac{\alpha_o}{1 + jf/f_\alpha}$ where α_o = value of α at low frequency and f_α = frequency where $|\alpha| = 0.7\alpha_o$. This value f_α is sometimes known as the "3 dB down frequency" or, more often, as the "alpha cut-off frequency." The above expression is by no means exact, but is found to be sufficiently accurate at frequencies up to about $0.5 f_\alpha$.

(b) It is necessary to take into account the capacitance (C_c) that appears across the collector-base p-n junction.

(c) There is also a capacitance C_e across the emitter resistance, r_e. This is not a straightforward p-n junction capacitance, but is due to transit time effects and is known as the "emitter diffusion capacitance." C_e may be deduced from the expression

$$C_e = \frac{1}{2\pi f_\alpha r_e}$$

r_e being given by

$$r_e \text{ (ohms)} \sim \frac{25}{I_e}$$

where I_e is the emitter bias current in milliamps.

(d) The value of the base resistance is much lower at high frequency (e.g. 100 kc/s) than at low frequency (e.g. 100 c/s). The high-frequency resistance is known as the extrinsic base resistance, r_{bo} (or, sometimes, r_b'), and is the resistance of the section of germanium between the point where the base lead is soldered on to the germanium and the point where "the transistor proper" may be considered to start.

As an example, consider a GET4 transistor operated at a collector voltage of $-$ 12 volts and an emitter current of + 1mA.

$r_e = 25\,\Omega$
$C_e = 0.006\,\mu\text{F}$
$f_\alpha = 1.4$ Mc/s
$r_c = 1\,\text{M}\Omega$
$C_c = 45$ pF
$r_{bo} = 70\,\Omega$
$\alpha_o = 0.975$

At 465 kc/s the value of C_c is such that it heavily shunts r_c; it may therefore be possible to ignore r_c (compared with C_c) except in circuits where C_c is part of a tuned circuit and where very high values of

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* Research Laboratories, The General Electric Company.

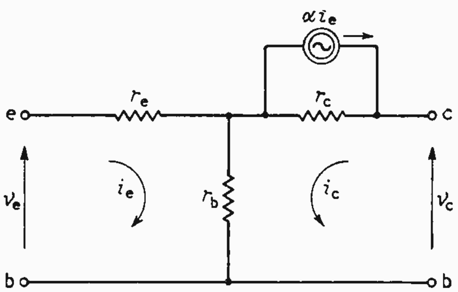


Fig. 1. Low frequency equivalent circuit.

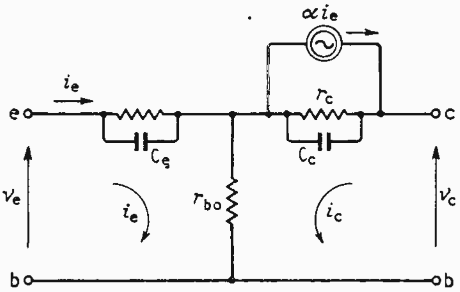


Fig. 2. High frequency equivalent circuit.

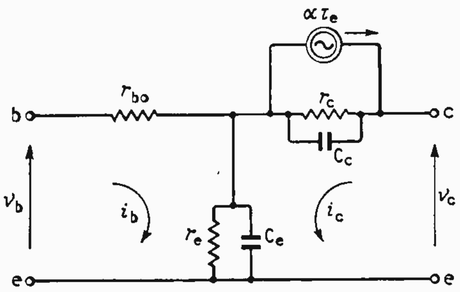


Fig. 3. The circuit of Fig. 2 rotated to represent the common emitter arrangement.

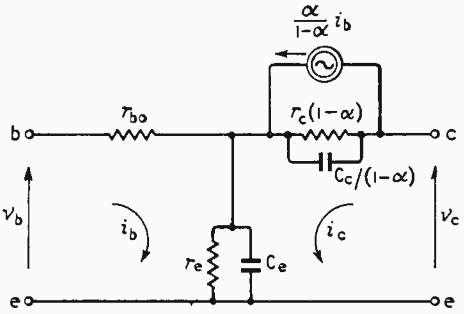


Fig. 4. The circuit of Fig. 3 modified so that amplification is expressed in terms of i_b

dynamic impedance are used. However, at 465 kc/s, the reactance of C_e is roughly twice the magnitude of r_e and in certain circuits it must be taken into account.

The high-frequency equivalent network thus becomes that shown in Fig. 2. This relates to the common-base arrangement but may easily be adapted for the case of the common emitter amplifier by simply rotating the arms of the T; this is shown in Fig. 3. However, in the common-emitter arrangement, it is sometimes preferable to express the current generator that indicates amplification (i.e. the αi_e part) in terms of the current flowing in at the input terminals. The input current is now i_b and by using the expression

$$i_b + i_c + i_e = 0$$

it is possible to transform the network of Fig. 3 to that of Fig. 4.

Using these various equivalent networks it is possible to calculate input and output impedances when using various generator and load impedances, and also to determine the gain of the amplifier. They can also be used, and this is at least as important, to indicate how the internal feedback occurs and thus how to design circuits that neutralize its effects.

The importance of the various factors that limit high-frequency performance will now be considered in turn.

Alpha cut-off frequency.—The most obvious limitation is the reduction of α with increasing frequency. The effect of this in circuit performance depends on the values of load and generator impedances. As an example, consider a common-base amplifier working into a load R_L which is very small compared with r_c. Using the equivalent network shown in Fig. 2 the input impedance at the emitter is then given approximately by the expression $Z_{in} = Z_e + r_{bo}(1-\alpha)$ where Z_e is the impedance of C_e and r_e in parallel. Hence, if the amplifier is supplied from a generator (v_g) of resistance r_g, we find that the current flowing in the input loop is given by

$$I_{in} = \frac{v_g}{r_g + Z_e + r_{bo}(1-\alpha)}$$

Since α decreases with increasing frequency, Z_{in} will increase and hence I_{in} will decrease. In order that this reduction in I_{in}, which results in a decrease in the gain of the amplifier, be kept as small as possible it is necessary that

(i) r_{bo} be as low as possible.
(ii) r_g be as high as possible.

The frequency f_α is determined by applying a constant-current signal into the emitter and varying the frequency until the voltage developed across a very low resistance (e.g. 300 Ω) in the collector circuit is reduced to 0.7 of its amplitude at low frequency. Thus f_α may be regarded as the bandwith of a common-base amplifier driven from a very high-impedance generator and working into a low-impedance load. As was shown above, the effect of changes in α with frequency become more marked as lower values of r_g are used. Since it is necessary, in a practical circuit, to use a value of r_g of the same order of magnitude as Z_{in} in order to obtain high gain, the limitations due to the variation of α with frequency are likely to occur at frequencies well below f_α.

In fact, the bandwidth of an untuned amplifier working into a low value of R_L is found to be given approximately by

$$\left\{1 - \frac{\alpha_0 r_{bo}}{r_g + r_e + r_{bo}}\right\} f_\alpha$$

The complex nature of α also means that Z_{in} has an inductive component.

Another case worth considering is the effect of the variation of α with frequency on the performance of a common-emitter amplifier. The network in Fig. 4 shows that the current gain factor in this case is given by the factor $\alpha/(1 - \alpha)$; this is often termed α_{eb}. In this case the current gain cut-off frequency, $f_{\alpha cb}$, is found to be given by

$$f_{\alpha cb} = (1 - \alpha_o) f_\alpha$$

Taking the GET4 example considered earlier, we obtain a value of 35 kc/s. That is, the bandwidth of an untuned common emitter amplifier (measured, as before, from zero frequency) fed from a high generator impedance (constant-current source), and working into a very low load resistance, is given by $f_{\alpha cb}$. It may at first sight, therefore, be surprising that such a transistor as the GET4 should be considered at all for use in a common-emitter amplifier at 465 kc/s.

However, for the common-emitter amplifier (with low R_L) the input impedance is given approximately by

$$Z_{in} = r_{bo} + \frac{r_e}{1-\alpha}$$

and, hence, using a generator, r_g, the input current is given by

$$I_{in} = \frac{v_g}{r_g + r_{bo} + \dfrac{r_e}{1-\alpha}}$$

In this case, as the frequency is increased, α decreases as before but the effect now is to reduce the value of Z_{in} and hence to increase I_{in}. As a result the bandwidth now becomes substantially greater than $f_{\alpha cb}$; the lower the value of r_g, the higher does the useful range of operating frequency extend. In practical amplifiers r_g is comparable with Z_{in} and this results in a substantial increase in bandwidth.

Base resistance and collector capacitance.—In both the common-base and common emitter cases considered above, the effect of frequency variations of α on the frequency range of the amplifiers becomes more pronounced as r_{bo} is increased.

Consider also the feedback due to r_{bo} and C_c. This may be seen from the network shown in Fig. 2. If an a.c. voltage V_1 is applied to the collector terminal, and the emitter terminal is a.c. open circuited, a voltage V_f will appear at the emitter terminal. At a frequency f, V_f will be given by

$$V_f = \frac{j2\pi f\, C_c\, r_{bo}}{1 + j\,2\pi f\, C_c\, r_{bo}} V_1$$

This expression shows that the product $C_c r_{bo}$ must be kept as low as possible if the resulting internal feedback is to be small. It also shows that it is the product of C_c and r_{bo} that is important.

The parameter r_{bo} depends largely on the resistivity of the germanium used and on the geometrical construction of the transistor; it is found to be substantially independent of the d.c. operating conditions.

The collector capacitance C_c, on the other hand, is highly dependent on the operating conditions. Thus for a p-n-p transistor, such as the GET4, made by the "alloy" process, C_c varies with the d.c. collector voltage V_c as follows: $-C_c \propto 1/\sqrt{V_c}$. Thus if V_c is reduced from -12 volts to -6 volts in the example considered earlier, the value of C_c is increased by 50%.

Figure of merit.—It has been shown above that, in order to obtain good high-frequency performance, it is necessary that

(i) f_α be as high as possible.
(ii) r_{bo} and C_c be as low as possible.

A useful performance criterion is given by what has become accepted as a "figure of merit" for transistor amplification. This is designated by the factor M_g, where

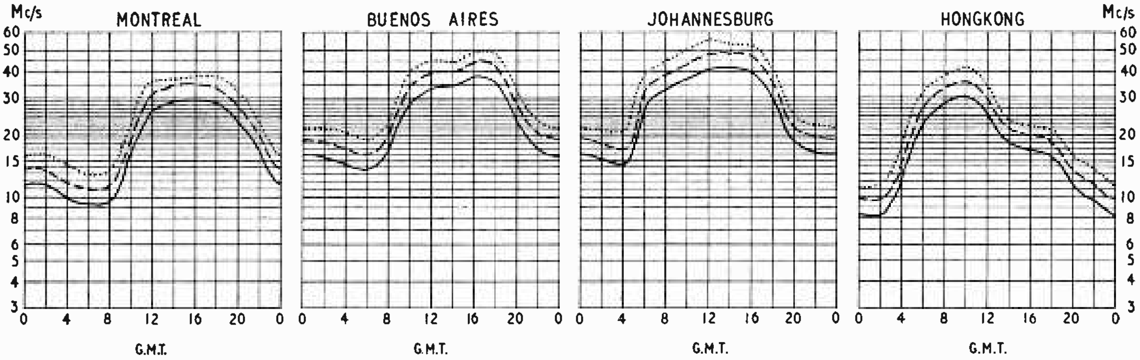
$M_g = \dfrac{f_\alpha}{r_{bo}\, C_c}$, with f_α expressed in kc/s, r_{bo} in ohms and C_c in pF.

For a transistor having the values quoted above, M_g is 0.44.

The more practical aspects of designing transistor h.f. amplifiers, with particular reference to neutralization and a.g.c., will be discussed in Part 2 of this article.

(To be continued.)

SHORT-WAVE CONDITIONS *Prediction for October*



THE full curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during October.

Broken-line curves give the highest frequencies that will sustain a partial service throughout the same period.

F.M. Receiver Design

Methods of Improving Capture Ratio to Combat Multi-path and Co-Channel Interference

By LAWRENCE W. JOHNSON*

In America, where more than 500 f.m. broadcasting stations are in regular service, the problems of co-channel interference have lately directed attention to the inadequacy of "traditional" receiver designs.

This article presents the arguments which have led to the adoption of wide-band discriminator circuits in some of the more advanced American commercial f.m. tuners, and outlines alternative techniques for improving f.m. reception under adverse conditions either of receiver siting or anomalous propagation.

CONTRARY to expectations, frequency modulation has so far failed to bring about the revolution in broadcasting which has been predicted from time to time. F.M. was announced over twenty years ago; its advantages have been widely admitted, but nowhere has it replaced a.m. as the main broadcasting medium. The reasons are many, varied, and interesting; but in this article it is proposed to discuss one single contributory factor, namely the imperfect performance of f.m. receivers of what we may call "traditional" design.

Receivers at present used for f.m. reception are variants, almost without exception, of the basic design used by Major Armstrong in his tests in the middle thirties. On the one hand this might not seem too surprising, since a.m. receivers have undergone relatively little refinement in basic design in the same 20-year period. Yet it is perhaps just this tendency to think about new things in terms of similar subjects with which we are already familiar that leads to such "follow-the-leader" situations. Much that has been added to the literature of f.m. receiver design in the last 20 years has yet to find its way into receivers in commercial production. It cannot be denied that Armstrong's work[1] represented a thrilling example of creative engineering in the face of monumental scepticism on the part of organized radio, and it is no reflection on his work that the type of receiver he originated has since been shown to suffer from shortcomings, albeit subtle ones. But first let us review what has been accomplished in spite of them.

Before an f.m. broadcast service is established, field tests are generally made. Inspection of the available reports[2, 3, 4, 5] of these field tests reveals an interesting point. Although they were carefully conducted and meticulously recorded, it is apparent that some of the conclusions can be questioned. It must be clearly realized that such conclusions are valid concerning only the whole combination of transmitter, propagation medium, and receiver, rather than purely and simply about f.m. as a basic system of broadcasting. It appears that this distinction has been lost. Consider an analogy with a.m. broadcasting; one would not perform an a.m. field test with a crystal set, or even with a 1936 t.r.f. receiver, yet the diligent reader can find examples of recent f.m. field tests using receivers which from all accounts appear to be no more than refined versions of Armstrong's original design, to which we have assigned, we hope without offence, the descriptive adjective "traditional." It is of considerable importance to note that f.m. has been adopted in spite of the receivers used.

No stigma should be attached to the incorrectness of conclusions mentioned above, for the history of radio shows that many of the foremost authorities in the field, past and present, have jumped to incorrect conclusions about f.m.'s capabilities. It seems, in fact, to have been a sort of occupational hazard for radio engineers and scientists, afflicting the great and small alike. Perhaps it still is.

