Wireless World

MAY 1955 VOL. 61 No. 5

Ineffective Regulation

ACCORDING to the summary given on p. 207 of this issue the G.P.O. has found that electric motors are now responsible for just about as much interference with broadcast reception as all other devices put together.

This being so, it is to be regretted that the Postmaster General's recently assumed powers to control interference from electric motors are unlikely to have the fullest possible effect in abating the trouble. The issue of the Regulation giving these powers, which comes into force on September 1st, was reported on p. 155 of our April issue. Briefly, all users of motors will be required to keep radiated and conducted interference within specified limits on the bands of frequencies used for television Band I and for medium- and long-wave sound broadcasting.

It must be admitted that, on the face of it, this new Regulation might be considered likely to have the desired effect. But its launching was followed by a Press statement (to which publicity was unfortunately given in the newspapers) which, we fear, will weaken the Regulation. "The new powers," said the statement, "will be used only where it is necessary for the Post Office to insist on an appliance being put right because it causes interference and the owner will not voluntarily have a suppressor fitted." That will be taken by the public to mean, "Don't go to the trouble and expense of fitting a suppressor to your motor-driven device until your neighbours complain to the Post Office."

Cloak of Security

IN drawing attention to the unsatisfactory system for controlling and administering radio matters in this country, we believe this journal is expressing opinions that are widely held among wireless people. It is encouraging to find our views are now given support by two members of Parliament. In the last issue there was a letter from Capt. L. P. S. Orr on the problems of frequency allocation and this month C. I. Orr-Ewing writes an "Open Letter to the Postmaster General," sketching in the framework for a new kind of communications commission which he proposes for regulating our affairs.

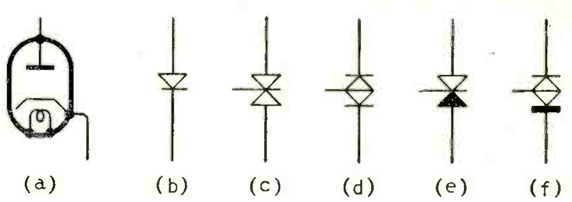
Both these legislators refer to the Defence Services in relation to frequency allocation. Possibly they feel as we do that the Services tend to get more than their necessary and proper share of the cake. Capt. Orr specifically refuses to accept the proposition that "security considerations" can automatically be accepted as a valid reason for making other than the most economical use of communication channels.

"Security" is a sadly abused word, and we would hazard a guess that its excessive use is responsible for many of the difficulties that arise in adjudicating between conflicting demands for channels between civil and military interests. Security-consciousness is infectious, too, and the word is used in relation to matters that in fact might be disclosed to anybody. Not long ago *Wireless World* was refused a list of the frequencies used for the v.h.f. section of the British Forces broadcasting network in Germany!

Transistor Symbols

IT is regretted that the diagram in the Editorial Comment of our April issue was incomplete; section (f) was cut off in making the printing block.

The full diagram is reproduced here. At (a) is shown the normal valve rectifier symbol and at (b) the conventional semi-conductor rectifier on which *Wireless World* suggests that transistor symbols may rationally and usefully be based. Diagrams (c) and (d) represent, respectively, the *p-n-p* and *n-p-n* transistor according to this system, and are similar to those



originally suggested by the Canadian Defence Research Establishment.

Finally, the modified symbols (e) and (f) for *p-n-p* and *n-p-n* junction transistors are suggested by *Wireless World* to simplify the reading of circuit diagrams by facilitating identification of the emitter element, which is thickened or blacked-in.

Twin-Channel Tape Records

H.M.V. Demonstrate "Stereosonic" System

IN addition to the single-channel high-quality tape records which were introduced by the Gramophone Company last year, twin-channel tape records are to be issued in the early autumn. Complementary recordings will be made simultaneously on parallel tracks at a speed of 7½in/sec on a ¼-in wide tape. Separate amplifiers and loudspeakers will be necessary to reproduce the two magnetic records and to establish a sound field in which it is possible to distinguish individual sources of sound when the originals were separated in space.

The system is termed "Stereosonic," which implies a difference from the conventional method of stereophonic recording and reproduction, in which omnidirectional pressure microphones are spaced some distance apart in the recording studio and more-or-less omni-directional loudspeakers are sited in similar relative positions in the auditorium. In the H.M.V. system the sound is analysed at a single point by a twin-ribbon microphone, the directional axes of which are fixed at right angles. Since there is no appreciable phase difference at the pick-up point, the outputs from the two channels differ primarily in amplitude and also in the ratio of direct to reverberant sound. The spacing of the twin reproducing loudspeakers is not important, but they should be arranged with their axes more or less at right-angles (60° to 90° is recommended). These conditions can be met in a living room of any size with the reproducers in adjacent corners.

Best results are obtained at the junction of the loudspeaker axes, where the "wall-eyed outlook" of the special microphone is exactly compensated by the "squint" of the loudspeakers, but the "Stereosonic" effect covers a much wider area, as was evident at the inaugural demonstration given at the Abbey Road studios of the Gramophone Company. Most effective items in a varied programme were excerpts from operas in which orchestras, soloists and chorus were well spaced. But it was noticeable also, that piano reproduction had a subtle "live" quality which is not often present in single channel reproduction. The demonstrations also supported the claim that, with this method of partitioning the sound field, directional effects are sustained at much lower frequencies than in the spaced pressure microphone technique.

A "Stereosonic" reproducer for use with these tape records will be available in the autumn and will consist of two cabinets, each with elliptical moving coil units for medium and low frequencies, and electrostatic "tweeters" for 6 kc/s and above. Ten-watt power amplifiers will be housed in each cabinet and one cabinet will carry the tape mechanism and two pre-amplifiers, while the other will be fitted with a three-speed automatic disc record changer. A three-position switch will give the choice of "Stereosonic" reproduction, or single-channel through one or both loudspeakers. In addition to volume, bass and treble tone controls there will also be a balance control to give a shift of the virtual sound image between the speakers and to compensate where necessary for the acoustic characteristics of the listening room.

BOOKS RECEIVED

Department of Scientific and Industrial Research. Report for the Year 1953-54. Includes a summary of the work of the Radio Research Organisation which has covered investigations into the phase changes in low-frequency waves at a coastline, propagation at h.f., v.h.f. and u.h.f., the nature and distribution of atmospheric noise, and the use of the noise spectra of semi-conductor junctions to provide information about the physical processes involved. Pp. 326. Price 9s. Her Majesty's Stationery Office.

Schaltungstheorie und Messtechnik des Dezimeter-und Zentimeter-wellengebietes, by Albert Weissfloch. Textbook of circuit theory and measurement technique in the decimetre and centimetre ranges. Pp. 308; Figs. 282. Price 33.50 Swiss francs. Verlag Birkhäuser, Basle, Switzerland.

Electric Transmission and Distribution. Edited by B. G. A. Skrotzki. Theory and practice of power supply and the equipment used in distribution systems; contributed by leading American professional engineers. Pp. 448; Figs. 292. Price 56s 6d. McGraw Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Electric System Operation. Edited by G. B. A. Skrotzki. Symposium on fault protective device, load control and dispatching, and power supply economics. Pp. 370; Figs. 277. Price 49s. McGraw Hill Publishing Co., Ltd., 95, Farringdon Street, London, E.C.4.

Single Sideband for the Radio Amateur. Digest of articles from *QST* covering design of transmitters and receivers. Pp. 208; Figs. 166. Published by the American Radio Relay League. Obtainable from The Modern Book Company, 19-23, Praed Street, London, W.2. Price 14s 6d by post.

Remote Control by Radio, by A. H. Briunsma. Description of an amplitude-modulation system with two independent channels, and an eight-channel pulse-modulation system, as used in the Philips radio-controlled model ships. The text includes complete circuit diagrams with component values. Pp. 97 + VIII; Figs. 74. Price 8s 6d. Cleaver Hume Press, Ltd., 31, Wrights Lane, London, W.8.

Television Principles and Practice, by F. J. Camm. Description in simple terms of the technical basis of television transmission and reception, including hints on choosing a receiver, a summary of the Beveridge report and a dictionary of television terms. Pp. 215; Figs. 144. Price 25s. George Newnes, Ltd., Southampton Street, London, W.C.2.

Licence Manual for Radio Operators, by J. Richard Johnson. Model answers to questions likely to be asked in the Federal Communications Commission examinations for American commercial radio operators. Appendices give source references for questions relating to law, common communications abbreviations (including the Q code) and a bibliography. Pp. 430; Figs. 140. Price $5.00. Rinehart & Company, 232, Madison Avenue, New York, 16.

Mobile Radio

P.M.G. Accepts Plan for Clearing Band III

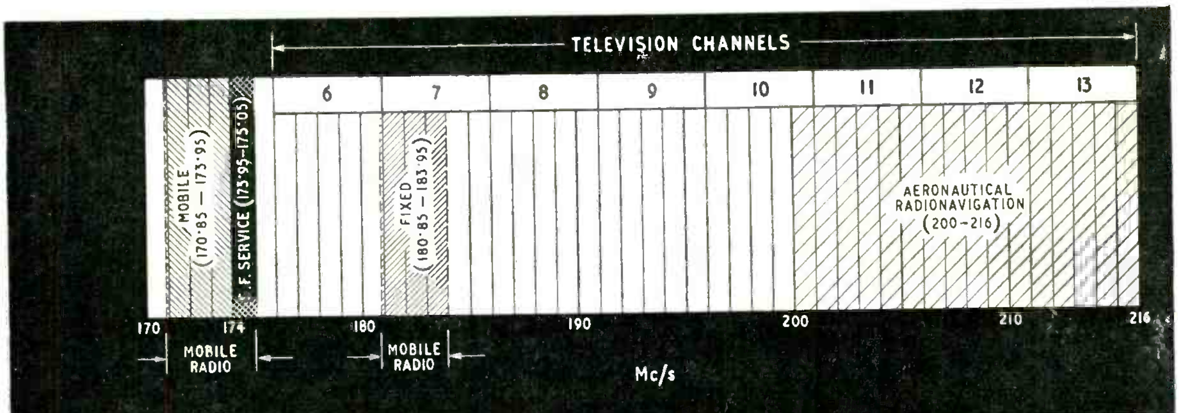
A YEAR ago the Postmaster General appointed a committee to examine the problems (so far as mobile radio is concerned) arising from the decision to clear Band III (174-216 Mc/s) for television. This Mobile Radio Committee—which includes representatives of the Post Office, Ministry of Transport and Civil Aviation, Mobile Radio Users' Association and the Marine Radio Advisory Service, under the chairmanship of R. J. P. Harvey (G.P.O.)—was unable to make firm recommendations by the end of the year as requested. The committee was reconstituted in January and given a further three months in which to complete the enquiry. With the reconstitution the P.M.G. added three independent members to the committee: Dr. R. L. Smith-Rose (D.S.I.R.), F. Jervis Smith (I.E.E.) and H. S. Vian-Smith (Association of British Chambers of Commerce).

The Committee's report has now been published* and was accepted in full by Earl De La Warr the day before retiring from the Government.† He pointed out, however, that it is in some ways an interim report—concentrating on the immediate problems of relieving Band III—and he has, therefore, asked the Committee to continue to advise the P.M.G. on future developments of the mobile radio service.

As will be seen from the diagram the recommended changes involve all the fixed stations, those mobile stations operating between 173.05 and 173.95 Mc/s and the single-frequency services. All private mobile radio users will, in future, be accommodated in the band 165-173 Mc/s. They will occupy all but 0.7 Mc/s of the band which is required for other services.

The re-arrangement provides for a guard band of 3 Mc/s between the new mobile radio band and the lower limit of television channel 6. It is, however, pointed out that it may be found possible to reduce this to 2 Mc/s so that those operators at present working between 173.05 and 173.95 Mc/s (shown dot stippled in the diagram) may not have to move.

The possibility of reducing the width of channels from 100 kc/s to 50 kc/s, thereby doubling the capacity of the band, was considered by the Committee, but no decision was reached. It is, however, stated that on the evidence given by manufacturers the change could be introduced within two years.



The present position of mobile radio is shown here in relation to the television channels in Band III, with (left) the space the service will occupy when the Mobile Radio Committee's recommendations are put into effect. The top half of Band III has still to be cleared.

The Committee was concerned solely with the question of mobile radio as affected by the introduction of television in Band III and have not, therefore, made any recommendations regarding the removal of the aeronautical radionavigation service, which, by international agreement, we are operating in this band.

A minority report by Captain L. P. S. Orr, M.P., representing the Mobile Radio Users' Association, is appended to the Committee's report. The views expressed, which are endorsed by the M.R.U.A., are concerned mainly with compensation for the expense involved in modifying equipment, security of tenure and the P.M.G.'s "refusal to ensure that the loss of frequencies was borne equitably and not exclusively by land mobile radio services."

* "Report of the Mobile Radio Committee," H.M.S.O., price 9d.

† The new P.M.G. is Dr. Charles Hill.

PUBLICATION DELAYS

WE offer apologies to readers who have been inconvenienced by the unavoidable delay, caused by difficulties in our printing works, in the publication of recent issues of *Wireless World*. These difficulties have now been overcome and it is hoped that this and future issues will be available on the correct day of publication—the fourth Tuesday of each month.

WORLD OF WIRELESS

Wrotham Opens this Month ◆ B.S.R.A. Exhibition ◆ International Standards for Colour TV?

V.H.F. Service

PREPARATORY to the opening on May 2nd of the f.m. service from the Wrotham v.h.f. transmitter, test transmissions were radiated daily on one frequency from April 7th to 20th. Since then all three transmitters have daily been testing, radiating the Light Programme (89.1 Mc/s), Third Programme (91.3 Mc/s) and Home Service (93.5 Mc/s). Each transmitter will eventually have an e.r.p. of 120 kW, but during the tests and for the first few weeks of the regular service they will operate with reduced power.

The low-power transmissions from Alexandra Palace during the temporary close-down of Wrotham were discontinued on April 7th.

A further v.h.f. station—making eleven so far approved—has been sanctioned by the P.M.G. It will be at Penmon in Anglesey and, because it will be on the site of the medium-wave station, it is expected that one of the transmitters will be in use by the end of the year. The frequencies for the three-programme service are 89.6 (Light), 91.8 (Third) and 94 Mc/s (Home). Its effective radiated power permitted by the Stockholm Convention is 100 kW but initially it will operate on low power when only the Home Service transmitter will be used.

Sound Recording Show

AS already announced the seventh annual exhibition organized by the British Sound Recording Association will be held at the Waldorf Hotel, Aldwych, London, W.C.2, on May 21st and 22nd. Admission to the exhibition, which opens at 10.0 each day and closes at 6.45 on Saturday and 6.0 on Sunday, is by catalogue obtainable at the door (price 1s 6d), or by post (1s 8d) from the honorary librarian, 3, Coombe Gardens, New Malden, Surrey, after May 10th.

This year's exhibitors are: Acoustical Manufacturing Co., British Ferrograph, C. T. Chapman (Reproducers), Cosmocord, E.M.I. Factories, G.E.C., Garrard Engineering, Goodmans Industries, Grundig, H. J. Leak & Co., Leevers Rich Equipment, Lowther Manufacturing Co., M.S.S. Recording Co., Minnesota Mining & Manufacturing Co., Mullard, Reslosound, Rogers Developments Co., Simon Sound Service, Sugden, Thermionic Products, Truchord, Vitavox, Wharfedale, *Wireless World*.

Colour Television Standardization

A STUDY GROUP of the C.C.I.R. (International Radio Consultative Committee), which met recently in Brussels, agreed that common standards for colour television should be adopted throughout Europe and urged that countries should not make any separate decisions before such standards could be worked out.

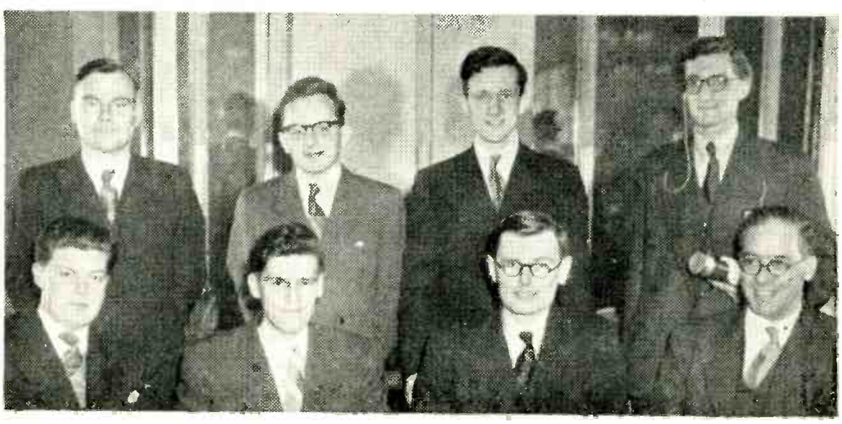
Most delegates also agreed that Bands IV and V would have to be utilized for European colour television, though the British group said that this did not exclude the possibility of colour in Bands I and III as well. In these last-mentioned bands, it was suggested by the Belgians, colour ought to be compatible whereas in Bands IV and V non-compatible systems might be introduced.

The French delegation mentioned the difficulty of standards conversion for shared programmes in colour if common standards were not adopted and also stressed the need for a colour system which would not demand expensive receivers. Existing American colour standards, said the U.S.A. group, would not be modified to conform to any C.C.I.R. standards that might be adopted in Europe.

Component Production

SOMETHING in the neighbourhood of 1,000 million parts, valued at £50M, are now produced annually by the components side of the radio industry. This is more than five times the pre-war production figure. The broad summary of the "end-uses" to which components are applied given in the twenty-second annual report of the Radio and Electronic Component Manufacturers' Federation, gives some indication of the ever-widening industrial field this side of the radio industry now serves. Whereas before the war over 90 per cent of the total component production was used in domestic sound and television receivers, the present figure is under 50 per cent. Nearly 25 per cent is now absorbed by what is generally called the "heavy" side of the radio industry—transmitters, communications equipment and navigational aids—and direct exports account for some 16 per cent.

TECHNICAL WRITERS. Some of the recipients of the Radio Industry Council's premiums recently awarded for technical writing in 1954. In the back row are (left to right) D. H. Towns (British Electricity Authority), W. R. Cass and R. M. Hadfield (Pye) and H. S. Jewitt (Decca Radar). Those in the foreground are G. R. Gibbs, E. J. Kaye, Dr. J. M. M. Pinkerton and E. H. Lenaerts, all concerned with LEO (Lyons Electronic Office)



PERSONALITIES

T. P. Douglas, M.B.E., has been appointed engineer-in-charge of the Sutton Coldfield television station in succession to R. C. Harman (see below). Mr. Douglas joined the B.B.C. in 1938 as a junior maintenance engineer at the Daventry transmitting station, to which he returned in 1946 after war service. He was transferred to Kirk o'Shotts television station in 1951 and in 1953 became assistant e.-in-c. of the Sutton Coldfield transmitter.

R. C. Harman, A.M.I.E.E., who has been engineer-in-charge of the Sutton Coldfield television station since January, 1952, has left the B.B.C. and joined I.T.A. as superintendent engineer (operations and maintenance). He joined the B.B.C. in 1935 at the Daventry short-wave station, transferring to television at Alexandra Palace late in 1937, where, after the war, he became senior engineer (transmitters). In 1949 he was transferred to Sutton Coldfield as assistant engineer-in-charge.

The I.T.A. also announces the appointment of two other ex-B.B.C. television engineers—**A. M. Beresford-Cooke,** as senior planning engineer, and **W. N. Anderson,** A.M.I.E.E., as senior lines engineer. Mr. Beresford-Cooke joined the B.B.C. at Alexandra Palace in 1938, having been for two years in the E.M.I. Research Laboratories. During the war he served in A.A. Command on radar, becoming chief R.E.M.E. Radar Officer. Since 1946 he has been a senior member of the television section of the B.B.C.'s Planning and Installation Department. Mr. Anderson, who received his early technical training in the E.M.I. Research Laboratories where he was employed for eight years, joined the B.B.C. Designs Department in 1948 and worked on the design of test equipment for television transmission circuits. He later transferred to the Planning and Installation Department where he was responsible for the development of radio O.B. links.

H. T. Greatorex, B.Sc.(Eng.), A.M.I.E.E., has been appointed assistant head of the Engineering Information Department of the B.B.C. He joined the engineering staff of the Corporation in 1932 and after three months' service in the London Control Room transferred to Brookmans Park and later to the Daventry transmitting station as assistant maintenance engineer. Mr. Greatorex became a member of the Engineering Information Department in 1935

Dr. A. C. B. Lovell, O.B.E., B.Sc., Ph.D., professor of radio astronomy at the University of Manchester since 1951, has been elected a Fellow of the Royal Society. Professor Lovell, whose work on the planning of the giant radio telescope, being built at the Jodrell Bank Establishment of the University, has received a good deal of publicity, was, from 1939 to 1945, at the Telecommunications Research Establishment, Malvern. Before going to T.R.E. he was for three years assistant lecturer in physics at the University, to which he returned as lecturer in 1945.

G. A. Whitfield, B.Sc., at present head of the controlled weapons division in the armament department at the Royal Aircraft Establishment, Farnborough, is to be head of the new department of aircraft electrical engineering at the College of Aeronautics, Cranfield, Beds. He takes up his appointment to the Chair of Aircraft Electrical Engineering on June 1st. It will be recalled that last year Mr. Whitfield was granted an award by the Royal Commission on Awards to Inventors for work on the development of the proximity fuze.

Sir Robert Renwick, K.B.E., has accepted the invitation of the Radar Association to become its president in succession to Air Vice-Marshal D. C. T. Bennett, C.B., C.B.E. Sir Robert, who was president of the Television Society from 1947-1954 and has been president of the R.E.C.M.F. since 1947, was controller of communications in the Air Ministry and of communication equipment in the Ministry of Aircraft Production during the war.

C. M. Benham, B.Sc., M.Brit.I.R.E., A.M.I.E.E., the new chairman of the Radio and Electronic Component Manufacturers' Federation, is chairman and managing director of Painton & Company, of Kingsthorpe, Northampton, which he joined in 1937. He was for eleven years with Standard Telephones & Cables, where he ultimately took charge of the radio engineering department at the New Southgate Works. He studied at the City & Guilds College.

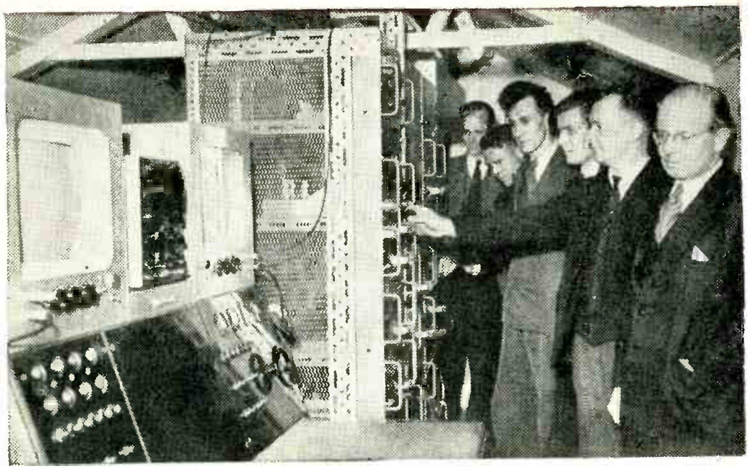
The Insignia Award in Technology (C.G.I.A.) has been conferred by the City and Guilds of London Institute upon two telecommunication engineers for theses submitted. **Arthur H. Watkins,** who receives it for his thesis "The Setting-up and Testing of a Wideband Co-axial Telephony Line Link", joined the Post Office in 1936 and is now executive engineer-in-charge engaged on the installation and testing of wideband co-axial telephony lines. From 1943 to 1946 he was assistant engineer at the G.P.O. Central Training School. **Thomas A. Lewis,** B.Sc., A.M.I.E.E., receives the award for his paper "The Measurement of Radio Interference with Particular Reference to Very High Frequencies and Television." He, too, is in the Post Office, which he joined in 1937. Since 1947 he has been in the Radio Experimental Development Branch at the Backwell laboratory, working on the investigation of radio interference problems, and the design of measuring equipment and receivers for the 30-200-Mc/s frequency range. The Institute has also conferred the award on **J. A. Mason,** M.I.E.E., manager of the Automatic Telephone and Electric Company, which he joined on leaving school in 1911. After military service during the first world war he went into the Engineering Department, where he subsequently became assistant chief engineer.

Cable & Wireless, Ltd., announce the appointment of **Ronald L. Saunders** and **Donald Scott** as assistant engineers-in-chief in succession to **W. J. Knight, M.B.E.,** who becomes deputy engineer-in-chief on the retirement of **E. B. Dillow.** Mr. Saunders joined the Pacific Cable Board in 1926 and transferred to Cable & Wireless on its formation in 1929. During recent years, as engineer-in-charge of the laboratories and workshops at Radio House, Wilson Street, London, E.C.2, he has been responsible for the company's development work. He is a B.Sc.(Eng.) of London University. Mr. Scott, after serving at twelve stations overseas, was transferred to the company's engineer-in-chief's department in 1948, where he has been responsible for the day-to-day operation of the wireless services. He was for four years seconded to the Hong Kong Government as wireless adviser.

OUR AUTHORS

Charles Ian Orr-Ewing, O.B.E., M.I.E.E., M.A., M.P., whose open letter to the Postmaster General is published in this issue, is Member of Parliament for North Hendon and parliamentary private secretary to the Minister of Labour and National Service. After obtaining an honours degree in physics at Oxford he was for three years a graduate apprentice with E.M.I. For some eighteen months before joining the R.A.F.V.R. in 1939 he was in the Television O.B. Department of the B.B.C. to which he returned in 1946 to take charge of the department. He left the B.B.C. in 1949 to join Cossor's, of which he is now a director.

J. A. Lane, joint author with **Dr. J. A. Saxton** of the paper in this issue on the effect of obstacles on high-frequency reception, joined in 1940 the Department of



MEMBERS of the team that designed, built, and installed the Belling-Lee television transmitter (G9AED) at Croydon for experimental transmissions in Channel 9. On the right is F. R. W. Strafford (Technical Manager). A test pattern is radiated daily from 10 a.m. to noon on 194.75 Mc/s with an e.r.p. of 1 kW and a tone (approx. 600 c/s) on 191.27 Mc/s. There is also to be an afternoon transmission from 2.0 to 4.0.

Scientific and Industrial Research where he is now a senior scientific officer in the Radio Research Organization. He is mainly concerned with investigations on various aspects of short-wave propagation and in particular with measurements of dielectric properties and power at centimetre wavelengths. Dr. Saxton, who last year contributed an article on assessing the service areas of v.h.f. and u.h.f. transmitters, needs no introduction to *Wireless World* readers.

IN BRIEF

Broadcast Receiving Licences current in the United Kingdom at the end of February totalled 13,916,246, including 4,407,393 for television and 265,468 for car sets. Television licences increased by 99,621 during the month.

Comparative Recordings (made at the same time and place with a medium-wave receiver and a v.h.f. receiver) will be used by the B.B.C. at the Manchester exhibition, which opens on May 4th, to demonstrate that interference from foreign transmitters is absent on v.h.f. and that electrical interference too is greatly reduced by the use of frequency modulation. Several examples will be given of simultaneous recordings of the same programme transmitted in both bands and the point will be made that there is no difference in the quality as transmitted but that the improved reception on v.h.f. is due to the advantages of frequency modulation.

The annual **International Contest** for radio-controlled model boats will be held at Saltwell Park, Gateshead-on-Tyne, on July 30th and 31st. The contest for radio-controlled model aircraft will be on August 1st at Croft Aerodrome, near Darlington. Details of the contests, which are organized by the International Radio Controlled Models Society, are obtainable from D. W. Aldridge, 1, Fowberry Crescent, Fenham, Newcastle-upon-Tyne, 4.

Four premiums, each valued at £5, have been awarded by the **Television Society** to the following authors for papers read at London meetings during 1954 (titles of the papers are given in parentheses): Dr. G. N. Patchett ("Problems of Interlacing"); G. B. Townsend, E. Ribchester and D. Bauer ("An Investigation of the 625-line C.C.I.R. System"); R. J. Boddy and C. D. Gardner ("An Industrial Television Channel"); and G. G. Gouriet ("Colour Television").

A three-day conference is being held at High Leigh, Hoddesdon, Herts, from May 13th to 15th by the **National Federation of Gramophone Societies.** Details of the fees and the programme, which will include technical and music lectures and demonstrations of high-quality reproducing equipment, are obtainable from G. E. Palmer, 106, Streatfield Road, Kenton, Harrow, Middx.