Many vague and excessively inclusive claims have been made at one time or another for f.m. Some have been incorrectly stated and others have been idealized versions of what f.m. can do when receivers of advanced design are used; but all these claims, of whatever validity, are based on the capture effect, by virtue of which a signal effectively "takes over" at the f.m. detector if its amplitude exceeds the sum of the amplitudes of any other signals present there. Proper consideration of the relevant vector diagrams will yield the correct answer. The literature[6,7,8] explores the subject in detail and we will do no more than outline some of the procedure by which the details of performance can be deduced.

Consider the rather special situation that exists when two signals of constant power are present on the same carrier frequency in nearly the same strength. Suppose that one signal has a field strength which yields one millivolt at the aerial terminals while the other yields nine tenths of a millivolt, and that both are now frequency-modulated. Let us examine their vector sum during a period short compared to the highest modulating frequency. Of particular interest is the angular velocity of the resultant, R, since it is that angular velocity which carries the intelligence we are planning eventually to recover. At the same time we must not lose sight of the amplitude behaviour of the resultant, since that too must influence our design decisions. Suppose for the time being that we have available a limiter circuit which will accept the sum signal and yield an output of constant amplitude, which will of necessity have the same angular velocity—or instantaneous frequency—characteristics as the original sum vector. For convenience we shall choose the one-millivolt vector as our reference in time, and we shall suppose that the other vector is slightly higher in frequency during the period of our examination, and so will be rotating anti-clockwise about our reference

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*Hewlett-Packard Company, Palo Alto, California.

vector. Fig. 1(a) shows the situation when the two vectors are pointing very nearly in the same direction; then the resultant is nearly 1.9 millivolts, and is rotating with an angular velocity relative to the 1-mV vector only slightly different from half that with which the 0.9-mV vector is rotating.

Some time later—approximately one half cycle of the frequency difference between the two component vectors—the situation is as shown in Fig. 1(b); here the two vectors are very nearly directly subtracting. Now the resultant is very nearly 0.1 mV, and of particular interest is the fact that its angular velocity relative to the 1-mV vector is now something like nine times that with which the 0.9-mV vector is rotating; but note that now the resultant vector is going clockwise, and so corresponds to an instantaneous frequency considerably below the frequency of the 1-mV signal, while in Fig. 1(a) its direction of rotation and relative angular velocity corresponded to an instantaneous velocity slightly above the frequency of the 1-mV signal. Thus the instantaneous frequency of the resultant varies over a considerable range during one cycle of the difference frequency, but since in the long run the resultant makes the same number of total revolutions as the longer vector, their average angular velocities must be equal. Also shown in Fig. 1(b) is the locus of the tip of the sum vector for one complete difference frequency cycle; this is to emphasize the extent of the amplitude variation during the difference frequency cycle.

Frequency Spectrum After Limiting

Thus we see that the resultant instantaneous frequency goes through periodic variations at the difference frequency, its average frequency being that of the larger vector; and the amplitude also undergoes variations at the difference frequency. A plot of the instantaneous frequency versus time would show a series of sharp spikes whose maximum frequency deviation from the nominal carrier frequency can exceed by far the nominal 75-kc/s peak deviation. Prior to limiting, that is to say for all stages which do not limit, purposely or accidentally, a 150-kc/s bandwidth will nevertheless suffice for undistorted transmission of the resultant; for since such a bandwidth would suffice for either signal separately it will by superposition, valid for linear systems, transmit them equally well simultaneously. But once limiting has taken place, having the useful effect of removing the amplitude variations, we encounter as an unavoidable consequence a broadening of the frequency spectrum which means that succeeding stages must have the new wider bandwidth if they are to transmit faithfully the limited signal. The frequency spectrum for the general case of the limited signal requires a bandwidth wide enough to accept at least the highest angular frequency deviation which the process described above may bring about; and this bandwidth must be present in all circuits after the first non-linear circuit, thus including, in terms of conventional design, the anode circuit of the first limiter, any subsequent limiters, and the detector.

For our purposes it will suffice here to record that the expansion of required bandwidth brought about by the ideal limiting of the resultant of two signals depends in a simple fashion upon the ratio of the magnitudes of the two signals.

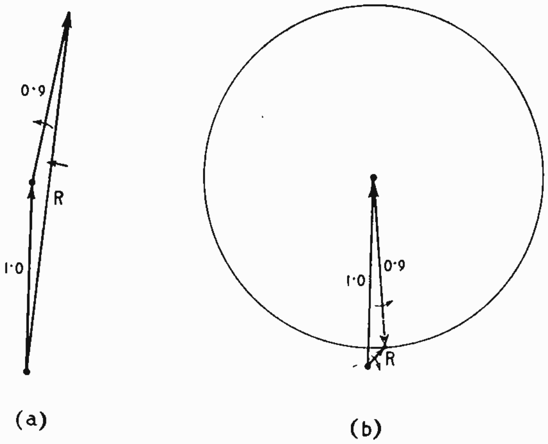

Fig. 1. The resultant of two signals of nearly equal strength and frequency varies in "instantaneous frequency" as well as amplitude, but the average frequency is exactly equal to that of the stronger signal.

If we let a be the ratio of the weaker signal strength to the stronger, and B be the expanded bandwidth, if f_d is the maximum permitted frequency deviation at the transmitter, we have the relation:

$$B = 2 f_d \cdot \frac{1 + a}{1 - a}$$

If, for example, it is desired to receive the stronger of two signals when the weaker is 95% as strong as the former, in an f.m. system using 75 kc/s as the permissible peak deviation, the relation gives 5.95 Mc/s as the bandwidth required of the limiter and detector. This is quite a startling departure from the usual 150 kc/s, to say the least. That this extended bandwidth is necessary, but not sufficient, will be discussed below. Before this result has a chance to discourage the reader, let us turn to the general question of the applicability of the rather special problem we started out with, involving two signals of nearly equal strength.

It is plain that our problem applies directly to co-channel interference; that is the problem associated with the reception of one or the other (or, in unfortunate cases, both) of two signals using the same carrier frequency. That it should apply to most other interference problems as well takes a little more explaining. Adjacent-channel interference, so important in a.m., cannot be ignored in f.m. The example above covers adjacent-channel interference if we note that the difference frequency would simply be bounded differently. In the co-channel case the difference frequency can vary from zero to 150 kc/s, while in the adjacent-channel case it can vary from 50 kc/s, when carriers of adjacent channels are modulated the maximum amount toward one another, up to 350 kc/s, when they are modulated the maximum amount away from one another. Multi-path transmission, responsible for ghosts and aircraft interference on television, is perhaps for British listeners the most important of the types of interference; it arises when two paths of appreciably different length are possible, as in the case of reflection from a mountain, building, or airplane. When one observes that two versions of the same signal, one delayed, appear to the receiver much the same as two separate and distinct signals on the same channel, it is apparent that the same situation regarding expansion of bandwidth applies for multi-path transmission interference.

Impulse noise goes a little farther afield; what happens is that the transient shock-excites the receiver's front - end circuits at their natural resonant frequencies. Since these frequencies are within the pass-band of the receiver, they are amplified along with the desired signal, and appear to the limiter and discriminator stages as discontinuous bursts of unfrequency-modulated co-channel signal. Thus for a period of time of the order of the ringing time of the front-end circuits the situation is roughly the same as that which we chose, with almost startling foresight, as our special example. In this connection we note that the conditions of maximum selectivity and minimum ringing time are mutually incompatible, making some sort of a compromise necessary.

It should be clear, then, that the problem brought about by spectrum expansion is substantially the same for all the kinds of interference mentioned above, which with their variations constitute a fairly complete list of the things that keep radio transmission from working properly or perfectly. And we have established certain bandwidth requirements which when met allow the distortionless reproduction of the patterns of frequency spikes mentioned earlier. At this point one may sensibly ask whether or not this is worth doing, granting that the proper circuitry—rather fancy circuitry—can do it. This very question must have bothered some fairly high-powered authorities for some years; the principles behind the formation of the spikes had been well understood for some time before anyone decided that building a receiver with wide-band limiters and detector to do a good job of demodulating them might in fact be worth while. Until the work in the middle and late forties done by a group at M.I.T. under L.B. Arguimbau, it had apparently been concluded that the spikes represented unavoidable distortion that sufficed to prevent successful reception of the stronger of two signals of nearly equal strength. And it may be a holdover of this same feeling which accounts for the apparently wide-spread opinion that noise suppression suffers if the bandwidth is widened beyond, say, 200 kc/s.

Capture Ratio

The work of Arguimbau's group established that the actual audible distortion introduced by the spikes can be held to a very low degree, if the customary de-emphasis time constant is used at the receiver. Arguimbau's work, described in many publications,[6, 7, 9, 10, 11] was directed primarily at multi-path problems, and in particular at investigating the possibility of trans-Atlantic communication via f.m.[12, 13] It is interesting to note that his tests revealed that the principal drawback in that application lies in the fact that in trans-Atlantic work a multiplicity of signals is involved, no one of which is greater than the sum of the rest; since the best that can be done today in receiver design requires that one signal exceed the sum of all others, success has not yet been achieved.

It is probably an over-simplification, perhaps a permissible one, to say that the principal conclusion of the M.I.T. work is that an f.m. receiver should have a good capture ratio. After explaining the term "capture ratio," we will discuss the capture ratio of the "traditional" receiver when compared with that of receivers built according to the M.I.T criteria, following which there will be a few words. about the steps one takes to embody these criteria.

We spoke earlier of the quantity a, which was defined as the ratio of the weaker signal strength to the stronger. The largest value of a—that is, the nearest to unity—for which a receiver will provide an interference-free signal is that receiver's capture ratio. (This definition glosses over the question of just exactly when is a signal interference-free; since there seems to be good precedent for this neglect, no more will be said.) One may also encounter capture ratio expressed in decibels; this is obtained by taking the negative of 20 times the common logarithm of the quantity a, or alternatively, 20 times the common logarithm of the reciprocal of a. Bearing in mind that capture ratio is a quantity of importance in reduction of all types of interference, let us consider the capture ratios of the general run of f.m. receivers. Several references point out that in general it has been observed that the desired signal must exceed the undesired by some 20 to 30 decibels for noise-free reception. Thus we may deduce directly that the receivers used in those tests had capture ratios of no better than 20 dB, or 0.1 in the fractional notation. Preliminary tests made as part of the work at M.I.T. support these observations, so that it is quite safe to say that until Arguimbau's group fabricated the first wide-band f.m. receiver in the early forties, capture ratios of twenty decibels and more were the order of the day.

Commercial Wide-band Receivers

Here we might pause and note that, while f.m. has been adopted by several nations in spite of the handicap under which it functions when receivers of poor capture ratio are employed, as far as can be determined no official field test has yet been conducted with receivers designed to take advantage of the M.I.T. research. It is fortunate that f.m. still surpassed a.m. even when forced, so to speak, to labour under an unfair handicap.

Earlier it was indicated that a receiver whose limiter and discriminator had bandwidths of 5.95 megacycles could possibly have a capture ratio of 0.95, or in decibels, 0.45 dB. The above phraseology is intended to suggest that other requirements must be met as well; if, for example, the intermediate frequency pass-band is x dB down ± 75 kc/s from channel centre, then the capture ratio cannot be better than x dB, even if the limiter and detector bandwidths are infinite. More about this later; suffice it to say that it is possible to build f.m. receivers with capture ratios as good as $\frac{1}{2}$ decibel. It is not easy, nor is it inexpensive, but such receivers are described by Arguimbau, Granlund, Paananen, and Cross.[9, 10, 11, 14, 15]

A short description of what is now commercially available along these lines may be of interest. One manufacturer, Radio Engineering Labs., intimately associated with Major Armstrong during his f.m. work, makes an adaptation of the $\frac{1}{2}$-decibel M.I.T. receiver; that this receiver should be the most expensive (over $300) on the American market is easily understood when the reports on its ancestor are inspected. Two other manufacturers, H. H. Scott and the National Company, make less expensive receivers ($100 to $200) embodying many of the characteristics recommended in the same and later

M.I.T. work. The capture ratios of these two are of the order of two decibels, while it appears that other manufacturers propose that the same amount of money should be paid for a receiver or tuner with a capture ratio of the order of 20 dB. Having no positive information about the characteristics of British or European f.m. equipment, the author would be pleased to think that the situation is more hopeful outside the U.S., but as yet no indication that this is so has been seen.

The bandwidth requirement for limiters and detectors has been dwelt on in some detail, and the requirement for flatness of i.f. amplifier pass-band touched upon. Further details along that line are contained in the literature; in passing it may be noted that if a receiver of infinitely wide limiter and detector bandwidths has an i.f. down 3 dB at ± 75 kc/s, then, when it receives a signal at band centre which is (at the aerial) 3 dB below a signal 75 kc/s away from band centre, the two signals will be of equal amplitude at the discriminator, and the effort devoted to widening the bandwidth of the limiter and detector will have been wasted. Thus we can see the type of reasoning behind the requirement that there be negligible ripple in the i.f. pass-band, where negligible means a variation in response small compared to the relative sizes of signals it is desired to separate.

The bandwidth and flatness requirements bear equally on all types of interference, as can be seen from the preceding discussion. A special problem associated with adjacent-channel interference is that of selectivity; it should be clear that its minimization dictates a maximum of selectivity as early in the receiver as possible. This same conclusion presents itself as a means for admitting a minimum amount of wide-band noise.

Ease of Tuning

An extra dividend is gained through the use of a wide-band detector in conjunction with a flat-top steep-skirted i.f. This dividend, having nothing to do directly with interference suppression, is that the receiver is many times easier to tune than the "traditional" design with round-topped i.f., and detector bandwidth of the same order as the i.f. bandwidth. In the "traditional" design one encounters "three-point tuning", which is an unavoidable consequence of the S-curve detector characteristic; thus the subsidiary linear sections of the S-curve on each side of the main linear section give rise to additional responses to the same station as one tunes on either side of the main response. These responses are generally weaker than the main response, are usually noticeably distorted, and can serve to confuse the operator. In addition there is the fact that the limited width of the main linear portion of the characteristic makes tuning for minimum distortion very critical with receivers of "traditional" design. The wide-band flat-top steep-skirt design, on the other hand, gives a tuning ease comparable to if not exceeding that encountered in a good a.m. receiver. This is by virtue of the fact that the discriminator characteristic, as modified by the i.f. response, is more like a letter N than an S on its side; thus the subsidiary responses are so very narrow, being associated with slope detection on the i.f. skirts, that they are heard only as noisy spots on each side of a broad area of undistorted reception. This fortunate situation seems generally to make unnecessary automatic frequency control.

This must not be interpreted as justification for avoiding the building of a stable local oscillator. It is simply that a.f.c.'s chief reason for being—ease of tuning—is no longer existent. Just as one should not design a sloppy audio amplifier, expecting to clean up its deficiencies later on with inverse feedback, neither should one depend on slipping by with an unstable receiver with the idea of covering up those deficiencies with a.f.c.