R.E.C.M.F. Council.—At the annual general meeting of the Radio and Electronic Component Manufacturers' Federation, which now has a membership of 164, the following firms were elected to form the council (the names of the companies' representatives are in parentheses): Automatic Coil Winder (R. E. Hill); British Moulded Plastics (G. F. Carnell); Garrard Engineering (H. V. Slade); A. H. Hunt (S. H. Brewell); Morganite Resistors (E. T. Treganza); Multicore Solders (R. Arbib); N.S.F. (K. G. Smith); Painton (C. M. Benham); Plessey (P. D. Canning); Standard Telephones & Cables (E. E. Bivand); Telegraph Construction & Maintenance Co., (W. F. Randall); Truvox (K. Short). The new chairman and vice-chairman are C. M. Benham and S. H. Brewell, respectively.

Club secretaries may like to know that the latest edition of the 16-mm colour sound film "**Mechanical Handling**" includes sequences on some of the applications of electronics in the handling of goods. One of the sequences covers a combined conveyor and elevator system which is electronically controlled for both flow and sorting of boxes according to colour or size. Applications for the loan of the film, which lasts approximately 40 minutes, should be made to H. A. Collman, *Mechanical Handling*, Dorset House, Stamford Street, London, S.E.1.

Isotope Instrumentation.—Radioactive isotopes are finding increasing uses in industry, medicine and research, and to facilitate the correct choice of detecting and measuring instruments, a comprehensive catalogue has been produced by the Scientific Instrument Manufacturers' Association of Great Britain, Ltd., Queen Anne Street, London, W.1. In addition to details of the products of the member firms there is a useful technical introduction and bibliography on the principles underlying radioactive isotope instrumentation. The brochure is produced under the joint editorship of Dr. Denis Taylor (A. E. R. E., Harwell) and A. G. Peacock (Mervyn Instruments).

Correction.—We tender our apologies to R. F. Gilson, the author of the article "Output Transformer Design," whose name was misspelt on p. 195 of the April issue.

BUSINESS NOTES

Wolsey Television has been acquired by the Gas Purification and Chemical Company who control, among other companies, Grundig (Great Britain), Ltd., and Grundig International, Ltd. H. S. Melly remains on the board and is joined by A. E. Johnson, G. S. Taylor and D. D. Mathieson of Grundig.

An office has been opened at 86, Holly Road, Uttoxeter, Staffs, by the **Narda Corporation,** of Mineola, New York, for the sale of its microwave test equipment in this country.

Demonstrations of **Pye** industrial and underwater television equipment will be given at the Kongresshaus in Zurich from May 11th to 13th. Examples of the company's television broadcasting equipment will also be on show.

The radio communication equipment and electronic aids to navigation on board the 20,000-ton passenger liner *Southern Cross*, which is now on her maiden voyage round the world, were installed by **Marconi Marine.** The sound reproducing and order system feeds a network of 200 loudspeakers and incorporates a tape recorder for recording news and other broadcast programmes received at times inconvenient for immediate diffusion over the loudspeaker system.

The B.B.C. has ordered from **British Acoustic Films, Ltd.,** twelve combined sound and picture film cameras. Built to a B.B.C. specification, they will produce either a 35-mm picture film with a separate 35-mm magnetic sound track, or a 16-mm picture film with a separate 16-mm sound track.

V.H.F. radio-telephone equipment supplied by **Hudson Electronic Devices, Ltd.,** has been installed by the Automobile Association on the cross-channel car ferries *Hallidale, Lord Warden and Dinard*. The A.A. staff on board are thus able to 'phone details to the Association's headquarters in Dover, so facilitating the rapid transit of motorists through the customs.

Sydney S. Bird & Sons, manufacturers of Cyldon capacitors, have moved their works from Enfield to Fleets Lane, Poole, Dorset (Tel.: Poole 1640). A London sales and technical liaison office has been opened at 3, Palace Mansions, Palace Gardens, Enfield, Middx (Tel.: Enfield 2071), under the direction of G. B. Francis.

Aero Research, Ltd., of Duxford, Cambridge, manufacturers of synthetic resins, have moved their northern area office to 409, Royal Exchange, Manchester, 2. (Tel.: Blackfriars 9445.)

The **Plessey Company,** of Ilford, Essex, announce the appointment of Thomas P. Collier, of 120, South La Salle St., Chicago, as their sole representative in the U.S.A.

A London office and show room, at 53, Victoria Street, S.W.1 (Tel.: Abbey 4704), has been opened by **Atkins, Robertson & Whiteford, Ltd.,** of 92-100, Torrisdale Street, Glasgow, S.2, manufacturers of electronic instruments.

The telephone number of **A. F. Bulgin & Co.,** of Bye Pass Road, Barking, Essex, has been changed to Rippleway 5588.

OVERSEAS TRADE

Equipment for the two-way u.h.f. radio-telephone service recently introduced between Algeciras, Spain, and Ceuta, Morocco (a distance of some 20 miles) has been supplied by **Standard Telephones & Cables.** The installation provides for 24 simultaneous two-way conversations.

With the opening of the new Sarawak broadcasting service, the government distributed 2,600 receivers amongst the population. The **General Electric Company** supplied the 4-valve all-dry superhet receivers which cover both the medium-wave and short-wave bands.

Two radio manufacturers were among the 60 or more British firms who exhibited at the **Lyons International Trade Fair** which closed on April 25th. The two firms are Erie Resistor, Ltd., and Standard Telephones and Cables, Ltd., who were showing respectively, capacitors and valves.

Two 485-ft mast radiators, complete with r.f. transmission line of the 5-wire unbalanced type, aerial matching equipment and an earth system, are to be erected by **Marconi's** for the Greek broadcasting authorities on the site of a 50-kW station on the island of Corfu. The order was secured by Marconi's agents P. C. Lycourezos, Ltd., in the face of severe German competition.

Bayerische Rundfunk, the Bavarian broadcasting organization, has secured from **Pye** a television O.B. van which has provision for three camera chains.

Kelvin & Hughes have supplied a modified version of their "Kingfisher" echo sounder for the *Sea Diver* being used by the American expedition seeking the remains of Columbus' *Santa Maria.* The leader of the expedition is Edwin A. Link, the inventor of the Link aircraft trainer, who is concentrating his search off the north coast of Haiti.

Jamaican Agency.—Masterton, Ltd., P.O. Box 73, 23-25, Hanover Street, Kingston, have advised the U.K. Trade Commissioner in Kingston that they would like to act as agents for a British manufacturer of broadcast receivers not already represented in Jamaica. Full particulars should be sent direct to the company, but manufacturers are asked to notify the Trade Commissioner (Royal Mail Building, P.O. Box 393, Kingston, Jamaica, B.W.I.).

SOURCES OF INTERFERENCE

IN view of the recent publication of the regulations covering interference from small motors and refrigerators (see page 155, April issue), a summary of the 140,000 complaints investigated by the Post Office last year is of particular interest.

Sources of interference	Number of complaints	
	Sound	Television
Bedwarmers	578	1183
Calculating machines	342	818
Drills	1177	2492
External cross modulation	280	45
Faulty electrical wiring of premises	2194	494
Hair driers	598	6954
Ignition systems of petrol engines	49	1313
Industrial and medical r.f. equipmt.	196	887
Lighting, filament type lamps	66	2569
Lighting, fluorescent tubes	1676	233
Lighting, street	712	113
Neon signs	416	1444
Power lines	814	3789
Radiation from TV time base circuits	6805	3
Radiation from superhet, local oscillators	62	1604
Refrigerators (compressor, fan, or thermostat)	1228	1587
Transmitters, amateurs	125	303
Transmitters, others in U.K.	142	476
Transmitters, foreign	533	146
Sewing machines	1577	8956
Smoothing irons	399	198
Vacuum cleaners	1043	3269
All other identified sources: contacts type	1978	3356
All other identified sources: commutator type	2930	7056
All other identified sources: miscellaneous types	1468	1692
Unknown	12206	21877

By far the largest individual source of interference with television was electric sewing machines (8,956) with hair driers (6,954) next. The table excludes the 11,495 complaints which were found to be due to defective conditions in the receiving installation. All together, 83,514 complaints of television interference were investigated.

Of the 57,324 cases of interference with sound broadcasting investigated the largest source of trouble, excluding the 19,020 complaints found to be due to "a condition or function" of the receiving installations, was radiation from television time-base circuits (6,805).

It will be seen from the table that there were large numbers of complaints investigated which are classified as "source unknown." These include those in which the interference ceased before or during the investigations, or where the interference was of such infrequent occurrence that it did not justify continual investigation "to the exclusion of more deserving complaints."

Ignition interference is generally so transient that the number of complaints in the table bears no relation to its prevalence.

To give a complete list of sources of interference is impracticable and many of the identified sources are grouped under contacts, commutator and miscellaneous types.

At the end of the year there was a backlog of 9,961 (sound) and 15,417 (television) complaints.

By P. J. WALKER*

Wide Range Electrostatic

1.—*Principles of Design for Operation at Low as well as High Frequencies*

A closer examination of underlying principles leads to the conclusion that the electrostatic loudspeaker may well supersede the moving coil for high-quality sound reproduction. Designs recently developed have proved to be capable of reproducing the full audio-frequency range, with harmonic distortions no higher than those of the associated amplifier.

EVERY loudspeaker designer must, at some time or other, have looked longingly at the electrostatic principal of drive as a solution to his problems of improving quality of reproduction. The movement of a diaphragm driven all over its surface is entirely predictable. The diaphragm can be as light as required. The impedances influencing performance can be predominantly acoustic and—since there are no shape restrictions—entirely under the control of the designer.

What has held it back? First, the fact that *in its generally known form* it is intrinsically non-linear and even in a push-pull construction linearity can only be approached for small amplitudes. Secondly, in order to obtain adequate sensitivity the available gap is small; the diaphragm movement limited and largely stiffness controlled, both factors restricting its use to high frequencies. Thirdly, that being essentially a capacitive electrical load, it is difficult to match to an amplifier.

The first of these objections, that of non-linearity, can be removed completely by an expedient which is spectacular in its effectiveness and simplicity. The second and third difficulties will resolve themselves, as we shall see later, when the designer makes his choice of the interdependent mechanical, acoustical and electrical variables.

Fig. 1 (a) shows diagrammatically the connection of a conventional electrostatic loudspeaker in which the polarizing voltage is applied to the centre diaphragm and the signal in push-pull to the outer perforated fixed plates. Under conditions of no signal, Fig. 1 (b), and assuming the diaphragm to be central, there will be equal and opposite attractive forces on the diaphragm. If one fixed plate is now made positive and the other negative so that the diaphragm will be deflected to the right, the effective capacitance will increase, and to satisfy the relationship Q=CE the charge Q will also increase and will be supplied by a current i during the movement. The force acting on the diaphragm per unit area will, however, be proportional to $\left(\frac{E+e/2}{d_2}\right)^2 - \left(\frac{E-e/2}{d_1}\right)^2$. The relationship will be non-linear. Note that the charge Q, although varying, does not enter directly into the relation.

Suppose that after having charged the diaphragm electrode the source of polarizing potential is disconnected (Fig. 1(d)). The diaphragm now carries a constant charge Q which experiences a force proporional to the product of the field intensity and the charge. This force will be independent of the position of the diaphragm between the plates since both Q and the distance between plates are constants; the only variable is the applied voltage e. Note that the difference between d_1 and d_2, although varying, does not enter into the relation.

The above is perhaps an over-simplification, but it shows that distortion is not necessarily inherent in the electrostatic principle.

The "constant Q" method of operation has another very important advantage in that it reduces the risk of collapse, which occurs at large amplitudes with the conventional method of connection, when the negative stiffness resulting from electrical attraction exceeds the positive mechanical stiffness of the diaphragm. As the diaphragm approaches one of the fixed plates the capacitance is increased, but as the charge Q has been assumed constant, E must fall since E=Q/C.

Professor F. V. Hunt of Harvard University has shown† that the criterion for dynamic stability under large excursions is that the time constant R_oC_o of the charging circuit (Fig. 1(e)) should be large compared with 1/2f, the half-period of the applied frequency. This also supplies the condition for low distortion and Professor Hunt gives the results of measurements (Fig. 6.14, p. 212, *loc. cit.*) showing the dependence of second harmonic distortion on both the degree of unbalance due to displacement of the central electrode (in terms of $\Delta C/C$) and of the ratio of time constant to half period $2fR_0C_0$. Even when this latter parameter was reduced to unity, and the diaphragm displaced by a distance equivalent to a capacity unbalance of 25 per cent, the second harmonic did not exceed 0.5 per cent, when driven at 150 c/s by 780 V r.m.s. (plate-to-plate) with a polarizing voltage of 500. Third and higher harmonics were always less than the second.

So much for the driving mechanism; it now remains to see how it fares when coupled to the air and to an amplifier.

It will help in understanding the broad principles involved if we start by considering a loudspeaker whose diaphragm is large compared with the longest wavelength of sound to be reproduced. Under these conditions the mass reactance of the air load on both sides of the diaphragm can be neglected and the impedance per unit area $2\rho c$ offered to the motion of the diaphragm is predominantly resistive ($\rho c = 42$ mechanical ohms per cm^2). With constant voltage driving the diaphragm the force will be proportional to the applied signal voltage and independent of frequency. If the load is resistive the velocity, and also the acoustic power output, will be independent of frequency.

At very high frequencies the mass reactance of the diaphragm can exceed the radiation resistance and will cause a falling off in velocity when the force remains constant; the acoustic output will then decline by

* Acoustical Manufacturing Co., Ltd.

† "Electroacoustics" by F. V. Hunt, chapter 6. Published by John Wiley & Sons (Chapman & Hall).

Loudspeakers

with Negligible Distortion

6 db/octave, but, with suitable choice of diaphragm material, not until a frequency of 20 to 25 kc/s is reached. (How different from the average moving coil in which the cut-off starts at about 1,000 c/s and must be sustained by focusing of high frequencies along the axis or by juggling with cone "break-up.")

Similarly at low frequencies a 6 db/octave falling off with reducing frequency will result when the reactance due to the stiffness (reciprocal of compliance) of the diaphragm exceeds the resistance air load. This state of affairs is shown graphically in Fig. 2. Unfortunately, it is not so easy to put the frequency at which the stiffness begins to exercise control outside the audible range. The choice of stiffness will be dictated by the necessity of constraining the diaphragm against the forces associated with the polarizing voltage. Under "static" conditions ($2fR_0C_0$ less than unity) these forces can increase as the diaphragm approaches the fixed plates and must be limited by a suitable choice of stiffness, polarizing voltage and plate spacing. The plate spacing also determines the electrical capacitance of the loudspeaker, and the impedance offered to the amplifier at the frequency chosen for "matching."

Thus the bandwidth available for constant output, under the acoustic conditions postulated, is limited at low frequencies by the diaphragm stiffness required for stability and at high frequencies by the conditions of matching to the amplifier. (The inertia cut-off will always be well above the matching frequency and can be ignored.)

The true efficiency of an electrostatic loudspeaker is very high indeed, but it is difficult to realize because of the large wattless current which has to be provided due to the electrical capacity of the loudspeaker unit. Thus it is necessary to waste watts in the amplifier or in resistances associated with crossover networks of which the loudspeaker may be part. For purposes of simplification, therefore, it is convenient to use the term "apparent efficiency" the meaning of which is the ratio of the acoustic power output of the loudspeaker to the amplifier volt-ampere output necessary to provide the required voltage across the loudspeaker capacity.

The way in which the designer can trade bandwidth for "apparent efficiency" is illustrated by Figs. 3 and 4. In both cases we assume the maximum output will be available at the high-frequency matching limit, and that constant voltage will be available at this and lower frequencies.

In Fig. 3 let curve (a) represent the response with a given electrode spacing D=1. If we double the spacing the diaphragm stiffness required for stability

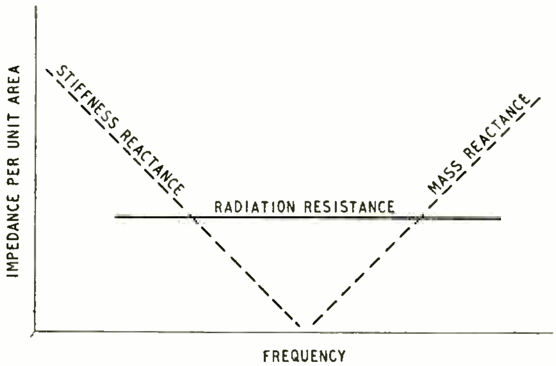


Fig. 2. Variation of acoustical and mechanical impedances with frequency in a diaphragm which is large compared with wavelength.

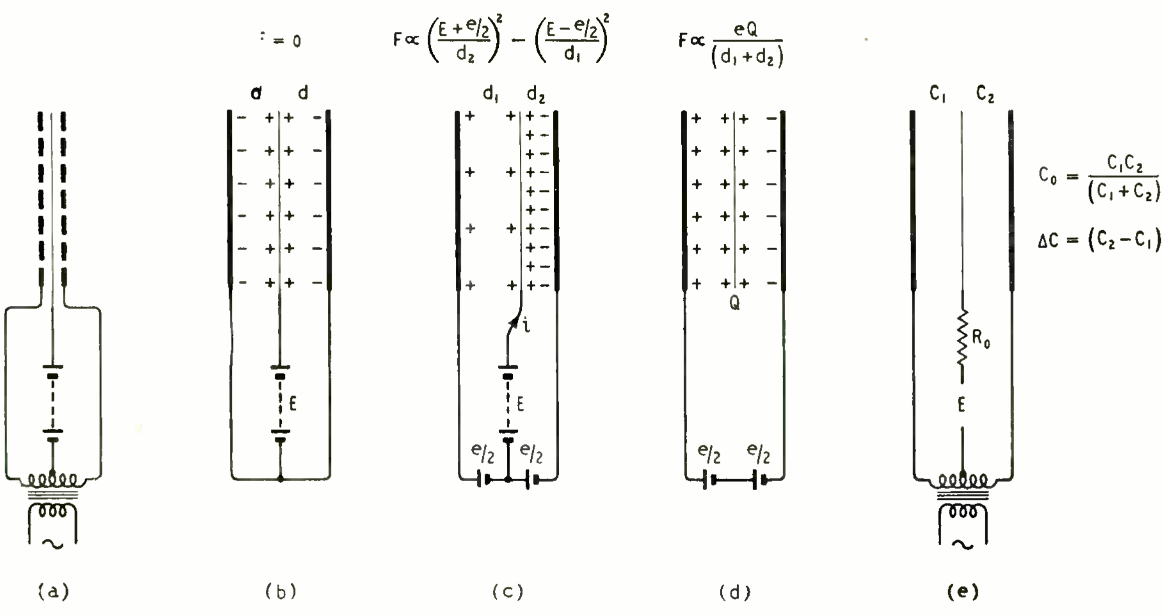
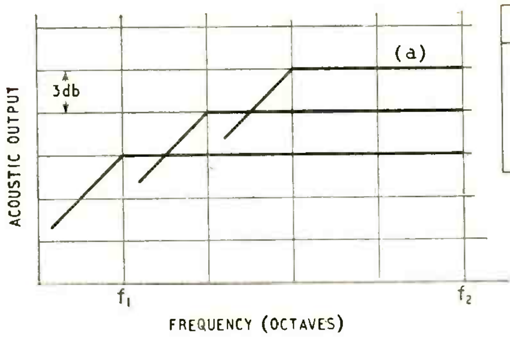


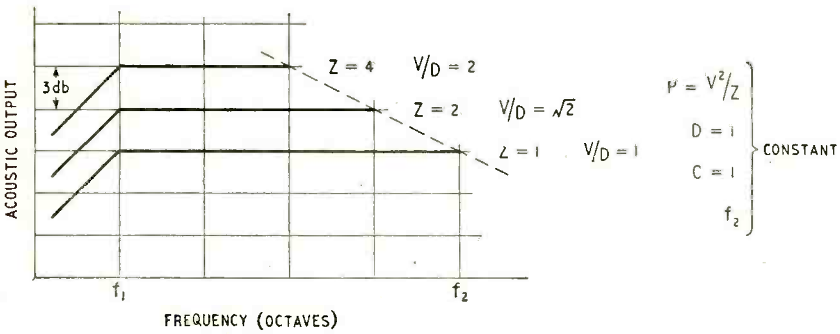
Fig. 1. Essential differences in the operation of electrostatic loudspeakers with "constant voltage" and "constant charge" on the centre diaphragm.

Right: Fig. 3. Low-frequency response can be extended, at the expense of "apparent efficiency," by increasing the plate spacing and re-matching to the amplifier at f_2, the upper frequency limit.



D	C	Z	V	V/D
1	1	1	1	1
2	1/2	2	$\sqrt{2}$	$\sqrt{2}/2$
4	1/4	4	2	1/2

$P = V^2/Z$, f_2 } CONSTANT



Left: Fig. 4. Alternatively, with constant spacing and a fixed low-frequency limit the high-frequency response can be extended, again at the expense of "apparent efficiency," by varying the frequency f_2 at which the capacitive impedance is matched to the amplifier.

can be halved and the low-frequency cut-off goes down an octave. At D = 2 the capacitance is halved and the impedance doubled, but because the power is limited the volts rise by only $\sqrt{2}$ when the amplifier is re-matched. Thus the field strength V/D available to drive the diaphragm is reduced to $\sqrt{2}/2$ and the response falls by 3 db. We have thus gained an octave for a drop of 3 db in output, and, of course, the necessity of finding twice the polarizing voltage.

We can, if required, regain the lost efficiency by re-matching an octave lower at the top end, as shown in Fig. 4. We now keep D (and C) fixed, and with it the low-frequency cut-off. The field strength available for driving the diaphragm will be proportional only to the voltage available from the amplifier. If we re-match an octave lower Z will be doubled and V will increase to $\sqrt{2}$, so there will be a 3-db rise in acoustic power for the loss of an octave at the high-frequency end.

Since very high efficiencies are not a pre-requisite of high-quality reproduction, it is convenient to arrange the apparent efficiency to be similar to the efficiency obtained from present-day commercial moving-coil speakers. Setting the efficiency at this level and applying polarizing voltages permissible in the given air gap, we find that the available bandwidth for level response is about four to five octaves.

Below the low-frequency cut-off we have the stiffness of the diaphragm controlling response, a large proportion of it under conditions where the "apparent efficiency" is high and wasted. (At low frequencies the impedance is high, and less power is required to maintain constant voltage.) Thus, by a progressive change of "matching" in this area, one can compensate to extend the level response below the mechanical cut-off. The effect of this mechanical stiffness is best considered when we deal with possible forms of loading, since it can be lumped in with the acoustical circuit loading the loudspeaker.

A high polarizing voltage is desirable in order to place a high value of charge Q on the diaphragm. Each small unit area of the diaphragm can be fed with a high voltage at very high impedance, thus charging up that part of the diaphragm in relation to the fixed plates. In this arrangement of the loudspeaker, where the signal is applied to the fixed plates only, there are no signal currents due to the wanted signal in the diaphragm itself, so that this arrangement of high-impedance charging of each unit area of the diaphragm is permissible, and is essential for linearity in any practical construction. Any tendency for the air to conduct between the diaphragm and the fixed plate at any point in the loudspeaker merely causes a slight drop in the voltage at that area on the diaphragm, so that in this way high voltages can be applied without any danger of sparking.

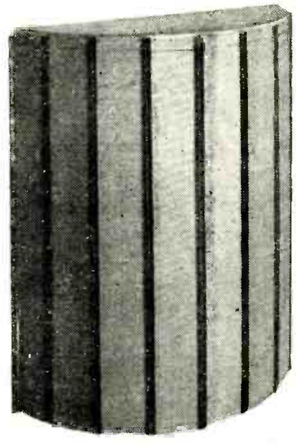


Fig. 5. High-frequency unit with dimensions large compared with wavelength designed to cover frequencies from 1,000 c/s to the upper limit of audibility.

Since the charge on the diaphragm is unvarying, it follows that the force on the diaphragm is completely independent of the position of the diaphragm in the space between these electrodes and the system in linear. With this arrangement, then, it is no longer necessary to restrict the allowable motion of the diaphragm to a small percentage of the available gap. Again, there is no restriction to the ratio of signal voltage to polarizing voltage. The only non-linear element entering the system at all is that due to the compliance of the diaphragm, and since in most designs this is not a controlling factor in the motion of the diaphragm its importance is small. There is no difficulty in producing units on this principle, the distortion content of which is even lower than that of present-day amplifiers, and many times better than a moving-coil loudspeaker of normal efficiency.

We have seen, then, that it is now possible to design loudspeakers on the electrostatic principle for a given bandwidth, over which the forces are acting directly on to the air. We have seen that this bandwidth can be placed anywhere in the audio range and that linearity represents considerable improvement on anything hitherto produced. The design of a loudspeaker unit on such principles is therefore purely one of applying it to its acoustical load to give any required performance.

We have so far assumed the simple case of $2\rho c$ loading on the diaphragm. Ignoring for the moment horn loading, this can only be achieved in practice at high frequencies, or for cases where the diaphragm is very large indeed.

A simple single unit construction for high frequencies is shown in Fig. 5. This loudspeaker covers the range from 1,000 c/s to the upper limits of audibility. Such a unit could, of course, be used with conventional moving-coil speakers for low frequencies, but the assumption that moving-coil units operate like distortion-less pistons at low frequencies is very far from the truth. It is obviously desirable to introduce the benefits of the electrostatic principle throughout the whole frequency range.

By way of showing what can be done, Fig. 6 shows a more complex design of electrostatic loudspeaker which, when properly loaded, covers the whole frequency range from 40 c/s up to the limits of audibility. In a future article it is proposed to discuss the operation of such loudspeakers, i.e., when size is no longer large compared to wavelength, and to show the basis of design approach for the whole frequency range.

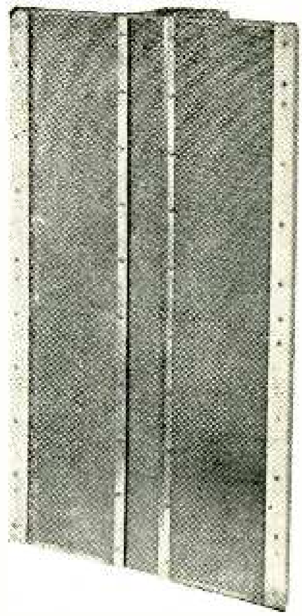


Fig. 6. Unit of more complex design which, with proper acoustic loading, covers the range from 40 c/s to the upper limit of audibility. Measurements on this and the unit of Fig. 5 indicate total harmonic distortions of less than 1 per cent.

Distortion measurements on these units gave figures well below 1%. Measurements were made out of doors, and noise, wind, and other restrictions due to imperfect conditions made it difficult to get reliable figures below 1%. Inspection of the residual waveform indicates that the distortion due to the units is considerably lower than this figure.

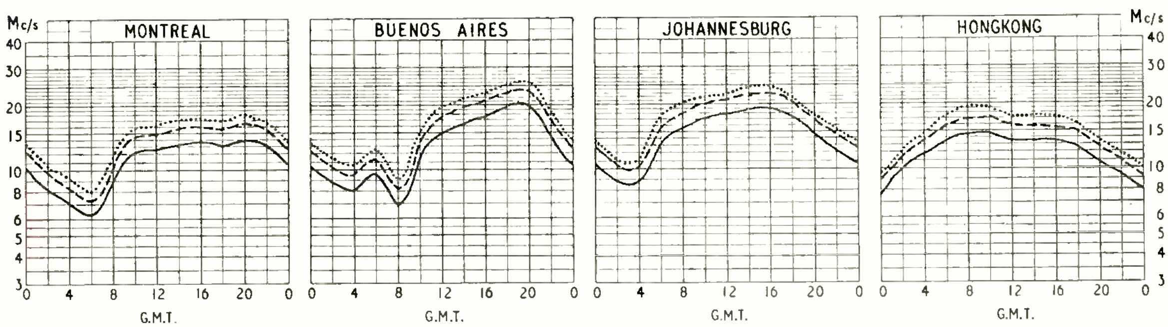
Similar remarks apply to frequency response, due to the fact that it is virtually impossible to achieve perfect loading conditions. Measurements produce responses which are within 2 db of the predicted curves, but the major part of these small discrepancies may be attributed to the approximations assumed in the structures used for loading.

Since 1953, electrostatic loudspeakers have been the subject of joint development between Ferranti, Ltd., of Edinburgh, and The Acoustical Manufacturing Co., Ltd., of Huntingdon. Some of the techniques involved in the design of these loudspeakers are the subject of joint patent applications by P. J. Walker and D. T. N. Williamson.