The considerable difference between frequency allocation policy in the United States and Great Britain places differing degrees of emphasis on the various types of interference. In many U.S. locations, particularly along the Atlantic seaboard, adjacent-channel and co-channel problems are serious, while there are probably a negligible number of such problems in Great Britain. On the other hand, multi-path transmission and impulse noise are not mitigated by careful and intelligent allocation planning, so that these problems are encountered in varying degrees in all parts of both areas, and thus provide good reason for the desirability of good capture ratio in f.m. receivers everywhere.

An interesting example of the importance of good capture ratio, suggested by B. G. Cramer[16], is particularly applicable to the co-channel situation common in the U.S., but is of sufficient interest and importance to be included here. It involves the rather theoretical situation of two transmitters on the same channel situated, say, some 100 miles apart on a flat earth free from mountains or other reflecting bodies. This distance of separation of co-channel stations is a realistic one for the U.S., and so is the assumption that they have the same effective radiated power, made only for convenience. Finally, if we assume, also for convenience, that the receivers to be considered use non-directional aerials we can plot contours which enclose areas for which a receiver of a given capture ratio will receive the stronger signal without interference from the weaker. Fig. 2 shows this situation plotted for stations 100 miles apart when receivers of 0.1 capture ratio (small circles) and 0.9 capture ratio (large circles). One would have predicted that the contours were circles, and naturally enough they are not centred on the transmitting sites. The usable areas inside the contours are actually reduced in accordance with whatever figure we may choose as the maximum service range for an f.m. transmitter of a given power. If we choose 100 miles as that maximum range, the shaded areas shown join the excluded cross-hatched areas. There is still quite a difference between the service areas brought about by the capture ratio difference between the receivers used.

We will now proceed with a few notes on the means now available for achieving the ends described above. Regarding broad-band detectors, it may be noted that several varieties are successfully used. The simplest are nothing more than versions of the familiar ratio detector modified for bandwidths of the order of megacycles, while considerably more complicated designs are used to achieve the 6-Mc/s bandwidth mentioned earlier. Regarding the ratio detector, it should be remarked that its inherent limiting properties are a valuable adjunct to limiters which precede it, but that these limiting properties are not sufficient to do a good job when used alone in a receiver intended to have a good capture ratio.

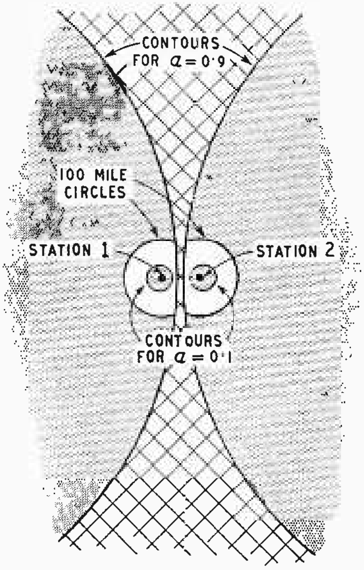

Fig. 2. Service areas (stippled) for capture ratios of 0.1 and 0.9 with co-channel transmitters spaced 100 miles apart.

Other things being equal, as one widens the detector bandwidth, the audio output amplitude for a given deviation decreases; as a consequence one must supply more audio amplification than is customary in conventional designs, but in these days of high-quality disc and tape recorder pre-amplifiers this presents no problem.

Another point in detector design is the choice of the intermediate frequency. On the chance that some may be daring enough to break away from the well-established 10.7 Mc/s, we may note that it is only with considerable effort that a 6-Mc/s bandwidth can be achieved at the standard i.f.; this is understandable in view of the large fraction, some 60%, of the centre frequency which the bandwidth represents. On the other hand, if an i.f. in the neighbourhood of 30 Mc/s were chosen, the problems associated with achieving a 6-Mc/s bandwidth are reduced considerably. It is a slight over-simplification to say that achieving 6 Mc/s at 30 Mc/s is just like achieving 2 Mc/s at 10.7 Mc/s, yet it may be that in these days of considerable experience with television's rather high i.f.'s, a higher f.m. i.f. might be a very sensible choice. Other pros and cons enter; spurious responses are probably reduced, local oscillator interference problems may be increased, etc.

The actual design decision regarding capture ratio deserves careful consideration. Here an analogy may be drawn with the sometimes-hazy subject of the source impedance of audio amplifiers used to drive loudspeakers. That certain benefits are derived from driving the loudspeaker from a source impedance low compared to the loudspeaker impedance is well known; the trend which some years ago led from un-fed-back pentodes, with their source impedances considerably higher than the load, has now brought us to source impedances of the order of one tenth the load impedance. The point here is that very little is gained in lowering further the source impedance, say, to one hundredth the load impedance, since the gain in performance is likely to be imperceptible while the effort involved in accomplishing the reduction is considerable. We are faced with a very similar situation regarding capture ratio; proceeding from the rather poor ratio of 0.1 up to a respectable 0.7 or 0.8 represents a great improvement in performance, while the additional effort required to extend the capture ratio to 0.9, 0.95, or even 0.99 would not be proportionately reflected in performance improvement, even though it would be interesting from a technical standpoint.

Improved Limiters

Limiters play an exceedingly important role in the overall system; they must remove the violent variations in amplitude which occur from many causes, including the mixing of two nearly-equal signals, as set forth earlier. Because of the speed with which amplitude variation may take place, the limiter must be fast-acting. Such is not the case with conventional designs depending on grid-current and cut-off limiting with pentodes operated at low screen and plate voltages; recent designs have unanimously adopted other means for limiting. The simplest quick-acting limiter employs biased diodes, with care taken to assure that time constants in the bias source do not lead to the same recovery time troubles which hamper pentode limiters.

A means which does not present the signal-attenuation disadvantage of the diode limiter is available through use of the gated-beam tube (6BN6) as a limiter. This tube was originally designed as a combination limiter-discriminator[17,18], and is so employed in many television receivers. Its use as a detector in high quality receivers has not yet been reported, but when properly used it is unsurpassed as a limiter[19]. It has the fortunate property of depending on electron-optical beam-switching for its limiting action, rather than on grid-current biasing. Literature on its application is extensive but apparently not widely familiar. Interested experimenters might do well to investigate its use as a combined wideband limiter and discriminator. Of course, in all limiting means mentioned, care must be taken that the bandwidth appropriate for the desired capture ratio is maintained; in general such wide-band limiters have single-tuned low-Q circuits and are only broadly tuned.

I.F. and front-end design should follow general good design practice for low noise, with special attention to selectivity and flat-top characteristics. As mentioned earlier, it is important to obtain as much selectivity as early in the receiver as possible. Special attention should also be directed to the overload characteristics of the front end, with an eye to minimizing spurious responses. Note also that the later stages of the i.f. amplifier should not limit, for if they do, the spectrum is broadened with consequent possible distortion and degradation of capture ratio due to loss of sidebands. Both of these last two points indicate the desirability of an effective, fast-acting automatic-gain-control system. If the a.g.c. is fast-acting enough, it will in fact be of considerable assistance to the limiters in maintaining a constant signal amplitude at the detector.

And now, in closing, a few remarks about some alternative schemes and some new developments. A device used successfully some years ago, which does not seem to have been exploited in the design of receivers of good capture ratio is the locked-oscillator detector[20, 21]. In short, this scheme locks the frequency of an oscillator in the receiver which is normally operating at the i.f. to that of the received signal; it is the resulting variations in the frequency of this oscillator which are detected. An advantage of this system is its inherently perfect limiting, since the oscillator's output amplitude depends in no way on the incoming signal amplitude. For satisfactory locking it is obvious that the incoming signal would have to exceed some threshold, as is always the case with any detector. With suitable design the frequency excursions encountered under interference conditions can be handled by making the oscillator such that it cannot quite follow the extreme variations; it will thus perform, in effect, to limit bandwidth.

Pulse-counting Discriminators

Counter-type detectors are frequently proposed for f.m. receivers[22, 23, 24]. Their advantages are considerable, the principal ones being excellent linearity over the design range, and in most cases, admirable simplicity. Since they customarily use a low i.f., of the order of 150 kc/s, it is easily predictable that strange things must happen under interference conditions. If the instantaneous frequency were to head towards 150 kc/s below channel centre, the frequency into the counter would approach zero, which it cannot be expected to detect satisfactorily. And if the instantaneous frequency heads for a frequency more than 150 kc/s below channel centre, it is plain that the i.f. output into the counter will reverse phase at zero frequency and start back up again, giving rise to considerable distortion, since if the instantaneous frequency went 300 kc/s low, the counter would think that it was seeing the same 150 kc/s that corresponds to an unmodulated carrier. These results are somewhat analogous to overmodulation in an a.m. transmitter, or to partial carrier suppression in an a.m. receiver; the consequence is that the obtainable capture ratio is severely restricted by the use of the low i.f. that is dictated by practical considerations in counter-detector design. Use of higher i.f.'s in counter-detector circuits brings with it considerable complication; if money and size were no object, one might employ a digital frequency divider to proceed from the customary i.f. range down to the neighbourhood where a counter discriminator can operate conveniently. The deviation would then have been reduced by the dividing ratio, making good capture ratio possible with a second i.f. of the order of 150 kc/s; other things held constant, the output voltage would be reduced by the same division factor.

A recent paper[25] describes the theory behind a plan to accomplish interference rejection without recourse to the wide-band limiter-detector system discussed above. This suggested system, results of the experimental confirmation of which have not yet been reported, is an outgrowth of the M.I.T. work mentioned earlier. Its conclusion is that the wide-band scheme is, in the mathematical sense, sufficient but not necessary, the newer plan involves alternate stages of amplitude limiting and bandwidth limiting. Thus every time a limiter broadens out the spectrum by removing amplitude modulation, a steep-skirted bandpass filter reduces the bandwidth at least part way back to its original value. Cascading a succession of such ideal limiters and bandpass filters is shown to be capable of yielding a good capture ratio without the necessity of including broad-band circuits. Pending further experimentation with this idea, one can be reasonably certain that the broad-band technique will do the job. Perhaps in a few years the broad-band techniques will have become the traditional techniques, with which the newer narrow-band system will be competing for recognition.

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[25] Baghdady, E. J., " Frequency-Modulation Interference Rejection with Narrow-Band Limiter," *Proc. I.R.E.*, January 1955, p. 51.

PIE-TEA

Regrettably Theoretical Refreshment

By "CATHODE RAY"

MY apologies for the title. The idea was to attract at least the momentary attention of the Billy Bunters of the electronic world. But perhaps there is small hope of expecting that attention to continue once I have confessed that the title really ought to have been "Π-T" and that I am offering no facilities for raising π to the tth in any grossly materialistic sense.

This is not the first time it has been appropriate to recall the celebrated radio journalist who passed off a fairly conventional receiver circuit as something startlingly novel by the simple expedient of drawing it in an unfamiliar pattern. (One of the features that seemed to put it in a class by itself was the l.t. battery in series with the aerial.) He was taking advantage of the very large extent to which our minds are guided by the way in which a circuit diagram is set out. In more recent times the late Mr. Bainbridge-Bell, who also realized this fact, made commendable use of it in his efforts to standardize a clear and logical style. But there are still differences between ourselves and the old heavy electrical engineers, who spend a lot of their time contemplating 3-phase power systems. Three impedances (or generators, or what have you), represented in Fig. 1 by oblongs, can be arranged symmetrically between three terminals in the two ways shown; the first is for obvious reasons called "star" or "Y" or "wye," and the second "delta" or "Δ" or "mesh." We people, on the other hand, are more interested in filters and attenuators, which are examples of 4-terminal networks or "quadripoles." There are two basic forms of these, shown in Fig. 2 and known for equally obvious reasons as "T" and "Π" respectively.

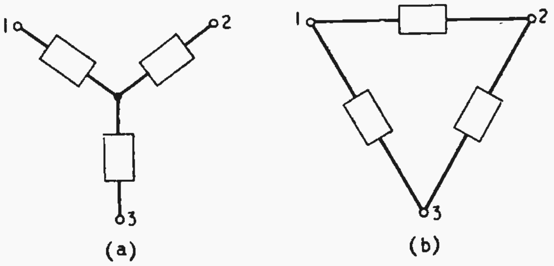
Students who have had to become acquainted with both the two main divisions of electrical engineering, and therefore with both Figs. 1 and 2, may (unless it was pointed out to them at the time) have experienced an appreciable time lag in seeing that electrically these two pairs of circuit formation are identical, the differences being confined to the way in which they are drawn. Billy Bunter, for example, or Pilot Officer Prune (if either of them got as far as a telecommunications course) would probably need a soldering iron for changing a delta system into a Π, and thereby raise a cackle from the superior mortals who had seen the light five minutes earlier. We, being more sophisticated still, are supposed to have reached the stage where we are no longer misled by any apparent differences between Figs. 1 and 2 but instead are interested in (a) and (b) in either Fig. being electrically identical.

For purpose of discussion it is desirable to settle on one particular nomenclature, and although our professional inclinations will naturally be towards Fig. 2, I am sufficiently conscious of the value of visual arrangement to admit that in this case the heavies have something. The triangular symmetry of Fig. 1 best matches the cyclic symmetry of its mathematics, as we shall see.

And so, although "Π-T" may have a more pleasurable sound for some, we are going to call our subject (embracing both Figs. equally) the Star-Delta Theorem. It states that any three impedances connected in one of these ways can be exactly replaced by three other impedances connected the other way, provided that their values are correctly chosen. It is only fair to add that the substitute impedances are liable to be awkward from a practical point of view—they may have to vary with frequency in a rather impossible manner, and resistances may come out negative. But at any one frequency the most that is needed to make each of the three "arms" is one resistance in series or parallel with one reactance.

The next thing is to find the formulæ for the substitute impedances. To do this we must have symbols for the three impedances in each formation. The general symbol for impedance being Z, the usual practice is to distinguish the six concerned here by subscripts—Z_1, Z_{ab}, or whatnot. But seeing that "Z" is common to all six, the information conveyed by that symbol is nil*, so it is redundant. It is much quicker and simpler and less liable to error (as I am sure the printer will agree) to label them simply a, b and c in the star and A, B, C in the delta, and away with anyone who grumbles that C stands for capacitance.

To preserve the symmetry, the a in the star should



(a) (b)

Fig. 1. Diagrams like this (or drawn with inductances in place of the oblongs) are common in books on 3-phase electric supply systems. They are called the star (a) and delta (b).

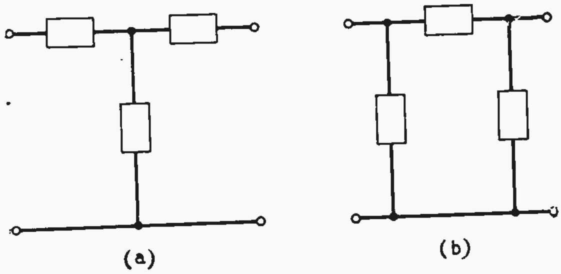

(a) (b)

Fig. 2. These diagrams of the T (a) and π (b) networks are common in books on communication circuits, and of course are electrically the same as those in Fig. 1.