(To be continued)

SHORT-WAVE CONDITIONS

Predictions for May



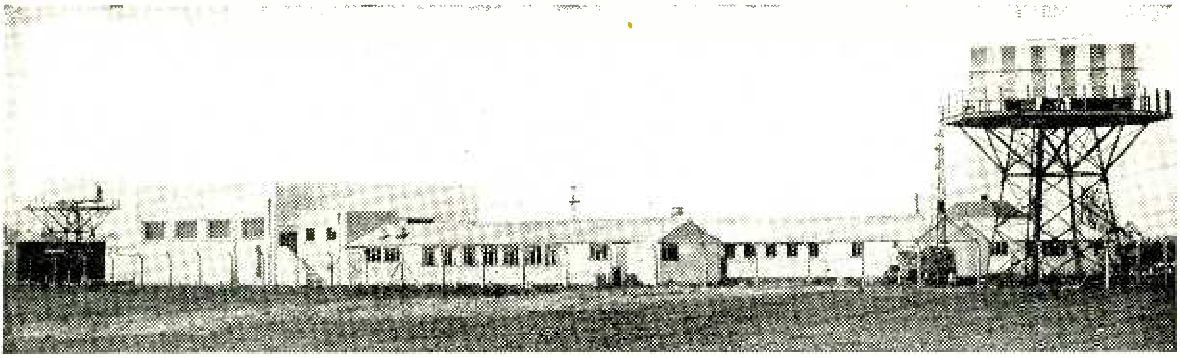
THE full-line curves given here indicate the highest frequencies likely to be usable at any time of the day or night for reliable communications over four long-distance paths from this country during May.

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

·············· FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE FOR 25% OF THE TOTAL TIME

— — — PREDICTED AVERAGE MAXIMUM USABLE FREQUENCY

———— FREQUENCY BELOW WHICH COMMUNICATION SHOULD BE POSSIBLE ON ALL UNDISTURBED DAYS



Air Traffic Control at London Airport

TWO new buildings were recently brought into use at London Airport for the purpose of effecting closer integration of the radio and radar aids to flying now in daily use there. One of the buildings, located on the northern boundary of the aerodrome, is the new air traffic control centre for the whole of southern England and was until recently located at Uxbridge. The main purpose of the move was to bring together in one room the radio and radar controllers who were hitherto widely separated.

No real significance attaches to London Airport as the site of this control centre since the controllers are not concerned with air traffic in and out of the airport, but it is a good radar site and the display information can be made available to the airport's control tower to reinforce data obtained from alternative aids.

The multi-channel v.h.f. area coverage radio-telephone system described in *Wireless World* of March, 1951, is operated from this building. The installation has been expanded a little since it was last described here and now provides 10 v.h.f. channels in the 118-to-132-Mc/s band.

Since both radio and radar controllers occupy the same room a major problem arose in regard to the lighting. Full daylight viewing of c.r. tubes is not yet accomplished, but it is said to be within sight. For the present purpose the lighting is provided by red, blue and green fluorescent tubes giving a mixed light having the appearance of white light, but lacking those shades responsible for strong reflections from the face of c.r. tubes. When used in conjunction with suitable amber c.r.t. filters perfect viewing is possible with an amount of light adequate for the radio personnel in the same room.

The other new building of interest at the airport is the control tower. It is located in the central terminal area and is approached by a 680-yd underground road tunnel. This building is the nerve-centre of the airport and contains the radio and radar controllers concerned witn the safe and expeditious movement of aircraft into and out of the airport.

Very comprehensive radio and radar facilities are provided. There are eight radio-telephone channels, seven in the 118-to-132-Mc/s band and one in the 3-Mc/s; an interesting feature of the v.h.f. system is the provision for sharing a common aerial. Cavity resonators enable up to four transmitters (or receivers) to use the same aerial at the same time with a frequency spacing of some 400 kc/s only. Transmitting and receiving stations are widely separated and remotely controlled, but the latter is within the airport boundary.

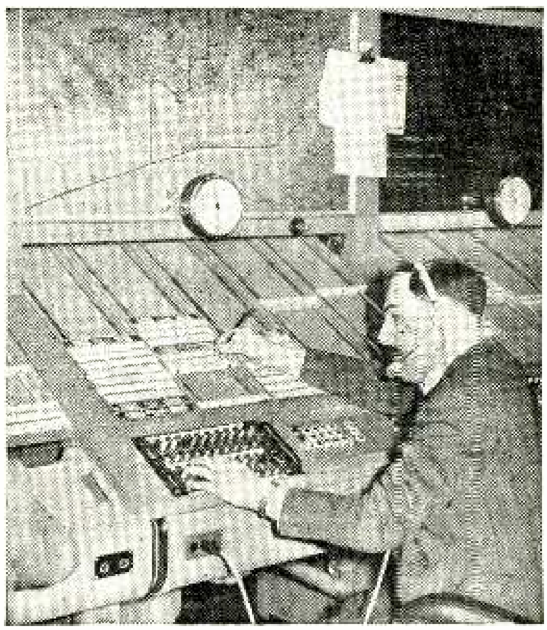
A Marconi v.h.f. fully automatic direction finder is installed in the tower with its aerial located about half a mile away. The only aerials on the tower are those concerned with the movement of all surface vehicles which are controlled by v.h.f. radio telephones and a scanner for a Decca 8-mm (or Q-Band) radar; Airfield Surface Movement Indicator.

Movements of aircraft within 60 miles of the airport are tracked, and when within tower control marshalled with the aid of the Cossor Airfield Control Radar Mark VI. In bad weather landing is assisted by a modified early model G.C.A. and the latest Pye Instrument Landing System.

A special feature of the new buildings is that only equipment essential for the controllers' needs is accommodated in the control rooms with the main items located in an equipment room immediately below. Here maintenance, repair and routine testing can be carried out and the whole station kept at top efficiency without in any way hindering the work of the controllers.

The need for some aid to location and movement of surface vehicles other than human vision will be appreciated when it is realized that the airport covers some six square miles of country, and some of the runways exceed two miles in length. A pool of walkie-talkie sets is maintained for communication with the control tower by personnel not normally using vehicles.

It is perhaps not surprising that London Airport has a reputation as being one of the safest in the world and the newest aids should materially strengthen this well-merited reputation.



Flying controller operating flight progress boards in control room.

LETTERS TO THE EDITOR

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

Transistor Letter Symbol

I READ with interest E. A. W. Spreadbury's letter in your March issue regarding the evolution of a suitable letter to denote the transistor.

It appears to me preferable to have a single letter symbol for what is, after all, a major element in its associated circuit. Hence I would suggest the use of the letter S to denote a transistor, on the grounds that it is a Solid-state device whereas a valve is a Vacuum device.

The existing use of the letter S to denote a switch may well be replaced by Sw, which letters are already in some use for this purpose.

South Harrow, Middlesex. D. NAPPIN.

I LEAN towards the argument put forward by E. A. W. Spreadbury (your March issue) that some distinctive letter symbol should be adopted for a transistor in order that its different mode of operation from the thermionic valve shall be readily apparent.

Personally, I do not look with favour on the letter V to indicate a transistor; the letter is hackneyed to the extent that it denotes (a) thermionic valve, (b) voltage, (c) velocity, (d) volume, to mention a few. I also feel that Mr. Spreadbury's double-letter symbols can be improved upon, and would suggest the letter Y. This letter is not so widely used as V, and to my mind it bears some resemblance to the graphical symbol that now seems to be fairly well established. In addition, it is not unlike V in appearance, so can impart some indication of the function of the circuit element.

St. Leonards-on-Sea, Sussex. W. E. THOMPSON.

Feedback I.F. Amplifiers

WITH reference to the very interesting articles by H. S. Jewitt (February and December, 1954), we can mention that work on such amplifiers has been going on for some time at the Radio Receiver Research Laboratory of the Danish Academy of Technical Sciences and has led to the following experience.

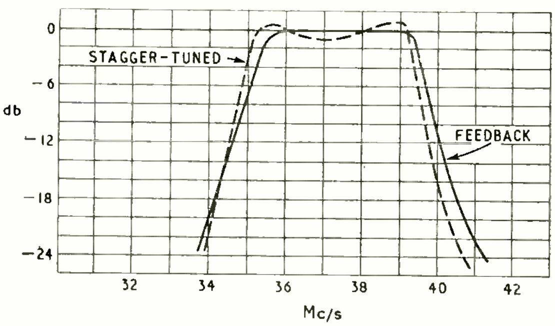
It has been found possible to avoid the difficulties mentioned by Mr. Jewitt in obtaining the wanted selectivity curve in feedback i.f. amplifiers for television when using values for the damping and feedback resistors calculated from the measured capacitances and loss factors of the coils and circuitry.

In i.f. amplifiers for television the valve and circuit losses are not negligible, and therefore the calculations should start from the formulæ for the π-network. The resistances of this network are formed partly by the loss resistances of the coils and valves and partly by extra damping resistances, and it is the network formed by the latter that should be converted to the T-network used in the actual amplifier. Furthermore, it should be taken into account that the capacitances of the different stages are unequal, and that especially the capacitance in the last tuned circuit is low because this circuit is coupled to the detector. Also the loss factor of the last circuit is high because of the damping from the detector, and it may be necessary to connect the detector to a tap on the coil. On account of this, the feedback T network in the last feedback pair of an i.f. amplifier should be unsymmetrical. This fact is apparently not taken into account in the amplifier described in the later of Mr. Jewitt's two articles.

Owing to the small values of the capacitances of the circuits it is not possible to tune all circuits of the amplifier to the centre frequency by short circuiting the cross resistor in the feedback T network, as described in the articles. This is due to the mistuning developed by the self-capacitances of the resistors. The mistuning can, however, be avoided if one circuit of a pair is damped by a suitable shunting resistor when the other circuit is being tuned.

The accompanying Figure shows a selectivity curve obtained from a feedback i.f. amplifier containing five valves arranged in two feedback pairs and one single stage, calculated to give maximum flatness. It is mounted with feedback T networks calculated for a bandwidth of 4.7Mc/s and a centre frequency of 37.12Mc/s from the measured circuit capacitances and the measured coil and valve losses. It should be mentioned that after the calculation and the tuning of all circuits to the centre frequency, no empirical change of the amplifier has been made apart from adjusting the distance of the feedback T network to the chassis in such a way that the stray capacitance gives the correct tilt of the selectivity curve. In this way it was not necessary to connect any extra capacitor across the cross resistor of the T network to give the correct tilt.

For comparison the figure shows also the selectivity curve of a stagger-tuned amplifier designed as a quintuple for same centre frequency and bandwidth and built with the calculated values of the damping resistors, the resonating circuits being separately tuned to the calculated frequencies. It will be seen that the selectivity curve is very similar to that of the amplifier with feedback pairs, and that both curves are close to the desired curve. The curves shown are measured on an amplifier without sound-traps. The insertion of these did not present any difficulties.



JENS RASMUSSEN, P. V. IVERSEN.
Radio Receiver Research Laboratory,
Danish Academy of Technical Sciences
Copenhagen.

"As She Is Spoke"

I AM afraid I cannot agree with Mr. Briggs that the manufacture of loudspeakers should be prohibited. "But," Mr. Briggs may protest, "I never said it should!" Quite. Neither did I say, or even imply, that use of the word "recording" as a noun was wrong. On the contrary, the use I advocated was as a noun, namely, the process of making a record. I would agree with Mr. Briggs in including within that term the quality of the process, as distinct from the mechanical quality of the individual record produced, just as a photographic *print* may be said to show evidence of faulty *printing*. But he goes on to say that a record on tape must be referred to as a recording. Why? If, as may well happen, it becomes customary to print photographs on plastic materials, will Mr. Briggs insist on their being called "printings"?

It is true that, as Mr. Arnot says, the public are accustomed to records in the form of discs. But if they will now have to get used to them in the form of tapes, what of it? For many centuries they associated the word "ship" with a wooden structure surmounted by sails, but seem to have experienced no insuperable difficulty in subsequently admitting metal structures, with no sails. The word "record" implies nothing about the material basis, and is equally valid for all. A cheque is usually drawn on a slip of paper, but, as Sir Alan Herbert has pointed out, there is no legal reason why it should not be on the back of a live cow.

A perfectly logical terminology is too much to expect, but please, gentlemen, do not let us go out of our way to introduce false associations.

Bromley, Kent. M. G. SCROGGIE.

Television-To-Sound Interference

WHEN "In Town Tonight" the other evening was broadcast on both the Home and Television Services, I was amused to hear, quite distinctly, vision-channel interference in the background of the sound signal on the Home Service.

This must be very heartening to anyone who has at any time had difficulty in excluding vision interference from the sound channel of a domestic television receiver—and who has not?

London, N.10. IAN LESLIE.

Television Quality

MAY I add my support to the points made by G. T. Clack in the January issue of *Wireless World* concerning the poor quality of television transmissions during the News and Newsreel programme. Obviously there are reasons for this deplorable state of affairs and I suspect that they are not solely concerned with technical considerations. It is, however, most regrettable that the B.B.C.—who are soon going to face strong competition—should have allowed their normally superior standards to fall to such a low level at this crucial time. I would earnestly implore the authority responsible for the nightly perpetration of this return to the magic-lantern era to think again. Even if we ignore the poor technical standards surely very few viewers prefer the present presentation of the News to the previous and more polished style of a few years ago. Mr. Bernard Hollowood has quite adequately summarized the position in a recent article in *Punch.* He suggests that the troubles of News and Newsreel are caused by misplaced enthusiasm and a misconceived notion of the function of the service.

CHARLES A. MARSHALL.

Carshalton,
Surrey.

"Telepathy by V.H.F."

I HAVE just seen "Free Grid's" reference to Maskelyne and his radio experiments in your January issue. This is of great interest to me because the Maskelyne he refers to was my father, the late Nevil Maskelyne, and there can be no doubt as to the seriousness of the work he did. It may be of interest to recall that he was a director of The Amalgamated Wireless Telegraph Co., Ltd., and one of his co-directors was Lee de Forest, whom I was privileged to meet many years later.

I remember, as a small boy, living at Seasalter, near Whitstable, and being invited to look across the Thames estuary on fine days to "see father's wireless mast," at or near Shoeburyness. About the same time he had erected other wireless stations in the country and among them was one near Porthcurno, Cornwall, and another, I think, at Cleethorpes.

I remember well hearing of the incident in which my father proved to an audience at the Royal Institute that there certainly were weaknesses in the tuning devices then in use, though my memory does not connect with it the name of Sir Ambrose Fleming. At or about this time he visited the then St. Petersburg and was instrumental in introducing wireless to the Russian Government, who carried out experiments with a view to equipping the Russian navy.

There can be no doubt that some of his most useful work was carried out in conjunction with the Rev. J. M. Bacon's balloons. Of the two men, the one was interested in balloons as such and the other as a means of carrying wireless equipment. My father was a long-sighted man and foresaw that success in the air would come with heavier-than-air machines, and I have no doubt that he foresaw also that here lay a field for the utilization of wireless.

It may be of interest to record here that I have before me as I write a few leaves from his experimental notebook. The notes are dated July 9th, 1906, and they record, with diagrams, experiments he was then making with "diodes" connected up to produce continuous oscillation. They also show that he wasn't having a very happy time with it. Using a circuit in which there were two diodes connected, he failed to get continuous oscillation. However, he recorded that "Cossor sent in a third valve," and he repeated the experiment using all three, without success. His reasoning shows clearly that it was not more valves that he wanted, but the third electrode. But he just didn't think of it. However, a page or so later he records that he got his oscillations, but could not induce any current in his aerial. In the end he did get a current in his aerial and says that his previous failure to do so was because "The tuning proved to be so sharp that, on passing to the next turn of the helix in either direction, there was no aerial current."

I place a high value on these few pages of a great man's notebook, because they stand for me as a reminder that, but for a certain legal dispute that went against him in the House of Lords, my father might have died one of the greatest personalities of his time.

In the days immediately following my leaving college I tried to follow in his footsteps with the Mullard Radio Valve Co., Ltd., but the attempt proved only that my father was a much greater man than I.

Lurgashall, NOEL MASKELYNE.
Sussex.

Musical Feedback

AS a Scot who used to play the bagpipes before he came to live among the unmusical English, I would like to add to the analogy which "Cathode Ray" uses in his admirable article on rectifier circuits (March issue).

Whereas a capacitor depends to a large extent on dryness for low leakage, the bag of the bagpipes depends on moisture—a minor discrepancy—and the moisture is supplied by pouring into the bag a special liquid which is distilled in the Scottish Highlands.

Also the analogy could have been extended to say that the conductor from G to C is the pipe through which the piper blows. The pipe includes a valve which, in common with other one-way devices, hasn't got infinite resistance in one direction, but "let's by."

What it lets by is the vapour from the liquid in the bag and it is the subtle aroma from the vapour entering the respiratory organs of the "intermittently breathing Scot" that inspires and stimulates him to produce the stirring music which one associates with the bagpipes. It acts, in fact, as a sort of musical positive feed-back!

Leafield, Oxford. A. CAMPBELL.

Electronics on the Farm

I HAVE read with interest letters in your recent issues from H. G. P. Taylor and D. A. Bond on the subject of electric fencers, and your readers may be interested to have a few comments from a manufacturer.

The "hoary old stager" referred to by Mr. Taylor (the inductive discharge type with a balance wheel) has many advantages from the farmer's point of view and is still very much the most popular, both here and (more impressively, perhaps) in the United States, which is the pioneer country in electric fencing and where every conceivable idea has been tried out from time to time. This balance wheel type is robust, efficient from the input-output point of view and, moreover, the audible click at each impulse provides an easy way of ensuring that the unit is working. Also, a great many farmers prefer the rechargeable accumulator to purchasing dry batteries.

I would add the following comments to the various points raised in the two letters referred to above:

(1) A neon tube will not discharge the condenser to sufficiently low voltage due to high extinguishing voltage.

(2) A neon tube will not carry the high peak current required.

(3) Grid-triggered neon tubes such as those used in stroboscopes, while they are capable of passing heavy peak currents, will not work at the voltage of a standard high-tension battery.

(4) Glass-enveloped tubes would not, in my view, be suitable for use under the trying practical conditions experienced on a farm.

(5) The method suggested by Mr. Taylor of permanently connecting a neon in series with a high resistance across the line and earth does not give an indication of a good line, since even with the line fouled so badly that there is only 180 volts (peak) available the neon will still give a flash, but the line at this voltage will be practically useless.

Testing with a blade of grass, as suggested by Mr. Bond, is probably more effective though again extremely inaccurate. We now manufacture a tester incorporating a variable spark gap in series with a neon light, which gives a far more accurate indication.

I think your correspondents may not have heard that there is a British Standard Specification controlling the output and frequencies of electric fencers. This does not allow an interval of less than 0.75 second between impulses.

R. S. DRAKE.

The Wolseley Sheep Shearing Machine Company,
Witton, Birmingham.

OPEN LETTER TO THE POSTMASTER GENERAL

Allocation of Frequencies: A British Communications Commission

DEAR P.M.G.,

During the last twenty years there have been a number of proposals to revise the system under which frequencies are allocated. I suggest that the time has now come when this problem needs tackling. Some of the basic arguments were well covered in the leading article of *Wireless World* for [illegible]ember, 1954.

I suggest it is highly desirable to have a body outside the control of the Postmaster-General responsible for allocating frequencies. It is obviously essential, however, that the Government should maintain overall control in view of the vital part played by radio and radar in the defence of this country.

In the absence of alternative proposals, may I submit the outline of a scheme which might replace that used during the last fifty years?

Need for an Early Change.—The rapid expansion of radio and radar equipments makes the allocation of suitable frequencies increasingly important and difficult. Blocks of frequencies are becoming ever more precious, and it is important that no user, be he civilian or military, should occupy more frequencies than are strictly necessary.

Possible Alternative Method.—As long as the Defence Services are large-scale users of frequencies, the Government must retain overall control. In my submission, this should be exercised, not by the P.M.G., who is himself a user, nor by the Ministry of Defence, which is the largest user; but by some authority under a Minister who is not himself an interested party. I suggest the Lord President of the Council, who controls the Government's scientific policy and therefore has suitable advisers.

I suggest he should control a British Communications Commission and that this Commission should consist of two panels:

(a) The Civilian Radio Panel, on which the radio industry, the Board of Trade and other interested Ministries would be represented.

(b) The Defence Radio Panel, on which the Service Departments, including the Home Office, and the Ministry of Supply would be represented.

It is important that there should be a connection between the work of these two panels. I suggest that the Secretariat should be common to both, and that the Chairman of each Panel should be a member of the sister Panel.

Proof of Occupancy.—The operational needs and radio techniques of the Defence Services are constantly changing. The same applies to the civilian radio services. It is important, therefore, that the frequency bands allocated by the British Communications Commission should be monitored to make sure that unnecessary interference is not being caused, and that the channels are being adequately used.

The responsibility for this monitoring service is a matter which could be discussed later. The G.P.O. have an obvious claim, as they have suitable equipment and personnel. The monitoring service should furnish reports direct to the British Communications Commission.

I don't pretend that this is the ideal set-up, but I would like to see some constructive alternative put forward which would ensure an independent and balanced control of the radio spectrum.

Yours sincerely,

House of Commons. C. I. ORR-EWING.

Design for an F.M. Tuner

(Concluded from p. 163 of the April issue)

2—Circuit and Constructional Details

By S. W. AMOS,* B.Sc. (Hons.), A.M.I.E.E. and G. G. JOHNSTONE,* B.Sc. (Hons.)

THE basic principles governing the design of an f.m. receiver were described in last month's issue and this article gives full details of an f.m. tuner based on these principles. The circuit comprises a pentode r.f. amplifier, a frequency-changer consisting of a pentode mixer and separate triode oscillator, followed by an i.f. amplifier employing two pentodes in cascade, the second acting as a high-level limiter. The next stage is a ratio detector with two crystal diodes feeding a triode cathode-follower output stage. The oscillator and cathode follower are the two halves of a double-triode valve and this, together with a magic-eye tuning indicator and h.t. rectifier bring the total of valves to seven (excluding crystals). There is considerable latitude in the choice of valves. The four pentodes are of the same type; the authors have successfully used B7G-pentodes of the EF91 type and B9A-pentodes of the EF80 type. The double-triode is a 12AT7 or equivalent and the rectifier can be any type delivering 40 mA at 250 V which can be operated from the general l.t. winding.

The complete circuit diagram of the tuner is given in Fig. 1. V_1 is the r.f. stage and the grid-circuit tuning is pre-set to approximately 94 Mc/s, the centre of the 12.5-Mc/s range it is intended to receive. To keep the loss in sensitivity at the ends of the band to less than 3 db, the effective Q of the grid circuit must be less than 94/12.5, or approximately 7.5. The input transformer L_1L_2 is designed to match an 80-Ω unbalanced feeder to a resistive load consisting of the input resistance of V_1 in parallel with the dynamic resistance of the secondary circuit. The dynamic resistance is approximately 2,500 Ω and the valve input resistance may be between 2,000 Ω and 4,000 Ω for an EF91 and 4,000 Ω for an EF80. The effective secondary load may thus be between 1,100 Ω and 1,500 Ω depending on the valve type; the average may be taken as 1,300 Ω, which is reduced to 650 Ω by the addition of the connection to the feeder. To obtain a Q of 7.5 from an L-C circuit of effective dynamic resistance of 650 Ω requires a reactance of 650/7.5, or approximately 90 Ω. At 94 Mc/s this implies a capacitance of 19 pF. Of this 14 pF is contributed by the valve and stray capacitance and remaining 5 pF is added in the form of a physical component.

The anode circuit of V_1 is tuned by L_3C_{15}, C_{15} being one section of the two-gang tuning capacitor. Each section of this capacitor has a capacitance range of about 7 pF and this must have in parallel a fixed capacitor to give the desired frequency range of 87.5 to 100 Mc/s. For a given inductor the reson-

* Engineering Training Department, British Broadcasting Corporation.

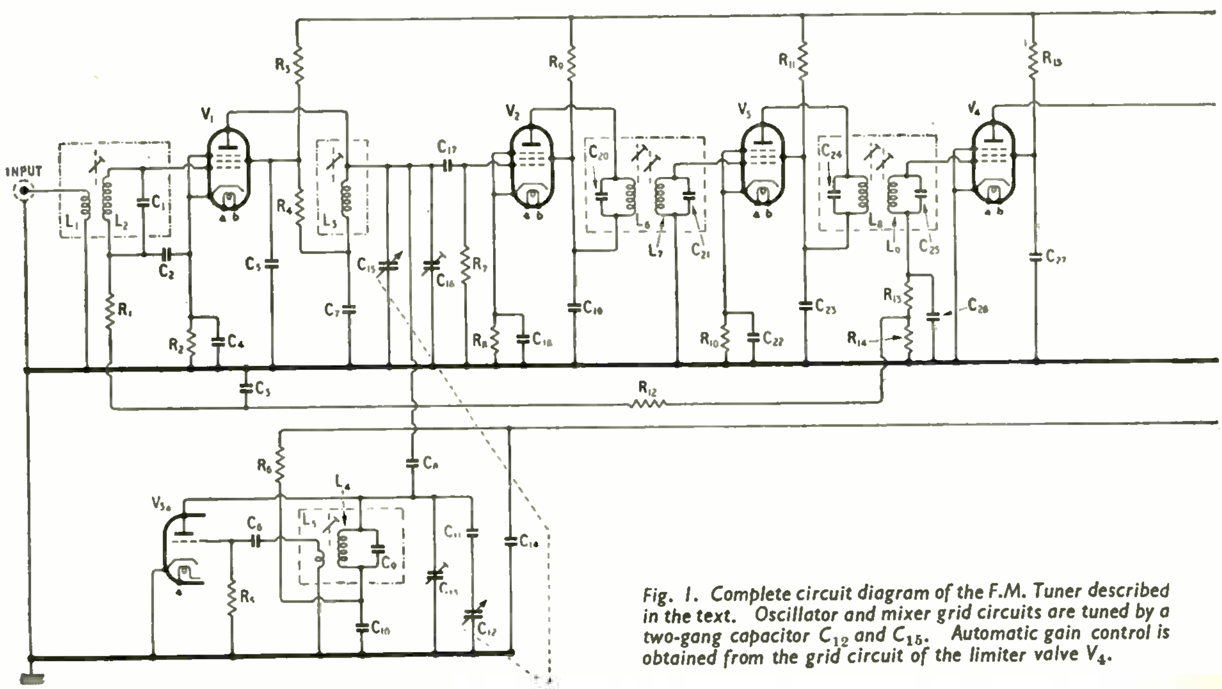


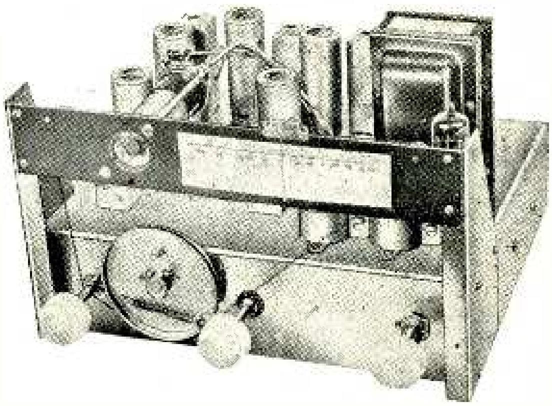
Fig. 1. Complete circuit diagram of the F.M. Tuner described in the text. Oscillator and mixer grid circuits are tuned by a two-gang capacitor C_{12} and C_{15}. Automatic gain control is obtained from the grid circuit of the limiter valve V_4.

ance frequency depends on the square root of the capacitance and thus we have

$$\frac{C + \Delta C}{C} = \left(\frac{100}{87.5}\right)^2$$

where ΔC is 7 pF and C is the fixed capacitance. This gives C as 22 pF. This is approximately the value of capacitance present in the circuit and is made up of the output capacitance of V_1 (4 pF), the input capacitance of V_2 (11 pF), the minimum capacitance of the tuning capacitor (3 pF), strays and the capacitor C_8 in the oscillator circuit. For alignment of the circuit it is necessary to have a trimmer in parallel with L_3 and, because the minimum capacitance of this component necessarily adds further fixed capacitance, the contribution from V_2 is reduced by using a 50-pF coupling capacitor C_{17}. By adjustment of the trimmer C_{16} the correct ratio of maximum to minimum frequency can be obtained and by adjustment of the inductance of L_3 operation can be secured in the correct frequency band.

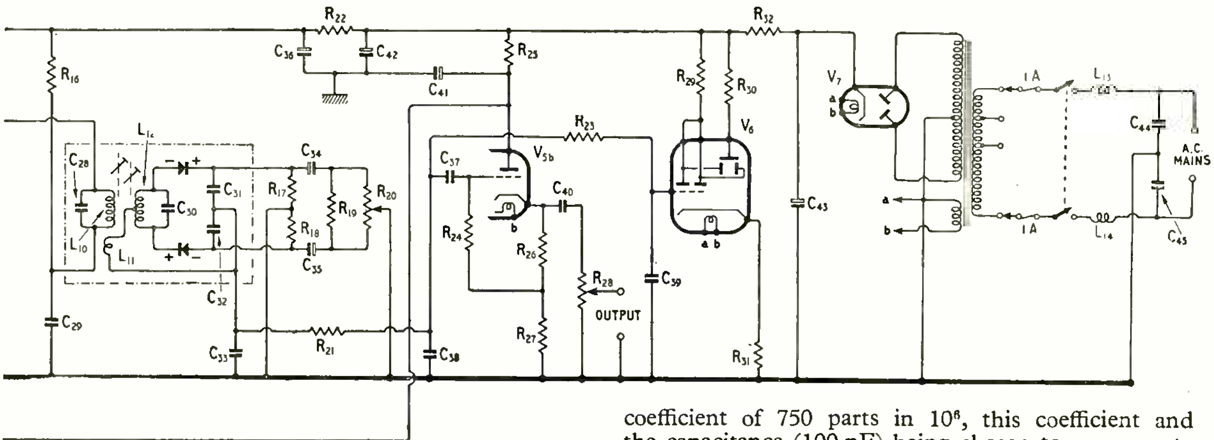
The oscillator is a triode (V_{5a}) operating on the high side of the signal frequency. The intermediate frequency is 10.7 Mc/s and the oscillator frequency limits are therefore 98.2 and 110.7 Mc/s. This is achieved with the second section of the tuning capacitor C_{12}, the capacitance swing being limited to 6 pF by a series fixed capacitor. The fixed shunt capacitance required to give the correct ratio of maximum to minimum frequency is also 22 pF as for the intervalve r.f. circuit. Of this approximately 4 pF is contributed to V_{5a}, 3 pF by the tuning capacitor, 1 pF by the coupling to the mixer grid and 2 pF by stray capacitance, leaving 12 pF to be included as a physical component. This is made up of a capacitor C_9 and a trimmer C_{13} which is adjusted, as explained in the alignment procedure, to give the desired ratio of maximum to minimum frequency.