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* If this proposition is new to you, consult any book on Information Theory, or "Cathode Ray" in the Sept. 1952 issue.

come opposite the A in the delta, and so on, as in Fig. 3.

One procedure is to reckon the impedance between each of the three pairs of terminals in turn in both arrangements. Then, if the two arrangements are electrically the same, their corresponding impedances must be the same, which we can express by equating them. The impedance between terminals 1 and 2 is $b + c$ for the star and A in parallel with B + C for the delta. We are going to make much use of the rule that to find the result of two impedances in parallel you divide their product by their sum. So

$$b + c = \frac{A(B + C)}{A + B + C}$$

The same method applies to the other two pairs of terminals, with the results

$$c + a = \frac{B(C + A)}{B + C + A}$$

$$a + b = \frac{C(A + B)}{C + A + B}$$

This is an example of the mathematical cyclic symmetry I mentioned; having one equation, we can arrive at the others by moving all the letters one place round each time, as in the Mad Tea Party

Now if we add the last two lots together (to give $c + a + a + b$) and then deduct the first, we eliminate b and c and leave $2a$, thus:

$$\begin{aligned} 2a &= \frac{B(C + A) + C(A + B) - A(B + C)}{A + B + C} \\ &= \frac{BC + BA + CA + CB - AB - AC}{A + B + C} \\ &= \frac{2BC}{A + B + C} \end{aligned}$$

$$\text{So } a = \frac{BC}{A + B + C}$$

In exactly the same way (or by using cyclic symmetry as a short cut) we find that

$$b = \frac{CA}{A + B + C}$$

$$\text{and } c = \frac{AB}{A + B + C}$$

So if we know the three impedances A, B and C in a delta we can calculate the correct values for the three impedances a, b and c to make a star that is electrically the same.

Although the foregoing, or its equivalent, is the treatment given in some books, it is really more by luck than judgment that it happens to be right. The only thing we have established is that the two arrangements related by the formulæ are equivalent as viewed between two of their terminals, the third being unconnected. But that is not how stars or deltas are normally used. The usual thing is to use one pair of terminals as the input and another as the output, and the impedance measured at one pair depends on what is connected between the other pair. It is not obvious that the formulæ we have derived for infinite output impedance would hold good for *any* impedance. When output impedances are brought into the problem, simple algebra is a clumsy tool for solving it, and I will refer you to the more advanced books for the full treatment, which by good fortune does give the same result.

To be fully armed, we need formulæ to perform the reverse transformation; i.e., given a, b and c, to find the equivalent A, B and C. One way of arriving at this second set of formulæ is to follow the same procedure as for the first, but *short-circuiting* one of the unused pairs of terminals in each arrangement. Alternatively, the second set can be derived from the first by algebra, but a little less easily than you might think. In any case, I consider it neater to call in the duality principle.

This was explained in the April 1952 issue, but as that is rather far back I had better just mention that equations which are true of one electrical circuit also hold if they and the circuit are systematically turned upside down. Among other things, series is replaced by parallel, open-circuit by short circuit, and impedance by admittance.

Now the delta is the dual of the star, and if the same procedure as before is followed, short-circuiting the output instead of open-circuiting it, and working in admittances instead of impedances, the form is exactly the same. I suggest you try it for yourself to make sure; what I am going to do is assume that duality works and use it to transform a sample equation in our existing set. It is

$$a = \frac{BC}{A+B+C}$$

Interchanging large and small letters and standing them all on their heads, we get

$$\frac{1}{A} = \frac{\frac{1}{bc}}{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}}$$

$$\text{From which } A = bc\left(\frac{1}{a}+\frac{1}{b}+\frac{1}{c}\right) = \frac{bc}{a}+c+b$$

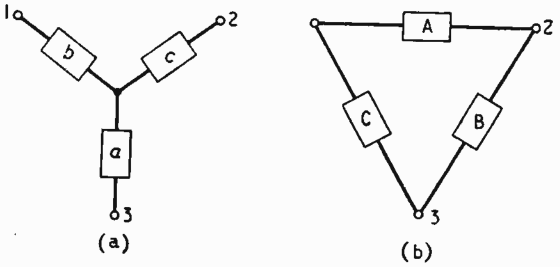


Fig. 3. The impedances in the two formations will be denoted by these letters.

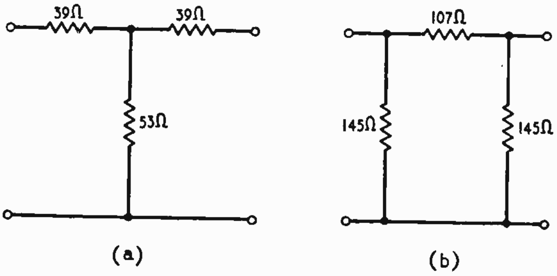


Fig. 4. These two attenuators are completely interchangeable.

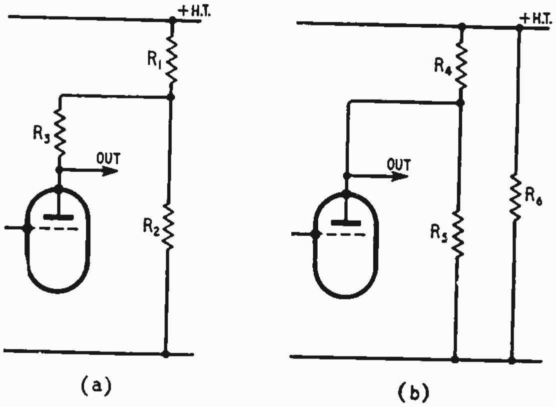


Fig. 5. By substituting a delta (b) for the star in (a), we find that the same job can be done with one resistor fewer.

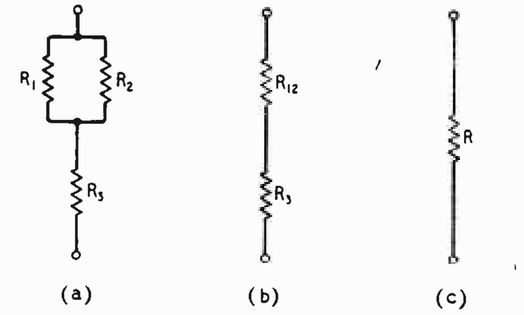


Fig. 6. The ordinary series and parallel additions can be used to find the single resistance equivalent to networks like (a), but . .

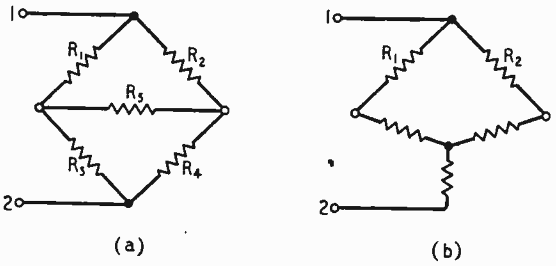


Fig. 7 . . . they fail when applied to a bridge circuit (a). However, the star-delta transformation succeeds (b).

This doesn't look very symmetrical, but it can be made to do so by writing it a little more fully:

$$A = \frac{ab+bc+ca}{a}$$

Encouraged by the fact that either of these is correct by the reference books, we write down the other two simply by cyclic symmetry:

$$B = \frac{ca}{b}+a+c$$

$$C = \frac{ab}{c}+b+a$$

A still neater use of the duality principle would be simply to say that as the two arrangements are duals of one another the second set of formulæ is exactly the same as the first except that the letters represent admittances instead of impedances.

It would be a pity if, having equipped ourselves with these two sets of formulæ, we were to find no use for them. Even in Mr. Squeers' system of education, theory was followed by practice. So the rest of the session will be devoted to this aspect of the matter.

Suppose an increase in power of the local television signal has made it necessary to cut it down at the receiving end, say by 10dB in a 75-ohm aerial line. We may have been informed that this can be done by inserting between the line and the receiver a T attenuator (Fig. 4(a)) in which the horizontal arms are 39-Ω resistors and the upright one 53 Ω. But if we had no resistors as low as this we might try the Π form (b) instead. The uprights are what we have been denoting by C and B in Fig. 3, and substituting $b = c = 39$ and $a = 53$ we get

$$B = C = 53 + 53 + 39 = 145$$

Similarly

$$A = \frac{39^2}{53} + 39 + 39 = 107$$

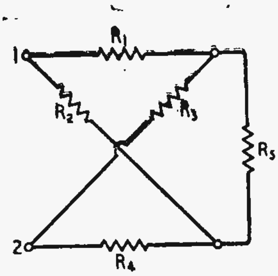
The "preferred values" 150 Ω and 100 Ω would do quite nicely, giving an attenuation of 9.6 dB at 75 Ω.

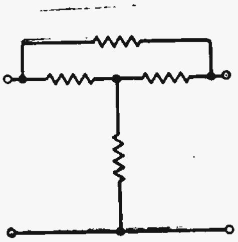
In this case it would be just as easy to find the values directly from the formula for matched Π attenuators, provided of course we happened to have it. However, it makes a nice simple example of the use of our Star-Delta Transformation. In so far as all the arms of the system can be regarded as pure resistance, the two arrangements are truly interchangeable at all frequencies. At Band-III frequencies, however, we have to be careful about the type of resistor we use; as little as 2 pF stray capacitance is about 400 Ω reactance, so is not a negligible path in comparison with 100 or 150 Ω. Not that it would be likely to cause trouble in such a non-critical application as a TV attenuator.

It is interesting to note in passing that the equivalent of a star in which all the arms are equal is a delta in which all the arms have three times the impedance—as can easily be discovered by using the transformation formulæ.

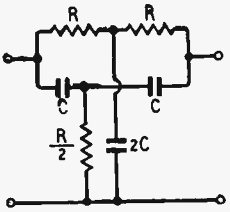
Another very simple purely resistive example was given by W. Tusting in the November 1954 issue, p. 552, where he showed that if one wished to run a resistance-coupled valve from a tapped-off point on the h.t. supply, as in Fig. 5(a), it was really unnecessary to use three resistors, because if the star system they form is transformed into its equivalent delta (b) it turns out that one of the resistors (R_6) serves no useful purpose and can be omitted.

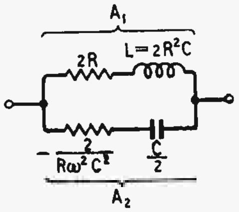
Most of the elementary books on electricity, after they have dealt with Ohm's law and series and parallel arrangements, show how the currents, etc., in complicated networks can be calculated by successive reduction. For instance, R_1 and R_2 in Fig. 6(a) can be replaced by R_{12} (= $R_1 R_2/(R_1 + R_2)$) at (b), and this in turn can be added to R_3 to give simple R at (c). But with some circuits this doesn't work. Perhaps the most important of these exceptions is the bridge network, Fig. 7(a). Suppose we wanted to find the resistance of this bridge as a whole, between the terminals 1 and 2. The difficulty is R_5, because it is not directly in





Left:—Fig. 8. This lattice circuit is just a different way of drawing the bridge—Fig. 7(a). Right:—Fig. 9. The bridged T is another network that can be simplified by the star-delta transformation.





Left:—Fig. 10. And so is the parallel T or twin T, of which this is an example. Right:—Fig. 11. The equivalent path between the top two ("live") terminals of Fig. 10 is shown here; it consists of a tuned circuit with infinite impedance at resonance.

parallel with any of the other arms. But if we spot that with R_3 and R_4 (or with R_1 and R_2) it makes a delta, we have only to transform it into its equivalent star, as in Fig. 7(b), which (after adding two of the new arms to R_1 and R_2) is the form we handled successfully in Fig. 6.

Incidentally, this is another example of how the same circuits can be made to look different, according to who is drawing the diagrams; or even the same person can draw them differently and not realize that they are the same. In books on electrical measurements one could hardly fail to find Fig. 7(a)—the familiar diamond-shaped Wheatstone bridge. In books on filters and attenuators one could hardly fail to find the lattice network (Fig. 8). Yet these are identical. Personally I consider Fig. (7)a much clearer than Fig. 8—it is easier to see that the attenuation can be made infinite, and what are the conditions for this—but perhaps that is because I studied Wheatstone bridges before attenuators.

Another commonly used arrangement that defies the series-parallel treatment is the bridged-T (Fig. 9). I will not go into this in detail, because Mr. Tusting did so in the article just referred to, but will just point out that the upper part of it forms a delta. When transformed into the equivalent star or T, it combines with its original "stalk" to form a simple T. Alternatively, the lower part of Fig. 9 is a T which can be transformed into a Π into which the original "roof" can be merged by paralleling.

In practice this sort of network nearly always has reactive arms, as in the Tusting example. This makes no difference to the formulæ, but in place of simple arithmetic we have to use the so-called "complex" algebra whose mysteries I attempted to dispel in the February 1953 issue.†

As an example of this let us take a slightly more complicated network—the parallel-T, embodied in a distortion meter described by V. J. Tyler in the September 1953 issue. In this particular case, Fig. 10, half its arms were resistors and half capacitors, and their ratios were as shown. The object of the thing was to remove entirely the fundamental of the signal being investigated and allow the harmonics to go on and be measured by a suitable valve voltmeter. So it must have infinite attenuation at some selected frequency and as little as possible at all others. Hence the need for reactances, to discriminate between one frequency and others. Like a bridge, which also can be adjusted to balance out the signal but has the disadvantage that there is no earthable terminal common to input and output, it is called a "null" network.

As the name "parallel T" suggests, it consists of two T filters in parallel between the usual input and output terminals. But since no arm is in simple series or parallel with any other, it completely defies straightforward calculation. However, by transforming both Ts into Πs, each of the three arms in one Π comes directly in parallel with the corresponding arm of the other so can be merged with it to form a single Π. And if you are wondering why Mr. Tyler didn't call for this single Π (or its equivalent single T) in the first place, instead of his complicated double T, wait and see.

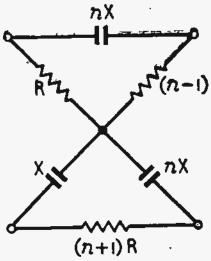


Fig. 12. The "bolted lattice" network—another that can be simplified by the star-delta transformation.

Suppose what we want to find is the correct value of C for rejecting a given frequency completely. That means the C that makes the impedance of arm A in Fig. 3 infinitely large. This arm will consist of two Π arms in parallel, say A_1 and A_2. Then

$$A=\frac{A_1\ A_2}{A_1+A_2}$$

and this is infinite if $A_1 + A_2 = 0$ (assuming $A_1\ A_2$ is not zero). Now as regards the capacitors in Fig. 10 it is the reactance of C that concerns us, which is $1/j\omega C$. Using our transformation and remembering that $j^2 = -1$ we have

$$A_1 + A_2 = \frac{b_1c_1}{a_1} + b_1 + c_1 + \frac{b_2c_2}{a_2} + b_2 + c_2$$

$$= 2R^2j\omega C + R + R + \frac{2}{R(j\omega C)^2} + \frac{1}{j\omega C} + \frac{1}{j\omega C}$$

$$= 2R^2j\omega C + 2R - \frac{2}{R\omega^2C^2} - j\frac{2}{\omega C}$$

To make this add up to nothing, the resistive and reactive parts must separately cancel out, i.e.,

$$2R^2j\omega C - j\frac{2}{\omega C} = 0$$

$$\text{and}\quad 2R - \frac{2}{R\omega^2C^2} = 0$$

In both cases this happens when $R = 1/\omega C$; in other words, when the frequency is such as to make the reactance of C equal to R. In the distortion meter

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† Or see "Second Thoughts on Radio Theory", Chaps. 28 and 29.

the middle value of R was $15\,\text{k}\Omega$, so for rejecting 1 kc/s (say) the reactance of C must be $15\,\text{k}\Omega$ at 1 kc/s. That works out at about $0.01\,\mu$F.[‡]

Fig. 11 shows the arms A_1 and A_2 in parallel, and answers the question about the point of using a double T. As our calculations show, the reactance in A_1 is $2R^2 j\omega C$, which varies directly with frequency, so is equivalent to an inductance equal to $2R^2C$. With $R = 15\,\text{k}\Omega$ and $C = 0.01\,\mu$F, that is 4.5 henries; and such an inductor alone would cost and weigh more than the whole double T. And what about A_2, which contains a negative resistance! To give us the equivalent of an easily tunable audio-frequency resonant circuit with infinitely high Q, this double T is a masterpiece of economy.

A closely related null network is shown in Fig. 12[§]. You may like to work it out in detail. The procedure is exactly the opposite of that followed with Fig. 10: the two deltas in series are transformed into stars, and the null occurs when the two vertical arms in series with one another, but shunted across the transmission path, add up to zero impedance. The answer (to check your working) is when $(X/R)^2 = (1 - n^2)/n^2$, which comes to much the same as with Fig. 10 (i.e., $|X| = R$) when $n \gg 1$.

The logical conclusion of all this is the theorem that *any* three or four terminal network of linear impedances can be reduced to an equivalent star or delta, and that its component values can be found by measuring any three of the four following: input impedance with output open and short-circuited; output impedance with input open and short-circuited. It is too late now to start on these aspects of the matter, but details can be found in the books on communication circuits.

[‡] If $1/(2\pi \times 1{,}000 \times C) = 15{,}000$, $C = 1/(2\pi \times 1{,}000 \times 15{,}000) = 1.06 \times 10^{-8}$F $= 0.0106\,\mu$F.

[§] Due to E. M Reid, *Electronic Engineering*, Oct. 1954, p. 445.

Radio Officers' Examinations

A CHANGE in the procedure and standards in the examinations for the P.M.G.'s certificate of competence in radio-telegraphy (1st and 2nd Class) is being introduced for the next exam which will be held in December. In the past, examiners have toured the country holding examinations at all the wireless schools in turn. Under the new arrangement exams will be held three times a year—March, July and December—simultaneously at all schools where suitable equipment, approved by the P.M.G., is installed. A list of these schools is given below.

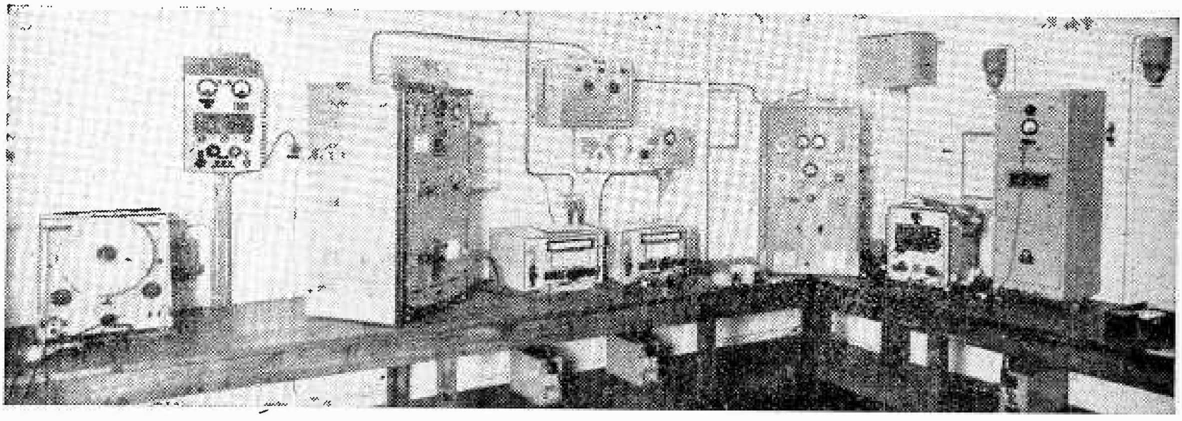
Under the new scheme the examinations for the P.M.G.'s certificate, which has to be obtained by all radio officers serving in British merchant ships, will be more comprehensive and the standard in general has been raised.

The syllabus of instruction for both the first and second class certificates is set out in two parts: the first, headed "technical electricity," and the second "radio communication."

The examinations for both certificates will be conducted in two parts: the first, theoretical; and the second, practical and manipulative.

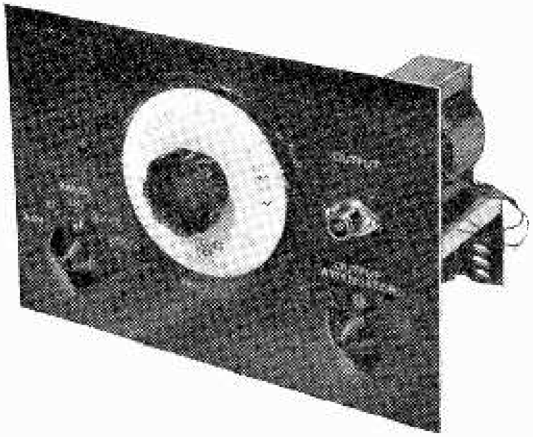
The revised details for the examinations are being incorporated in the "Handbook for Wireless Operators" issued by the Postmaster General (H.M.S.O. 3s). Further information on the syllabuses is obtainable from the principals of the colleges listed below.

ABERDEEN
Marine Radio College, 56 Union Street
BELFAST
Marine Radio College, 2 Eglantine Avenue, Lisburn Road
BRIDLINGTON
North Eastern School of Wireless Telegraphy, Radio House, Shaftesbury Road
CARDIFF
College of Technology and Commerce, Cathays Park
COLWYN BAY
Wireless College, East Parade
GLASGOW
Glasgow Wireless College, 26 Newton Place, C.3
GREENOCK
Watt Memorial School, Dalrymple Street
GRIMSBY
Grimsby College of Further Education, Nautical Department, Orwell Street
HULL
College of Technology, Park Street
LEITH
Leith Nautical College, Edinburgh, 6
LIVERPOOL
Riversdale Technical College, Riversdale Road
LONDON
British School of Telegraphy, 179 Clapham Road, S.W.9
London Telegraph Training College, 20 Penywern Road, S.W.5
Norwood Technical College, Knight's Hill, S.E.27
MANCHESTER
Wireless Telegraph College, 25 John Dalton Street
College of International Marine Radiotelegraphic Communication, Overseas House, Brook's Bar
PLYMOUTH
Plymouth and Devonport Technical College, Tavistock Road
PRESTON
Northern Counties Wireless School, 91 Lancaster Road
SOUTHAMPTON
The University, Dept. of Electronics, Telecomms. and Radio
The School of Marine Radio and Radar, Hamble
SOUTH SHIELDS
South Shields Marine and Technical College, Ocean Road



Typical marine radio equipment installed in the new examination room at G. P. O. headquarters. Radio officers employed at sea wishing to obtain a higher grade of certificate than that already held will be examined here. On the bench are, left to right, Marconi direction finder; Siemens emergency transmitter, receiver and automatic keying device; Marconi "Mercury" receiver; "Electra" receiver; Marconi transmitter; I. M. R. "Solas" life-boat equipment; and Marconi automatic alarm.

Wide-Range Audio Oscillator



Simple Design Covering a Frequency Range of 3 c/s to 300 kc/s

By R. WILLIAMSON

ON a number of occasions recently the writer has been unhappily reminded of the inadequacies of his present audio oscillator (vintage 1950). A few years ago a range from 25 c/s to 25 kc/s was considered quite adequate for the vast majority of audio testing applications. Nowadays, frequencies used in audio equipment and for the testing of such equipment may extend over a very wide range. Magnetic bias frequences are often as high as 120–150 kc/s and many wide-band low-frequency amplifiers have a measurable response from perhaps a couple of cycles to over 200 kc/s.

For these reasons it was decided to construct a new oscillator fully capable of use in testing all audio equipment of contemporary design. The functions desirable in the new design were carefully considered and are as follows:—

(*a*) The range should be from 3 c/s to 300 kc/s in five decade steps with overlap between ranges.

(*b*) Output to be pure sinusoidal with total harmonic content no greater than 1%.

(*c*) Amplitude linearity should be no worse than ± 0.5 dB over the entire range and no preset controls should be necessary.

(*d*) Finally, the unit should be fully self-contained, portable and on economic grounds of simple circuitry using standard components.

In the prototype model the above specification was satisfied completely, and in some instances improved upon. The unit is small, compact and of simple design. The total harmonic distortion on range 3, measured at 2 kc/s was considerably less than 1%. Linearity was ± 0.25 dB from 330 kc/s to 15 c/s and 0.75 dB down at 3 c/s. In fact, it proved possible to calibrate the output control directly in volts, thus obviating the necessity for a metered output stage. The maximum output voltage was 25 volts R.M.S. and the frequency drift checked after continuous operation for 3 hours was negligible.

Maintained Accuracy

It was decided to use the Wein bridge type of oscillator. For optimum performance in accuracy and frequency stability the variable element should be a ganged capacitor. But, unfortunately, to cover the specified range would mean either an abnormally low bridge input impedance on the highest ranges or unwieldly values of resistance on the lowest ranges. In one model constructed a carbon track type of ganged potentiometer was employed, and it is still accurate to the original calibration after three months' use, with the additional advantage of 300° scale coverage. However, if the constructor considers the extra expenditure worth while a wire-wound ganged potentiometer gives frequency stability comparable with variable capacitors.

LIST OF MAIN COMPONENTS WITH VALUES

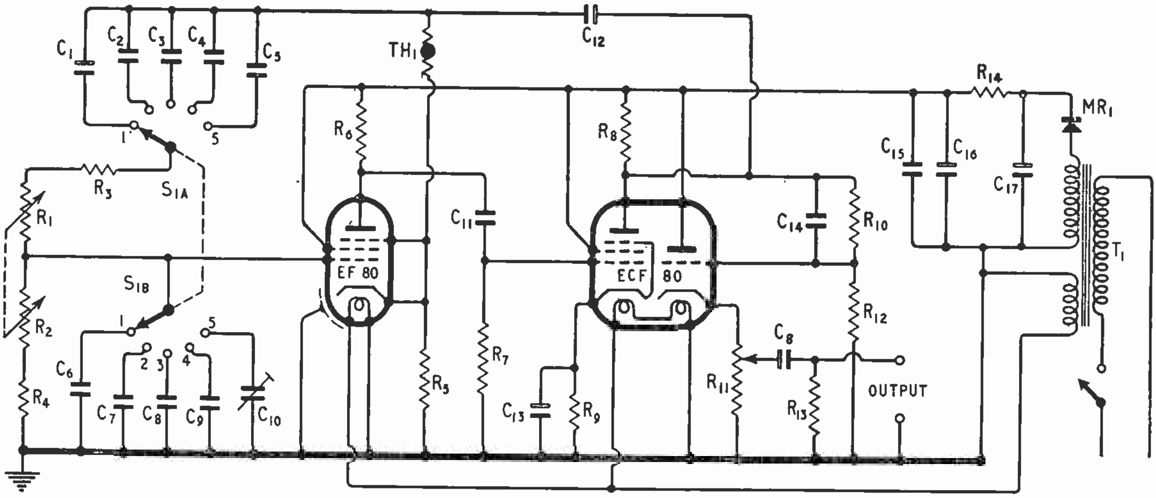
Capacitors

C_1	0.47 μF	Tolerances—see text
C_2	0.047 μF	
C_3	0.0047 μF	
C_4	470 pF	
C_5	47 pF	
C_6	0.47 μF	
C_7	0.047 μF	
C_8	0.0047 μF	
C_9	470 pF	
C_{10}	50 pF compression trimmer	
C_{11}	0.25 μF, 250V	
C_{12}	32 μF, 250V	
C_{13}	100 μF, 6V	
C_{14}	0.25 μF, 250V	
C_{15}	0.25 μF, 250V	
C_{16}	60 μF	350V
C_{17}	60 μF	
C_{18}	50 μF, 50V	

Resistors

R_1 R_2	100 kΩ + 100 kΩ*
R_3	10 kΩ, 2%
R_4	10 kΩ, 2%
R_5	4.7 kΩ
R_6	100 kΩ, ½W
R_7	560 kΩ
R_8	15 kΩ, 1W
R_9	330 Ω, ½W
R_{10}	100 kΩ
R_{11}	10 kΩ, wire-wound
R_{12}	560 kΩ
R_{13}	22 kΩ
R_{14}	2 kΩ, wire-wound, 3W
TH_1	S.T.C. Thermistor A2552/100
T_1	250 V, 30 mA; 6.3V, 1 amp.
MR_1	250 V, 50 mA. contact-cooled type.
$S_{1A,\ B}$	5-way, 2-pole Yaxley.

*Ganged; log law (Reliance Mfg. Co.).



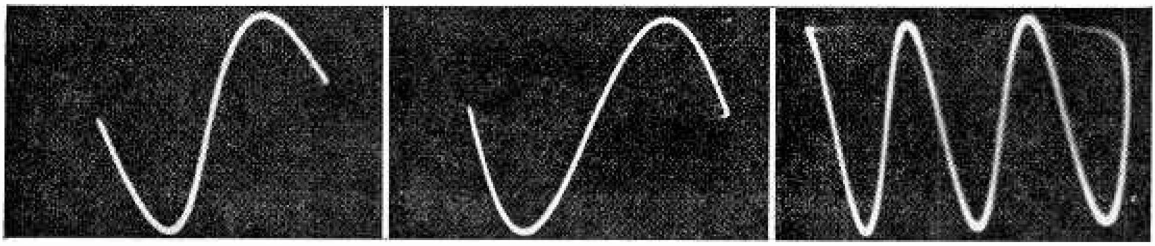
Circuit diagram of the oscillator. Frequency ranges are: 1, 3 c/s—33 c/s; 2, 30 c/s—330 c/s; 3, 300 c/s—3.3 kc/s; 4, 3 kc/s—33 kc/s; 5, 33 kc/s—330 kc/s.