General layout of the front of the tuner.

being connected across a small coupling coil, has little effect on frequency of oscillation. Variations in grid-cathode capacitance can cause significant fluctuations in frequency if the resonant circuit is connected between grid and cathode. In the circuit adopted the resonant circuit is shunted by the anode-cathode and anode-grid capacitances which are more stable than the grid-cathode capacitance. It is this latter capacitance which principally controls the frequency drift in the first few minutes after switching on, the total change in this period being of the order of 25 per cent. With the particular form of oscillator circuit adopted, this warming-up shift is reduced to negligible proportions.

The components used in the oscillator circuit are chosen to minimize long-term frequency drift. For example C_{11} in series with the tuning capacitor is an N750 type, i.e. has a negative temperature



The particular oscillator circuit employed was chosen because it enables the cathode of the valve and the moving vanes of the tuning capacitor to be earthed. In this form of oscillator the resonant circuit can be included in the anode or the grid circuit but the former arrangement was considered better because it presents the valve with a higher value of anode load and thus gives a larger output. Moreover the grid-cathode capacitance of the valve,

coefficient of 750 parts in 10^6, this coefficient and the capacitance (100 pF) being chosen to compensate as far as possible for the positive temperature coefficient of the tuning capacitor. Similarly the capacitance and coefficient of C_9 are chosen to compensate for variations with temperature of the inductance of L_4; this capacitor is included in the screening can so as to have the same temperature as the inductor. Unless components of similar specification are used in this part of the circuit there may be an undesirable drift in tuning; the complete specification for these and all components in the tuner is given in the list

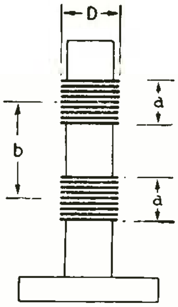


Fig. 2. The i.f. transformers used in the set take this form. As explained in the text the coupling coefficient and hence bandwidth is calculated from the dimensions a and b.

of parts. Provided the correct components are used the long-term frequency drift is very small.

The oscillator output is connected to the mixer V_2 by a small fixed capacitor C_8, the value of which is chosen to give the correct value of oscillator drive at the mixer grid. At the oscillator frequency the mixer circuit behaves as a capacitance the value of which is given approximately by $2Cf_1/f_2$ where C is the physical capacitance present, f_1 is the intermediate frequency and f_2 the oscillator frequency. Substituting C=25 pF, f_1=10.7 Mc/s and f_2=105 Mc/s (values applying when the tuning capacitor is at its mid-setting) gives the effective capacitance as 5 pF. The oscillator output at V_{5a} anode is approximately 20 V peak and the drive required at V_2 grid for optimum conversion conductance is 3 V peak; thus the optimum value of C_8 is less than 1 pF. In practice a 1-pF capacitor is used and the drive is about 4 V in peak value, varying slightly as the tuning setting is changed.

V_2 is an additive mixer and is biased partly by conventional cathode resistor and capacitor and partly by grid current flowing in the 1-MΩ grid leak R_7 as a result of the oscillator drive. The i.f. transformer connected in its anode circuit is of the usual double-wound type and has two similar windings on a former of 0.3 in diameter. To minimize any capacitance coupling between the windings (which might affect the shape of the response curve) the adjacent ends of the windings are arranged to be earthy. The position of the dust-iron cores can affect the mutual inductance significantly and to minimize these effects the design is such that at resonance the cores are only approximately half-embedded in the outer ends of the windings. The spacing between the windings is very critical and an error of as little as 1/16 in can alter the coupling factor (kQ) from 1.2 to 2.0! A formula which has proved very useful in calculating the required spacing (giving coupling factors within a few per cent of the measured values) is the following derived by one of the authors† some years ago:—

$$b = 0.44D\left[\left(\frac{1+2.3a/D}{k}\right)^{\frac{1}{3}}-1\right]$$

where b = distance between coil centres
D = overall diameter of windings
a = length of each winding

† S. W. Amos, Calculating Coupling Coefficients; *Wireless World*, September, 1943. p.p. 272, 273.

LIST OF PARTS

Coils:
Aerial. Allen type FMC102; Osmor type QAFM.
R.F. inter-valve: Allen type FMC103; Osmor type QRFM.
Oscillator: Allen type FMC104; Osmor type QOFM.
I.F. transformer: Allen type FMC101; Osmor type QIFM; Denco type IFT11.
Ratio-detector transformer: Allen type FMC151; Osmor type QICD.

Valves:
Pentodes: EF91, Z77 or equivalent.
EF80, Z719 or equivalent.
Double-triode: 12AT7, B309 or equivalent.
Rectifier: EZ80, U709 or equivalent.
Magic eye: EM34.
Crystals: GEX34 or OA72.

Mains transformer:
Electro-Voice type 104E.

Tuning-drive Components:
Spindle, drum, flywheel, universal coupler, pulleys, pivots, pointer, cord, spring etc. Jackson Bros.

Mains R.F. Chokes:
Dubilier 1-amp type.

Resistors:
All resistors can be ¼ W rating and ±20 per cent tolerance unless otherwise specified.

R_1 10 kΩ
R_2 270 Ω ± 10% for EF80 or 180 Ω ± 10% for EF91
R_3 1 kΩ
R_4 1 kΩ
R_5 47 kΩ
R_6 1 kΩ
R_7 1 MΩ
R_8 270Ω±10% for EF80 or 180Ω±10% for EF91
R_9 1 kΩ
R_{10} 270Ω±10% for EF80 or 180Ω ± 10% for EF91
R_{11} 1 kΩ
R_{12} 1 MΩ
R_{13} 100 kΩ
R_{14} 100 kΩ
R_{15} 100 kΩ
R_{16} 1 kΩ
R_{17} 8.2 kΩ ± 1%
R_{18} 8.2 kΩ ± 1%
R_{19} 6.8 kΩ
R_{20} 10 kΩ potentiometer

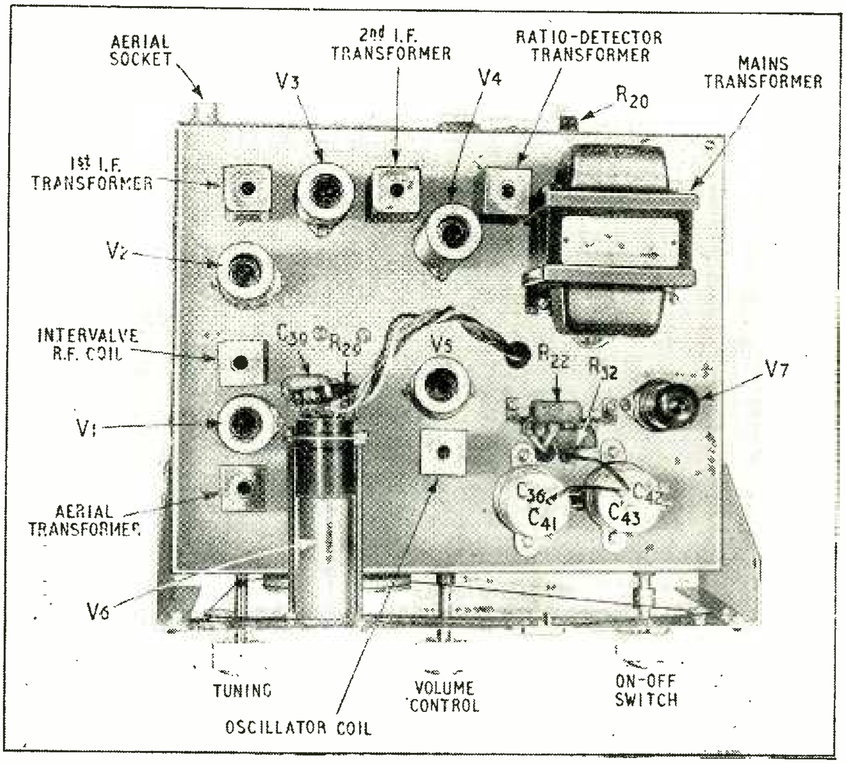
Resistors (*continued*)
R_{21} 100 kΩ
R_{22} 1.5 kΩ 3W
R_{23} 1 MΩ
R_{24} 1 MΩ
R_{25} 10 kΩ ½W
R_{26} 470 Ω±10%
R_{27} 47 kΩ
R_{28} 50 kΩ potentiometer
R_{29} to be selected
R_{30} 200 kΩ
R_{31} 1.5 kΩ
R_{32} 1 kΩ 3 W

Capacitors:
Where a capacitor is specified as a particular type, or with a particular value of temperature coefficient, it is essential to use this type.

C_1 5 pF
C_2 0.005 μF ceramic
C_3 0.1 μF 150V
C_4 0.005 μF ceramic
C_5 0.005 μF ceramic
C_6 20 pF Erie NPOK
C_7 0.005 μF ceramic
C_8 1 pF Erie NPOK
C_9 8.2 pF Erie N750K
C_{10} 0.001 μF silver mica
C_{11} 100 pF Erie NPOK
C_{12} 3-10 pF tuning capacitor, Jackson Bros. type U102
C_{13} 1.5-7 pF trimmer Erie type NPO557A
C_{14} 0.005 μF ceramic
C_{15} Same as C_{12}
C_{16} 1.5-7 pF trimmer Erie type NPO557A
C_{17} 50 pF
C_{18} 0.005 μF ceramic
C_{19} 0.005 μF ceramic
C_{20} 50 pF silver mica ±5%
C_{21} 50 pF silver mica ±5%
C_{22} 0.005 μF ceramic
C_{23} 0.005 μF ceramic
C_{24} 50 pF silver mica ±5%
C_{25} 50 pF silver mica ±5%
C_{26} 20 pF
C_{27} 0.005 μF ceramic
C_{28} 10 pF Erie type N750
C_{29} 0.005 μF ceramic
C_{30} 39 pF Erie type N330
C_{31} 300 pF
C_{32} 300 pF
C_{33} 300 pF
C_{34} 25 μF 25 V electrolytic
C_{35} 25 μF 25 V electrolytic
C_{36} 16 μF 350 V electrolytic
C_{37} 0.01 μF
C_{38} 500p F
C_{39} 0.1 μF 150 V
C_{40} 0.25 μF 150 V
C_{41} 16 μF 350 V electrolytic
C_{42} 16 μF 350 V electrolytic
C_{43} 16 μF 350 V electrolytic
C_{44} 470 pF Erie type CD9P/101
C_{45} 470 pF Erie type CD9P/101

These dimensions are illustrated in Fig. 2. As an example of the use of this formula suppose $a = 0.35$ in and $D = 0.32$ in. If the working Q value is 70, and the coupling factor is required to be 1.2, the coupling coefficient must be 1.2/70 = 0.017. Substituting in the above expression gives b as 0.68 in. The spacing between the adjacent ends of the coils must hence be 0.68−0.35 = 0.33 in.

V_3 is the first i.f. stage and operates at full gain. V_4, the second i.f. stage, is designed to work as a high-level limiter and operates with a screen-grid voltage of approximately 100. There is no cathode bias and on receipt of an input signal the valve takes grid current, developing a voltage across R_{13} and R_{14} equal to the peak value of the signal. The voltage across R_{14} is fed back to the grid of V_1 as a.g.c. V_4 acts as a leaky-grid detector and any amplitude modulation present on the input signal (due to ignition interference for example) appears across R_{14}. R_{12} and C_3 are included in the a.g.c. line to prevent such signals from reaching V_1. The grid base of V_1 is approximately 5 V and the a.g.c. line cannot therefore exceed 5 V no matter how strong the received signal. To give 5 V across R_{14} the input to the limiter must be 10 V peak; this is approximately 3 times the grid base of V_4 and thus ensures reasonably good limiting at high signal levels.