The operation of this type of RC oscillator is adequately dealt with in detail in the majority of text books, but a brief recapitulation would not be out of place. The circuit elements to determine the frequency of oscillation are in the form of a potential divider, the upper arm consisting of capacitance and resistance in series and in the lower arm identical values of resistance and capacitance in parallel. At a certain frequency attenuation is at a minimum of 9.54 dB and if the potential divider is connected in the regenerative loop of an amplifier stage with a gain slightly higher than this, oscillation will take place. Provided overloading of the amplifier does not occur, the harmonic content of the generated waveform can be of a very low order. To satisfy the stringent requirements of the amplifier stage, i.e., wide bandwidth, low distortion and minimum phase shift, a high degree of negative feedback is employed, the feedback attenuator completing the familiar Wein bridge. To compensate for minor tracking errors and maintain oscillation it is usual practice to include a non-linear element in the degenerative loop, and in this design an S.T.C. Type A thermistor is used. The oscillator has a buffer output stage in the form of a cathode follower and is partially d.c. coupled to maintain the amplitude of the lowest range. With this method of output control used the source impedance varies somewhat from about 400Ω at maximum to 2500Ω at the half-way setting In practice this is no serious disadvantage since there is no question of matching to the load, usually considerably higher.

Wiring should be rigid and as short as possible to keep stray capacitance to a minimum. Earth wiring should be *via* a common heavy gauge copper wire to one point on the chassis only. The accuracy of the generator will depend on the tolerance of the capacitors in the bridge, which should be as close as practicable. Of the high values in particular, padding may be necessary to bring the capacitors to within at most 2% of the specified value.

Calibration

Although calibration can be carried out by other means it is strongly recommended that an oscilloscope be used. By injecting the reference signal to the horizontal input and the generated signal into the vertical input, calibration by Lissajous figures on the fundamental and multiples of the reference signal is easily effected. At the same time a constant visual check can be maintained on the generated waveform for distortion. The reference signal should, of course, be of known accuracy; e.g., a pre-transmission B.B.C. tone, in which case calibration should be initially made on Range 3. Providing close-tolerance capacitors have been used, calibration on other ranges other than Range 5 should be accurate and in multiples of ten. On Range 5 the scale should be set to 200 kc/s and a radio receiver in close proximity tuned to the Droitwich Light Programmes transmission. C10 should then be adjusted until a zero beat note is heard. Similar checks can be made at other frequencies on the radio scale.



Oscillograms showing oscillator output at 3 c/s, 2 kc/s and 200 kc/s.

High-Temperature Components

New Materials and Methods to Meet Service Demands

By G. W. A. DUMMER, M.B.E., M.I.E.E.

IN 1939, Service components were tested to W.T. Board Specification K.110, in which the dry heat test was exposure of the components for six hours at 70°C. The 70° figure was made up by allowing 15° temperature rise in the equipment above the highest ambient temperature then measured, i.e., 55°C. Certain components, notably selenium rectifiers, could not be operated at temperature in excess of this in any case. With the increase in complexity of equipments and in the number of components used, it became obvious that this 15° rise was insufficient and therefore a new rating of 85°C was introduced, i.e., 55° ambient + 30° rise. The introduction of sealing and miniaturization techniques showed a need for a range of components rated at 100°C and in 1945 Specification RCS.11 required three categories of temperatures −40°C to +70°C, −40°C to +85°C and −40°C to +100°C. Recently a −40°C to +125°C category has been introduced and it is interesting to compare the increase in Service category temperature of components over the years—see Fig. 1.

In recent years considerable advances have been made in miniaturizing components. The use of these extremely small components in sealed assemblies aggravates the cooling problem, since there are smaller surface areas available to transfer waste heat to the surroundings. Various methods of cooling miniature equipments have been adopted, notably on airborne boxes, e.g., forced convection cooling; but it is obvious that if components were available which could operate at the maximum temperature ambients of valves, etc. in a confined space without cooling arrangements, considerable gains would be made.

In airborne radar equipments the following constructions are in use:—

Open Construction (Fig. 2). In this construction, heat losses occur mainly by natural convection and some radiation. The arrangement consists of a well-ventilated box with possibly an internal blower for a particular heat-producing component, for example, a magnetron or a large transmitter valve.

Pressurized Construction (Fig. 3). Heat losses in this construction are by radiation and convection; an internal fan is used to reduce excessive hot spots and an external fan, arranged to blow over the external surface, transfers heat to local air. It is possible to use ram air in place of the external fan in some cases, but either system becomes inefficient at altitudes over 30,000 feet because of the low density of the air available.

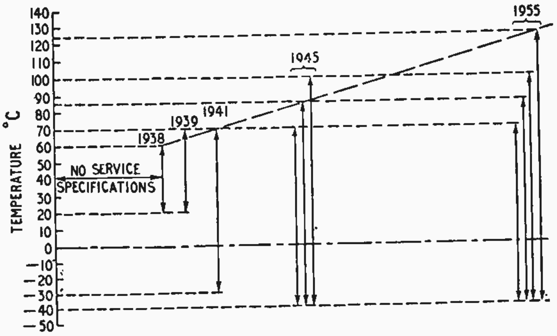
Pressurized Construction with Annular Heat Exchanger (Fig. 4). In this construction, heat losses are by radiation and forced convection. The annular space between the internal cover and outer shell is fitted with cooling fins or wires over which several pounds of cooling air can pass per minute. The source of mass flow can be air from the cabin spill-over, a ram scoop or, in some cases, a specially designed high-altitude blower.

The latter two methods are thermally inefficient because of poor heat transfer from the components to the pressurized container and it is neceessary to expend much horse-power in cold air units or blowers to cool equipment dissipating a few hundred watts at high altitudes.

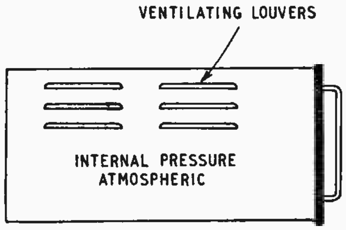
Aerodynamic Heating Effects. In low-speed flight, equipment cooling has generally depended on the losses due to natural convection and radiation, the heat being conveyed to the aircraft structure and thence to the outside air. Where forced convection cooling is used, outside air is collected and forced through ducts to the equipment or equipment bay, where it takes up heat, and is expelled as hot air farther down the aircraft. At high speeds, the temperature of the "cooling" air may be higher than the ambient temperature of the equipment itself.

Similarly, the aircraft skin temperature rises with speed until heat flows into equipment instead of away from it and even components which do not generate heat are heated above their maximum tolerable temperature. The rise in temperature in the Fairey D.2 aircraft was recently given in a television broadcast as 100°C. The main problem of cooling large electronic equipments in high-speed aircraft lies not so much in its practicability as in the formidable weight penalties involved in the provision of cooling apparatus.

Other Design Requirements.—With the continuing trend towards extreme miniaturization such as



Above: Fig. 1. Increase in range of temperature specified for tests of Service equipment since 1938.



Right: Fig. 2. Conventional cabinet with ventilation at atmospheric pressure (low at high altitudes).

Army pack transmitter/receivers, computors, etc., there is little doubt that as components are made smaller, heat dissipation problems become increasingly difficult. The development of high temperature components is, therefore, useful in all fields of electronic equipments.

Component Developments

In general, the development of components for use at high ambient temperatures precludes the use of organic materials such as paper and many of the plastics, and requires the use of inorganic materials such as glass or ceramics. Certain plastics, such as polytetrafluorethylene (p.t.f.e.) and materials such as silicones can be used with advantage.

The following is a general review of recent developments in laboratories in the United Kingdom and the United States of America and will be of interest to the electronics industry in this country.

N.B.—In all cases, temperatures on the surface of components are referred to.

Fixed Resistors[1].—British laboratories have worked on metal film resistors for some years and the platinum-gold types are now becoming commercially available. The platinum-gold fixed resistor is fired on a glass base at a temperature of the order of 600°C. The limiting factor is not in the film but in the solder which is used to attach the end connections. Temperatures of 180°C to 200°C have been reached with good stability and reasonably long life, but pressure connections in place of solder connections might enable 300°C to be reached. Metal oxide film resistors have also been developed, which are formed by spraying tin-antimony chlorides on glass rods at a high temperature. Upon impinging on the glass, these chlorides become oxides on the surface, forming a very hard adherent resistive film. It has been found experimentally that tin-antimony oxide powders mixed with alumina, pressed in the normal powder resistor manufacturing techniques and then fired at temperatures of the order of 900°C, can produce Grade 2 resistors which can be operated up to at least 400°C with pressed end connections. The temperature coefficient is, however, rather high and work is being done on other diluting materials with the aim of improving this characteristic. Existing types of pyrolytic or cracked carbon resistors, when de-rated, can operate at 120°C for long periods with good stability and at even higher temperatures for short periods. The normal carbon composition resistor is limited to about 115°C and no power can be dissipated at this temperature. Vitreous wire-wound resistors, when de-rated, can operate at 320°C or, in some cases, 450°C, depending upon the conditions.

It would seem, therefore, that already we have available a wide range of resistors, although some are in the experimental stage, capable of operating in the 150°C region with reasonable reliability and stability.

Variable Resistors.—Wire-wound resistors on ceramic formers and of all-metal construction are available, which can operate in excess of 150°C, but carbon composition resistors are unable to exceed 115°C. Some work is being done on the use of silicone mixes with carbon blacks to increase the operating temperature of the track, and it is hoped to produce a track operating up to 200°C. Recently developed metal film (platinum-gold) variable resistors may operate up to 200°C.

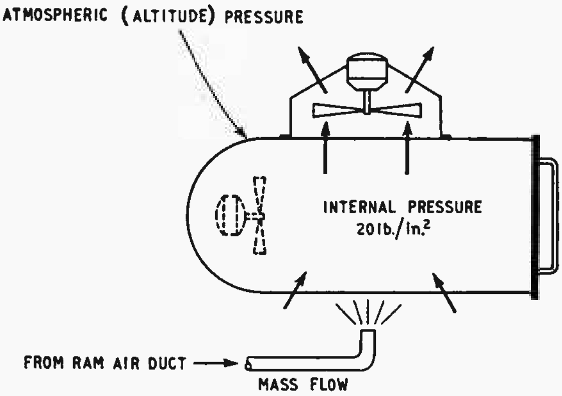


Fig. 3. Pressurized construction with external forced convection cooling by ram air or fan.

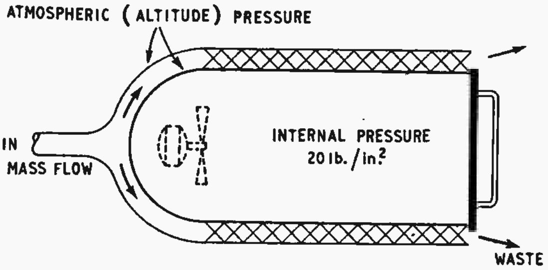


Fig. 4. Pressurized construction with annular heat exchanger.

Fixed Capacitors.—P.T.F.E. dielectric capacitors in America have operated for 20,000 hours at 200°C, but they are expensive and it has been found difficult to produce thin films of the material for winding. Glass dielectric capacitors, also available in America, are capable of operating continuously at 200°C. Similar work is being done by several British firms.

Mica as a dielectric can withstand temperatures up to about 400°C before dehydration occurs, but mica capacitors are limited by the sealing material. Silvered mica capacitors in "Mycalex" cases will operate at about 130°C. Vitreous glaze capacitors should operate satisfactorily at 150°C in sizes comparable to the mica capacitors.

High-permittivity ceramic dielectric capacitors are not, in general, capable of being operated over 100°C because of a degradation effect known as "creep", which becomes apparent as a change in capacitance with temperature; the mechanism of the change is not fully understood but is being studied.

Some low-permittivity ceramic capacitors can operate at temperatures up to 125°C. Polyethylene terephthalate, known as "Melinex," is capable of operating up to 130°C, but is temperature and frequency sensitive. Paper dielectric capacitors can be operated up to 100°C without too great a deterioration in insulation resistance, and metallized paper capacitors up to 125°C. The recently introduced tantalum pellet electrolytic capacitors can operate at 150°C for long periods without deterioration, but

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[1] See "Radio and Electronic Components, Vol. 1—Fixed Resistors," published by Sir Isaac Pitman & Sons.

TABLE

Type of Component	Approximate Maximum Operating Temperature
Gold-platinum film fixed resistors (de-rated)	200°C
Oxide film fixed resistors (de-rated)	200/400°C
Oxide powder fixed resistors (de-rated)	400°C
Cracked carbon fixed resistors (de-rated)	150°C
Carbon composition fixed resistors (dissipating no power)	115°C
Vitreous wire-wound fixed resistors (de-rated)	320°C
Wire-wound variable resistors on ceramic formers (de-rated)	150/200°C
Carbon composition variable resistors (dissipating no power)	115°C
P.T.F.E. dielectric capacitors	200°C
Glass dielectric capacitors	200°C
High-K ceramic dielectric capacitors	100/125°C
Low-K ceramic dielectric capacitors	125°C
Vitreous enamel dielectric capacitors	150°C
" Melinex " dielectric capacitors	130°C
Paper dielectric capacitors	100°C
Metallized paper capacitors (some)	125°C
Transformers and chokes (using silicone oil, etc.)	250°C (Normal types about 110°C)
Relays (ceramic and glass insulation, etc.)	150°C
Switches (ceramic base)	150°C
Plugs and sockets (ceramic)	300°C
Plugs and sockets, silicone (experimental)	200°C
Sleeving (silicone)	200°C
Cables (some)	250°C
Silicon rectifiers	180°C
Spindle seals	150°C

tantalum foil capacitors are limited to about 85°C.

Transformers and Chokes.—It is possible to operate transformers up to 250°C by the use of silicone-impregnated glass-covered wire with silicone-impregnated glass cloth interleaving, bobbins, etc., with normal grain-oriented silicon steel cores. Anodized aluminium wire is also being used experimentally. In America, fluoro-compound liquids with glass silicone wicks to convey the liquid to the hot spots, which act as vapour phase heat exchangers, are being used, there being a mixture of gases in the void space to give optimum heat transfer. Heat "sinks" consisting of copper plates are part of the design. In America, also, ceramic-covered wire with an external covering of p.t.f.e. is available which can operate at temperatures of up to 250°C.

Experimental transformers for operation at temperatures up to 500°C are being made in Britain by the use in their construction of such substances as asbestos, mica, glass and silica and by the use of core materials with high Curie points, of the order of 700°C. Tungsten or molybdenum wires may have to be used for conductors.

Relays.—Relays are available in the United States which operate at temperatures of 200°C, using ceramic and glass insulation and metal covers.

Switches.—Ceramic base switches are available which can operate to 150°C, but considerable work is being done on the development of switches for temperatures in excess of this.

Plugs and Sockets.—General purpose multi-way plugs and sockets with phenolic insulation are generally limited to approximately 85°C, but recent developments of loaded silicone insulating materials have led to new ranges being developed which can operate up to 200-250°C. In the United States of America, glass-sealed types of plugs and sockets are being used for operation at 200°C. Ceramic or sintered alumina plugs and sockets are available operating up to 300°C.

Cables and Sleeving.—Cables made with glass braid impregnated with silicone varnish and with p.t.f.e. insulation can operate at 200°C; non-flexible cables with ceramic insulation and copper external sleeving can run continuously at 250°C and, for short periods, up to 1000°C. Silicone sleeving can be used up to 200°C, but abrasion resistance is not yet too good.

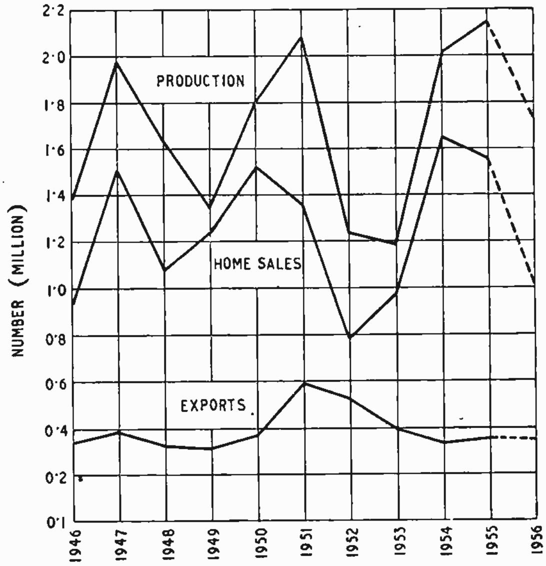
Power Rectifiers.—The recently introduced silicon rectifiers can operate at temperatures up to 180°C, have a much higher efficiency than the selenium or copper oxide types and are considerably smaller. Titanium dioxide rectifiers can operate for long periods at 100-150°C, but they are larger than selenium or copper oxide rectifiers and are moisture sensitive. Tellurium rectifiers have operated at much higher temperatures but are still experimental.

Spindle Seals.—A new type of spindle seal which has recently been developed, using spring-loaded p.t.f.e. bushes, is capable of operating in excess of 150°C for 20,000 operations. It can be used for high-temperature potentiometers, rotary switches, etc.

The accompanying table summarizes the surface temperatures of the above components. It should be pointed out that the figures relate to reasonably long life, but many components will work at much higher temperatures if a shorter life is accepted.

It thus appears that considerable progress is being made in the development of high temperature components, but valves must also be considered. Most valves will work at temperatures between 160°C and 200°C, although life may be reduced; some can operate up to 240°C. Valves are the main source of heat production in electronic equipments and it may be that in the future valves which will work at even higher temperatures may be required.

Acknowledgements.—The author is indebted to L. A. Williamson, S. C. Schuler, J. H. Bruce, D. E. H. Jones, C. H. Miller and C. H. Taylor for their co-operation in the preparation of this article.



PRODUCTION and home and export sales curves of sound receivers—including radiograms and car radio sets—plotted from figures issued by the Radio Industry Council at the Radio Show. The 1956 figures are calculated from the totals for the first six months of the year.

IMPORTING AN INSTRUMENT

A Guide Through the Official Maze

By A. J. REYNOLDS*

OVER the past twelve months or so the inflow of measuring instruments from abroad, and in particular from the U.S.A., has increased from a very slow drip to a thin trickle.

By virtue of their unfamiliar appearance and because of their temporary novelty value these instruments are shown to all visitors to laboratories owning them, the effect thus resembling that of the stage army—an impression of numbers out of proportion to reality.

Questions regularly put to the writer suggest that there is a great deal of ignorance concerning the legislation, practice and even ethics of importing these instruments, so perhaps an attempt at clarification might not be out of place.

To the telecommunications industry, instruments are the tools of trade. We are fortunate in this country in possessing a vigorous instrument industry which can fulfil most of our needs and at the same time make a useful contribution to exports. Only two other countries in the world are in anything like the same position—America and Germany. Even Russia, as far as can be judged, relies to a considerable extent on imported instruments.

Viewed as part of the general picture of the radio and allied industries, the turnover of the whole of the instrument industry is but a few per cent of the total turnover. That few per cent, however, has a virtually incalculable effect on the performance and abilities of the industry as a whole, the finished product being only as good as the tools with which it was made.

Just as incalculable but equally important is the effect on price of inefficient or time-consuming methods brought about by inadequate tools.

Divergent Industries

The enormous anti-import ditch dug between the U.S.A. and ourselves just after the war was most successful in preventing apparatus crossing the Atlantic and even more undesirably prevented American technical journals from being seen by all but a favoured few. It is not surprising, then, that, kept forcibly apart from each other, two rapidly expanding industries should progress along slightly divergent paths.

Different techniques were evolving in the U.S.A., some superior, some inferior, to our own solutions to the same problems. These techniques gave rise to their own individual instrument requirements and produced many instruments of types not even attempted by our own manufacturers. The converse also applies, but instances are fewer.

An excellent example of this is in the range of instruments manufactured by the Kay Electric Company in America. Here is a whole catalogue of thirty-odd instruments, hardly one of which has a British counterpart.

The range consists for the most part of sweep generators and noise generators. Sweep generators are available giving a sweep of ±30 Mc/s with a centre frequency continuously variable from 50 Mc/s to 1,000 Mc/s. There is a video sweep generator having ranges of 0-5 Mc/s, 0-10 Mc/s and 0-20 Mc/s with several crystal markers. Noise generators are available at all common impedances and covering the frequency spectrum from the low radio frequencies well into the microwave region.

Importance of Markets

In some cases component development plus the larger market has bred an instrument better than anything here by several orders. The availability of a valve that will work in a counter decade at 10 Mc/s with complete reliability has enabled Hewlett Packard to offer a frequency measuring counter which, with accessories, covers the fantastic frequency range of 0.006 c/s to 12,000 Mc/s with an accuracy of 1 part in 10,000,000.

The importance of the large domestic market in the U.S.A. is perhaps not realized sufficiently. To develop, engineer and manufacture an instrument such as the above counter is an enormously expensive business and the final instrument can only be sold at an economic price if the development and tooling charges can be spread over a very large number of instruments.

There is a factor in the order of tens between the potential annual demand for a given instrument in Britain and the U.S.A. In spite of this handicap there is a sprinkling of British instruments that have no peer in the States. To quote the one example that will not be invidious, there is no American multi-range meter with the performance and versatility of the Avometer.

There are, then, occasions when the only sane engineering answer to a particular problem involves importing an instrument. What is the procedure and how does one obtain the dollars?

Obtaining a Licence

The first step is to obtain a Board of Trade licence to import the item in question. This is achieved by filling in the inevitable form, which asks in effect: "What do you want? Why do you need it? Why won't the local product do?" The Board of Trade call on the Ministry of Supply for assistance in making their adjudication. In the case of instruments, at least, this involves the production officer responsible for the Ministry purchases of that type of equipment. These officers are engineers in their own right, with the result that, with very few exceptions, a good case is rewarded with a licence and any attempt at "pulling a fast one" reaps the raspberry it richly deserves.

Having got your licence you now have a title to the necessary dollars. Before sending off your pur-

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* Livingston Laboratories.

chase order to the manufacturer, however, you must apply to the Board of Trade again, this time for a document known as an import certificate, which must accompany your order to allow the manufacturer to obtain an export licence.

The vast majority of instruments as we know them are liable to a customs duty of 33⅓% on arrival, being subject to the Safeguarding of Industries Act, 1921, this duty being popularly known as "key industries duty." The Act was passed just after the first world war to protect the then infant British optical and chemical industries against German competition. It has been amended from time to time, one of the most important occasions being in the Finance Act introduced in 1936, when provision was made for the duty to be waived in certain exceptional cases.

Duty-free Import

Before the goods are imported a Treasury licence may be applied for. This document, if issued, enables goods subject to "key industries duty" to be imported duty free. The conditions required for duty-free import are very similar to those required for the original import licence. The adjudication is made on a basis of use, and available British alternatives.

Here, where the Government is concerned with money destined for its own pocket, the going becomes much tougher.

A lot turns on the question of what constitutes a "similar" instrument—and at times we appear to have the Gilbertian situation where the arbiter is the competing British manufacturer! By the time the argument has subsided the instrument has arrived and it is only necessary to wheedle it out of the customs. It may be costing £800 and be covered by a duty-free licence but do not be surprised to be charged 1s 9d duty on the mains lead if that was not listed separately on the licence.

If you see an instrument in *Electronics* that would halve your testing time or do a particular job three times as accurately in half the time, don't despair of getting it. There are only thirty-seven separate steps of paper work between needing it and having it on your bench.

The comparatively few instruments that have come in during the past couple of years have had a beneficial effect on the industry at large, out of all proportion to their cost. They have speeded development, cut production costs and acted as a gentle spur to many instrument manufacturers. The cost per year in dollars? Just about one token import of Californian dried fruit.

CLUB NEWS

Chelmsford.—"70-cm techniques" is the title of the lecture to be given by F. Turner at the meeting of the Chelmsford Group of the British Amateur Television Club on October 11th, at 7.30 at 10 Baddow Place Avenue, Great Baddow, near Chelmsford. Sec.: D. W. Wheele (G3AKJ), 56 Burlington Gardens, Chadwell Heath, Essex.

Crystal Palace.—At the meeting of the Crystal Palace and District Radio Club on October 20th, G. A. Bird (G4ZU) will speak on the design and construction of a three-band "minibeam" aerial. Meetings are held at 7.30 at Windermere House, Westow Street, London, S.E.19. Sec.: A. J. Worrall, 169, Kent House Road, Beckenham, Kent.

Plymouth.—Meetings of the Plymouth Radio Club are held on alternate Tuesdays at 7.30 at the Virginia House Settlement, Barbican. The next meeting is on October 2nd. Regular morse classes are held and occasional lectures given. Sec.: C. Teale (G3JYB), 3 Berrow Park Road, Peverell, Plymouth, Devon.

Sidcup.—The September meeting of the Cray Valley Radio Club will be held at the Station Hotel, Sidcup on September 25th at 8.0. R. G. Shears (G8KW) will speak on v.h.f. mobile radio communication. Sec.: S. W. Coursey (G3JJC), 49 Dulverton Road, New Eltham, London, S.E.9.

Warrington.—It is proposed to include in the winter programme of the Warrington and District Amateur Radio Society a series of lectures on radio theory up to the standard for the Radio Amateur Examination. Meetings are held on the first and third Thursdays of each month at 7.30 at the Royal Oak Hotel, Bridge Street. Sec.: R. Dyke, 22 Stetchworth Road, Walton, Warrington, Lancs.

OVERSEAS SALES

THE value of exports for the whole of the radio industry for the first six months of this year was nearly £19.6M which, if continued for the rest of the year, will mean a record figure of nearly £40M. As will be seen from the figures below giving the exports for the various sections of the industry since 1950, the largest percentage *increase* during the past seven years has been in the value of sound reproduction equipment. But by far the largest contribution to the industry's export figures continues to be made by the manufacturers of capital goods—communications equipment, transmitters, navigational aids, industrial equipment, etc. It is estimated by the Radio Industry Council that indirect exports of capital goods (e.g., fitted in ships and aircraft) represent a further 25% increase on the figures given for this type of equipment. It is worth recording that the number of car radio sets exported during the first six months of this year was over 6,500—a 50% increase on the same period last year.

Class of Product	1950		1951		1952		1953		1954		1955		1956 §	
	£M	%	£M	%	£M	%	£M	%	£M	%	£M	%	£M	%
Domestic Receivers	2.740	15	4.793	21	4.636	19	3.945	15	3.628	12	3.968	12	3.919	10
Sound Reproduction Equipment	1.133	6	1.711	8	2.123	8	3.056	12	3.760	13	5.728	17	7.262	19
Components†	4.607	25	6.014	26	5.931	24	5.386	20	6.543	22	7.484	22	8.294	21
Communications & Industrial Equipment	7.089	39	6.440	28	8.630	34	11.655	44	13.182	44	13.628	41	16.597	42
Valves & Cathode-Ray Tubes*	2.700	15	3.790	17	3.672	15	2.252	9	2.602	9	2.812	8	3.104	8
Total	18.269		22.748		24.992		26.294		29.715		33.620		39.176	

§ Estimate based on January-June figures.

† Kits of parts and some chassis are included under the components heading.

* All valves, whether loose or with apparatus, appear under the valve heading prior to 1953. Since January 1953 valves exported with apparatus are included under the apparatus heading.

OCTOBER MEETINGS

LONDON

4th. I.E.E.—Address by Sir Gordon Radley (president) at 5.30 at Savoy Place, W.C.2.

5th. Television Society.—"Impressions of commercial television" by Leslie Mitchell at 7.0 at 164 Shaftesbury Avenue, W.C.2.

17th. I.E.E.—"The electronic age" by Dr. R. C. G. Williams (chairman, Radio and Telecommunication Section) at 5.30 at Savoy Place, W.C.2.

19th. I.E.E.—Discussion on "Experiments for the electronics laboratory" opened by V. Attree at 6.0 at Savoy Place, W.C.2.

19th. B.S.R.A.—"A distortionless loudspeaker" by P. J. Walker at 7.15 at Royal Society of Arts, John Adam Street, W.C.2.

22nd. I.E.E.—"Use of transistors in radio and television" by Dr. A. J. Biggs and E. Wolfendale at 5.30 at Savoy Place, W.C.2.

23rd. I.E.E.—Discussion on "The use of electronic computers in nuclear reactor design studies" opened by R. W. Sutton at 5.30 at Savoy Place, W.C.2.

26th. R.S.G.B.—"More about the antenna match" by Frank Hicks-Arnold (G6MB) at 6.30 at the I.E.E., Savoy Place, W.C.2.

29th. I.E.E.—Five-day convention on ferrites opens at Savoy Place, W.C.2.

31st. Brit.I.R.E.—Address by George A. Marriott (president) at 7.15 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

31st. British Kinematograph Society.—"Colour television" by B. J. Edwards (Pye) at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

BIRMINGHAM

8th. I.E.E.—"Germanium and silicon power rectifiers" by T. H. Kinman, G. A. Carrick, R. G. Hibberd, and A. J. Blundell at 6.0 at Regent House.

29th. I.E.E.—"Stereosonic recording and reproduction" by H. A. M. Clark at 6.0 at James Watt Memorial Institute, Great Charles Street.

CAMBRIDGE

9th. I.E.E.—Address by J. G. Yates (chairman, Cambridge Radio and Telecommunication Group) at 6.0 at Cambridge Technical College.

23rd. I.E.E.—"Generation and synthesis of music by electrical means" by A. Douglas at 8.0 at the Cavendish Laboratory.

CARDIFF

31st. Brit. I.R.E.—"Applications of transistors to radio reception" by L. E. Jansson at 6.30 at Cardiff College of Technology, Cathays Park.

CHELTENHAM

5th. Brit. I.R.E.—"Television lighting effects" by A. E. Robertson at 7.0 at the North Gloucestershire Technical College.

GLASGOW

3rd. I.E.E.—Address by Prof. F. M. Bruce (chairman, S.W. Scotland Centre) at 7.0 at the Institution of Engineers and Shipbuilders, 37 Elmbank Crescent, C.2.

11th. Brit. I.R.E.—"The digital computer and its applications" by Dr. Barnett at 7.0 at the Institution of Engineers and Shipbuilders, 37 Elmbank Crescent, C.2.

25th. I.E.E.—"An introduction to computers" by P. A. V. Thomas at 7.0 at the Institution of Engineers and Shipbuilders, 37 Elmbank Crescent, C.2.

26th. Society of Instrument Technology.—"A flexible electronic recorder controller" by S. A. Bergen (Cambridge Instrument Co.) at 7.15 at the Building Centre, 425 Sauchiehall Street.

IPSWICH

8th. I.E.E.—Address by J. A. Sumner (chairman, East Anglian Sub-Centre) at 6.30 at the Crown and Anchor Hotel.

LOUGHBOROUGH

9th. I.E.E.—Address by Dr. H. L. Haslegrave (chairman, East Midland Centre) at 7.0 at Loughborough College.

MANCHESTER

4th. Brit. I.R.E.—"Education for electronics" by R. H. Garner at 6.30 in the Reynolds Hall, College of Technology, Sackville Street.

29th. Institution of Production Engineers.—"Computer-controlled machine tools" by D. T. N. Williamson (Ferranti) at 7.15 in the Reynolds Hall, College of Technology, Sackville Street.

NEWCASTLE-ON-TYNE

15th. I.E.E.—Address by A. E. Twycross (chairman, North-East Radio and Measurement Group) at 6.15 at King's College.

OXFORD

10th. I.E.E.—"A transatlantic telephone cable" by Dr. M. J. Kelly, Sir Gordon Radley, G. W. Gilman and R. J. Halsey at 7.0 at Southern Electricity Board, 37 George Street.

PORTSMOUTH

12th. B.S.R.A.—"A distortionless loudspeaker" by P. J. Walker at 7.30 in the Lecture Hall of the Central Library.

SHEFFIELD

17th. I.E.E.—Address by G. G. Nicholson (chairman, Sheffield Sub-centre) at 6.30 at the Grand Hotel.

TORQUAY

11th. B.S.R.A.—"Towards perfection: more news of the quest" by D. M. Chave (Lowther Manufacturing) at 7.45 at Callard's Café.

WOLVERHAMPTON

10th. Brit. I.R.E.—Lecture on colour television at 7.15 at the Wolverhampton and Staffordshire Technical College, Wulfruna Street.

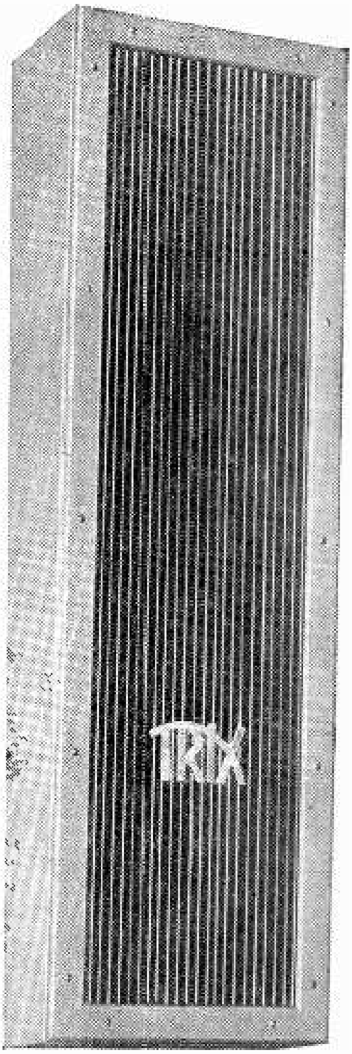
17th. Institution of Production Engineers.—"Electronic control in industry" by E. Heys at 7.30 at the Wolverhampton and Staffordshire Technical College, Wulfruna Street.

LATE-SEPTEMBER MEETINGS

LONDON

26th. Brit. I.R.E.—"Some aspects of transistor progress" by Dr. H. W. Loeb at 6.0 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

28th. Physical Society.—"Speech, music and hearing" by Dr. Winston E. Kock (Bell Telephone Labs.) at 5.30 in the Physics Department, Imperial College, Prince Consort Road, S.W.7.



RANDOM RADIATIONS

By "DIALLIST"

Faint, But Persuing

MY search for the v.h.f.-only, three-station, press-button receiver continues. I hear rumours that it is in course of production, or even that it has been produced by one or more manufacturers, but that's as far as it seems to get. I'm by no means alone in wanting such a receiver. Like innumerable folk who live on our east or south-east coasts, I find the medium-wave and long-wave bands completely useless owing to constant interference from foreign stations and a variety of devices which make for the greater safety of those who go down to the sea in ships. Therefore I see no point in paying for tuning circuits that will never be used, for a wave-change switch and so on. On Band II only three B.B.C. programmes, Home, Third and Light, are available. Hence there's no point in buying a receiver with continuous tuning throughout the band. A set pre-tuned to the three frequencies of the local transmitting station—and possibly provided with a trimmer for drift or for small changes in valve characteristics—would be ideal for the job and I'm sure there would be a good demand for it.

"Sound" Renaissance

INTEREST in v.h.f. broadcasting is steadily growing but the a.m. receiver with an added f.m. range won't in most cases do justice to the high quality of the transmitted signals. Those who get their first taste of v.h.f. broadcasting with such receivers can't possibly realize what splendid reproduction of music is obtainable from the service. People whose introduction to the new service comes by way of a good television console provided with a v.h.f. range may fare better, for many of these have audio departments designed to deal pretty well with a wider range of modulation frequencies. But there's one big improvement due to f.m. which users of both sound and television sets with the extra range are bound to observe: the completely quiet background. The spread of f.m. transmissions will, I believe, do a great deal towards restoring the popularity of sound broadcasting.

A New Menace?

THE ever go-ahead Bell Telephone Laboratories of America have, I observe, developed an up-to-date version of a device which enables those at each end of a line to see one another while they converse. It's certainly an ingenious contrivance, for, by working at the rate of one picture every two seconds, it has been found possible to transmit and receive over ordinary telephone lines. I see, of course, the attractions of this "picture-phone" affair; but it seems also to have rather awful possibilities unless you're provided with a switch enabling you to cut out at will the image transmitter at your end of the line. It would, for instance, no longer be seemly to answer calls clad only in a bath towel. Nor, again, could you wriggle out of an invitation on the grounds of being up to the eyes in work if a mid-morning caller could plainly see for himself that you had just tumbled out of bed. No, I think that the old-fashioned no-picture telephone will do well enough for me.

More Power to their Elbows!

BY the time that this is in print the Crystal Palace e.r.p. will have gone up to 120 kilowatts—and no doubt there will have been a heavy demand for attenuators in Sydenham and parts adjacent! Dwellers in erstwhile fringe areas will be getting the television reception for which they have been longing, or at any rate something like it, and those in the coastal parts of Kent will no longer be feeling quite so much left out in the cold. I have a fellow feeling for all those whose homes are in places where only a poor TV signal is available, since for more than a year now I've had to make do with a mingy 25 μV/m, which means a "snowy" picture and other inconveniences. However, it shouldn't be long now before the permanent station at Tacolneston, near Norwich, comes into action and then, one hopes, all will be well. This will have been a big year for television development. Before it comes to an end it will have seen the move from Alexandra Palace to Crystal Palace, the "hotting up" of the latter station, of North Hessary Tor, Rowridge and Tacolneston, besides the coming into action of the I.T.A. stations at Lichfield, Winter Hill and Emley Moor. Not a bad record!

Misleading?

IT seems to me rather a pity that the name ferroelectrics has been given to a range of materials which have, in fact, nothing ferrous in their make-up. They are actually mainly (if not exclusively) ceramics and none of those in present use contains any iron at all. The term ferroelectrics was adopted because the electrical polarization of these materials is in many ways similar to the magnetization of ferromagnetic substances. Ferroelectrics are likely to play an increasingly important role in electronic apparatus. I, for one, regret that any explanation to the uninitiated of what they are and what they do must begin with some sort of statement that "ferro-" doesn't mean what it says.

Names Again

WHY, I wonder, can't TV set makers come to an agreement to standardize the names of the "outside-the-cabinet" controls? It must often cause a good deal of puzzlement to the man in the street to find, when he buys a new set, that it appears to have controls quite different from those he had grown accustomed to in the old one. There's no line-hold, he finds, though there's a mystifying knob labelled line-speed, or perhaps horizontal-lock. Is frame-amplitude the same thing as height, he wonders; and can horizontal-form mean the same as line-linearity? I'm sure it would be worth everybody's while to adopt one set of names for the controls of all TV sets.

Moving-coil Microphone

DESIGNED specially for the requirements of magnetic tape recorders, whether of the domestic or office dictating type, the new "Lustrette" Model LD61, introduced by Lustraphone, Limited, Regent's Park Road, London, N.W.1, is of the moving coil type. It is available in a choice of impedances which satisfy the input conditions of all the principal makes of recorder, and is housed in a case which is inherently stable for desk use; there is provision for stand mounting if required.

"Lustrette" moving-coil microphone for tape recorders.

UNBIASED

By FREE GRID

Freud in the Bathroom

I AM surprised there are not more lightweight TV sets on the market fitted with a handle so that they can easily be carried from room to room. I don't mean the type which runs off mains or car battery because this is produced for a special purpose. The type I have in mind is the sort which is conventional in every way except in size and weight.

You may well ask why I or anybody else should want to lug a TV set from room to room. The answer is that I don't always want to be tied to the same room when I want to do some viewing. My ideal is to have an aerial connection in every room, including the bathroom, and I don't mind telling you that I have made a start at home by equipping the latter room with one.

Nothing delights me more than to relax in a steaming hot bath and watch television, although I must confess that so great is the power of suggestion that at first, whenever a lady announcer came on and gazed coldly at me in my bath, I used to go hot all over. I now invariably wear my bowler on these occasions. It adds a touch of sartorial formality which has an almost unbelievable psychological effect. No doubt Freud had a word for it.

Heretical Ideas

RECENTLY I took the opportunity to slip across to France to have a look at French 819-line television. I avoided Paris, as it is so full of other distractions which the Editor won't let me discuss here. I must confess that I was much impressed by the greater detail given and the absence of lininess. I know all the technical arguments against a larger number of lines but surely the need to transmit more information in a restricted bandwidth is a challenge to our engineers.

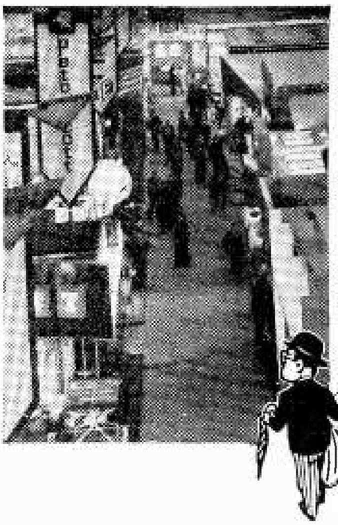
There would undoubtedly be a tremendous outcry if we all had to scrap our present TV sets, for it would be quite uneconomic to attempt to alter them. I cannot, however, see why the B.B.C. and I.T.A. second programmes, when they arrive, should not be radiated with a greater number of lines than 405. Those who wanted the second programmes would have to get a new set, but they couldn't grumble as the existing programmes would still be available on 405 lines. These could continue for some years until the owners of existing sets had received a fair run for their money.

Personally, I consider that a picture of greater detail would be preferable to colour. That brings me to yet another point. Why is so much effort being wasted in trying to produce a compatible colour system that is receivable in black and white on ordinary TV sets? Why cannot colour broadcasting—not necessarily by a compatible system—be confined for the first few years to the proposed two second programmes? Owners of existing sets would then have no grumble, as they would still be able to receive existing programmes and could change over to colour when they felt they could afford it.

As for the cost at the transmitting end, surely money could be saved on the programme side in a very simple manner. Don't have any second programmes, but let the B.B.C. and the I.T.A. radiate "second transmissions" of the same programme in higher lineage and subsequently in colour. Owners of existing sets would then have no leg to stand on as they could not complain that they were being cheated out of a second programme.

Radio Show Ramblings

WHY is it that the man in the street invariably wants to use the minimum in the way of an aerial? How often one heard enquirers at the Radio Show asking if this or that television set needed an outdoor aerial or whether an elaborate aerial was needed for "this 'ere v.h.f." I really wonder whether set manufacturers are to blame for this trend. Whilst they continue to produce sets with built-in or built-on aerials the wet-nosed viewer and listener are naturally going to expect a receiver to work with these, irrespective of the field strength available in their locality. I wonder if it was to set a good example that the I.T.A. adorned some of their receptionists with miniature arrays as head-gear?



At the B.B.C. enquiry bureau, where, incidentally, I noticed two well-known *Wireless World* contributors answering queries, the majority of the questions asked during the few minutes I was eavesdropping were concerned with v.h.f. That was to be expected in view of the excellent demonstration which the Corporation provided. It was certainly very convincing and I was glad to hear the demonstrator mention the need for a good aerial and refer listeners to the B.B.C. leaflet giving practical advice on v.h.f. aerials.

I was not very impressed by the "hi-fi" demonstrations at the Show. Perhaps it is that I have had a surfeit of these hyper-super-quality demonstrations. However, I was glad to find that in some of the demonstration rooms manufacturers had provided specialists to answer technical enquiries.

Apology Impending?

IN the September issue the Editor admitted to having had his knuckles rapped by the Post Office. His offence was that he had allowed to be published a description of a telephone answering machine with an implication that it satisfied P.O. rules and regulations. As everybody knows, each breath that we in radio draw is by permission of the Postmaster-General, and to offend him is a serious matter.

My sympathy went out to the Editor, but, now, in the light of something that has since happened, I doubt if there is any risk that publication of *Wireless World* will be suspended as a result of his indiscretion. In the latest number of the *Post Office Telecommunications Journal* there appears a summary of the offending *Wireless World* article, with no implication whatever that the device described fails to satisfy P.O. requirements. Indeed, the writer of the summary is at pains to quote the statement of the original author that the device, in "its respect for the sanctity of Post Office equipment, is virtually superhuman." Coming in a strictly official journal, that seems to me to amount to something very near official acceptance.