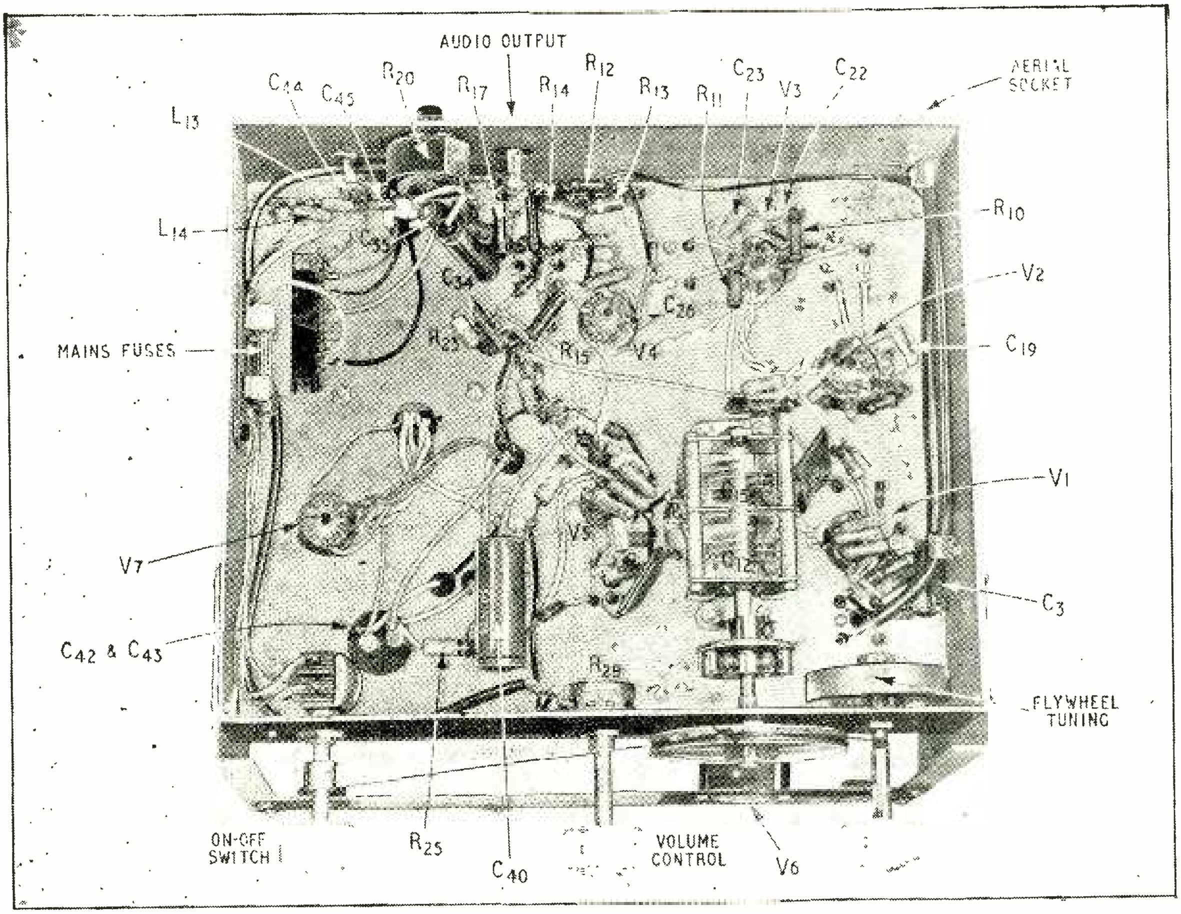
The relative position of the larger components, valves and coils is shown by this view.

The decoupling used in the i.f. amplifier must be satisfactory at 10.7 Mc/s and at very much higher frequencies in order to prevent parasitic oscillation and i.f. harmonic feedback to the r.f. stages. Satisfactory operation was obtained by using 0.005-μF ceramic capacitors for decoupling throughout the tuner. The heater current of all valves is supplied through tightly twisted twin flex. Decoupling was necessary only at the heaters of V_1 and V_5 where a 0.005-μF capacitor is joined between each heater socket in the valve holder and chassis in order to cure a slight modulation hum.

The discriminator transformer L_{10}, L_{11}, L_{12} was wound by the authors to a specification by the General Electric Company but it is also obtainable commercially (see the list of parts). It employs two crystals which are included with the capacitors C_{31}, C_{32} in the screening can. With a ratio detector of the conventional type, such as that used in the F.M. Feeder Unit (*Wireless World*, September 1952) amplitude limitation is adjusted to a maximum by variation of the resistance in series with the electrolytic capacitors. Such adjustments upset the d.c. balance of the circuit with the result that there may be a d.c. output when the applied signal is accurately in tune. This was of no significance in the F.M. Feeder Unit but in this tuner the d.c. output is used to operate a magic-eye tuning indicator, and for this to be successful, it is essential that adjustment of the series resistance should not affect the d.c. balance. The circuit used meets these requirements provided the resistors R_{17} and R_{18} are equal; 1 per cent tolerance components are recommended.

The output of the discriminator passes through the de-emphasis network (of 50 μsec time constant) R_{21}, C_{38} and then feeds the magic-eye through the network R_{23}, C_{39} which removes a.f. signals which would cause blurred tuning indication. The a.f. output is applied to the cathode follower V_{6b}.

The use of a cathode follower as output stage has the advantage that the tuner can feed amplifiers with comparatively low input resistance (such as 10 kΩ) without loss of audio signal. If such a resistance were to be connected directly across the output of the de-emphasis network there would be a loss of more than 20 db due to the series resistor R_{21} and this resistor cannot be reduced without affecting the performance of the detector. A second advantage resulting from the use of a cathode follower is that its low output resistance permits the use of comparatively long screened leads to the following amplifier without attenuation of upper audio frequencies. The highest output resistance occurs when the gain control, R_{28}, is at its mid-position and has a value of about 12.5 kΩ; it is possible to load such a generator resistance with as much as 600 pF of shunt capacitance before the loss at 10 kc/s approaches 1 db. The cathode follower has quite a small a.f. input and can operate satisfactorily with a low anode current. The current is approximately 2 mA and is kept low to reduce the rise in temperature of the valve. The cathode follower is in the same bulb as the oscillator and it is advantageous to keep the temperature rise as small as possible in the interests of frequency stability.



The bulk of the smaller components, including the gang capacitor, are located below the chassis. The annotation enables most of them to be identified.

It is by no means easy to tune an f.m. receiver accurately to a desired transmission by ear and some form of tuning indicator was considered necessary. The obvious choice is a magic eye connected across the a.g.c. line, or across the electrolytic capacitor of the ratio detector. This is unsatisfactory if the receiver has the right shape of passband because the deflection of the eye remains substantially unaltered over a frequency range of approximately 100 kc/s on either side of the correct tuning point. If, as is common, the selectivity characteristic is asymmetric as a result of Miller effect the maximum a.g.c. voltage can give a positively misleading indication.

A precise tuning indication can be obtained from the output of the ratio detector which is zero when the receiver is correctly tuned, but is positive or negative if the receiver is mistuned. In fact the polarity and magnitude of the ratio detector output indicate respectively the sense and degree of mistuning. The tuning indicator is thus required to show accurately when the ratio detector output is zero and it was found that a magic eye operated under certain conditions could be used for this purpose.

The magic-eye circuit is so designed that the eye is closed (shadow angle zero) when there is no input to the control grid. If a positive voltage is applied to the control grid the eye opens, i.e. the shadow angle increases and if a negative voltage is applied the sectors of luminescence overlap, corresponding to a negative shadow angle. To avoid grid current and to enable the eye to respond to positive inputs a resistor is included in the cathode circuit and the anode and target potentials are then so chosen that the eye is closed for zero input voltage. This condition can be obtained with a high value of target potential, but a low value of anode load is required and the sensitivity of the eye is poor. By using a lower target potential a higher value of anode load can be used and satisfactory sensitivity obtained, but the brightness of the eye is poor. In the compromise solution adopted the target potential is approximately 100 V and the anode load is of the order of 250 kΩ. Where a tuner is normally operated with a large input signal the maximum sensitivity of the eye is unnecessary and a brighter display could be obtained by using a higher target potential of say 170 V and a lower value of anode resistor.

The mains unit is conventional and includes a mains transformer with two secondary windings, one supplying 40 mA at 250—0—250 V and the other supplying 3 A at 6.3 V. The smoothing circuit includes three resistors R_{22}, R_{25} and R_{32} and four electrolytic capacitors; for convenience the capacitors are in the form of two 16 + 16-μF components. The mains lead includes an r.f. filter L_{13} L_{14} C_{44} C_{45} which prevents radiation of r.f. energy from the lead outside the chassis; this filter, to be effective, must be situated very close to the point where the lead leaves the chassis.

Before aligning the receiver it is advantageous to adjust the tuning indicator. To do this short-circuit C_{39} and replace R_{29} by a 1-MΩ variable resistor. Adjust R_{29} to give zero shadow angle, i.e. close the eye, and then replace the variable resistor by a fixed one of the same value. Remove the short circuit.

The alignment can now be carried out and for this purpose an a.f. amplifier is required and also an a.m. signal generator capable of giving an output at 10.7 Mc/s and between 87.5 and 100 Mc/s. With the amplifier connected to the tuner output apply a modulated signal at 10.7 Mc/s to V_4 grid and adjust L_{10} for maximum audio output. Switch off the modulation and with a plain carrier input to the limiter adjust L_{12} until it is accurately tuned as indicated by the magic eye. The correct tuning is achieved when the eye is just closed and with no overlap of bright areas and no shadow showing. As the core is rotated from this position the eye either opens or the bright regions overlap and display a brighter centre segment.

Now transfer the generator output to V_3 grid and connect the amplifier input across C_{26}. With a modulated r.f. input at 10.7 Mc/s adjust the cores of the second i.f. transformer to give maximum audio output from the amplifier. Transfer the generator output to V_2 grid and repeat the adjustment for the first i.f. transformer. These adjustments should be carried out at all times with the smallest output from the generator which can be heard adequately.

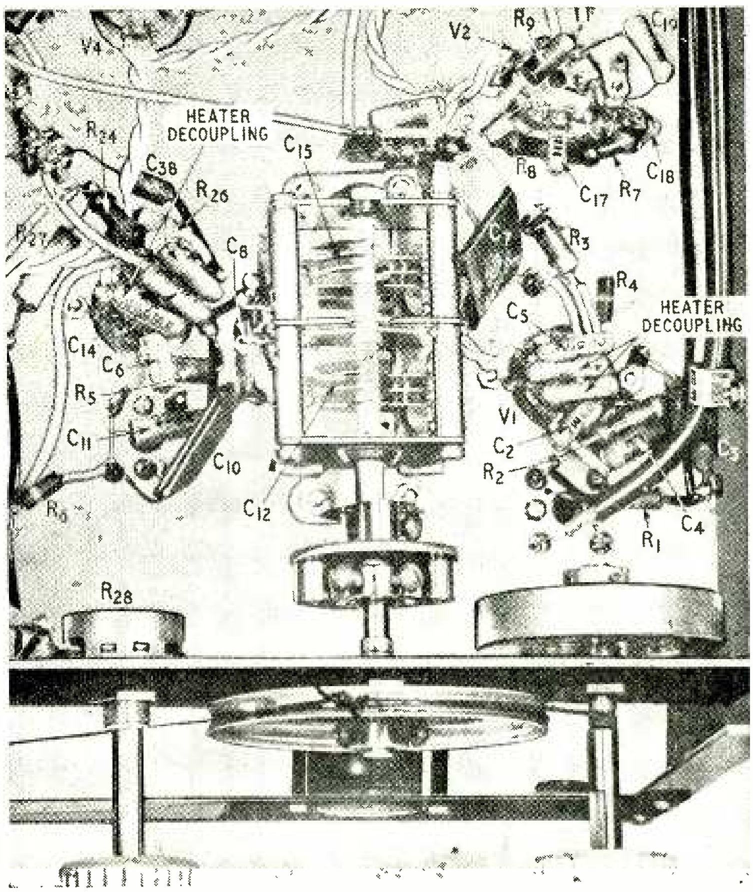
With the amplifier still connected across C_{26} transfer the generator to the aerial input socket of the tuner. Adjust the generator to give a modulated output at 87.5 Mc/s and set capacitors C_{12} and C_{15} to maximum. At this setting of the tuning capacitors the pointer should indicate 87.5 Mc/s. Tune in the signal by adjustment of L_4; if the signal can be heard at two core settings choose that corresponding to the smaller inductance. Then adjust L_3 to give maximum output. Now set the generator to 100 Mc/s and the tuning capacitor to minimum capacitance; the pointer should now indicate 100 Mc/s. Adjust C_{13} to tune in the signal and C_{16} to give maximum output. Repeat the inductance adjustment at 87.5 Mc/s and the capacitance adjustment at 100 Mc/s until no further improvement can be effected.

Disconnect the signal generator and reconnect the amplifier to the a.f. output socket of the tuner. Set the tuning control to approximately 94 Mc/s and adjust the inductance of L_2 to give maximum noise output.

Finally, to adjust the potentiometer R_{20}, connect an aerial to the tuner and find a weak signal. Adjust R_{20} to give minimum background noise; if the signal is frequency modulated this setting should also give best quality of reproduction. It is possible that a different setting of R_{20} may be required for a larger input signal. The value of R_{19} was found to be optimum for the particular ratio detector transformer and crystals used and should be generally suitable for commercial versions of it. If, however, the highest degree of a.m. rejection is required the value of R_{19} should also be adjusted.

Mechanical details of the tuner can be seen from the accompanying photographs. A conventional chassis of 16 s.w.g. aluminium measuring 10 in by 8 in by 2½ in is used. The tuning capacitor is mounted underneath the chassis and the coils above the chassis, and individually screened. The smoothing resistors dissipate approximately 4 W and are mounted above the chassis for good ventilation; if these components are located underneath there might be some frequency drift due to the increase in temperature of components near the resistors. The smoothing resistors are at h.t. potential and are placed away from the edges of the chassis to avoid, as far as possible, accidental contact with them.

The tuning spindle on the left-hand side of the front panel drives a cord which passes once round the 2¾ in diameter drum and over two pulleys riveted at the upper corners of the tuning scale, tension being applied to the cord by a spring inside the drum. The drum drives the tuning capacitor via a flexible coupling and the cord carries a pointer which slides along the top of the tuning scale, which is of 20 s.w.g.



This enlarged section of the underside of the chassis shows in greater detail the layout of the r.f. and oscillator stages.

steel. The tuning capacitor has no stops to limit its rotation to 180 deg and the necessary limitation is provided by a 6-BA cheese-headed bolt which is secured to the drum and strikes the heads of similar bolts secured to the front panel when the capacitor reaches its maximum and minimum settings. The pointer travel is nearly 4½ in but, because of the length of the slider, a space of 5½ in must be allowed between the magic eye and the right-hand pulley. Cord drives of this type tend to have a rather " dead " feel due to the friction present and this has been overcome by a lead flywheel secured to the tuning-spindle behind the front panel. The inertia of this wheel, though insufficient to give " spin-wheel " tuning improves the smoothness of the drive considerably.

The magic-eye holder is secured to the scale by two 3¼-in. lengths of 4-BA studding and the target is viewed through a ⅛-in. diameter hole in the scale.

For the benefit of constructors who prefer to wind their own coils, full details are included. There are, however, commercial coils quite suitable for use in this circuit and their type numbers are given in the list of parts. The layout and pin connections for the r.f. coils are given in Fig. 3; for the sake of clarity primary and secondary windings are shown as separate coils but they are in fact overlapping as mentioned in the specification.

Coil Winding Data—*Aerial Coil :* Primary—2¼ turns of 22 s.w.g. tinned copper wire in insulated sleeving inter-wound with earthy end of secondary. Secondary—4¾ turns of 18 s.w.g. tinned copper wire spaced so as to occupy 0.5 in. Former-Aladdin type PP5938. Core—Aladdin v.h.f. grade, colour-coded purple. Can—John Dale type TV2.

R.F. Inter-valve Coil: Winding—2¾ turns of 18 s.w.g. tinned copper wire space-wound so as to occupy a length of 0.3 in. Former, core and can as for aerial coil.

Oscillator Coil: Anode winding—2¼ turns of 18 s.w.g. tinned copper wire spaced so as to occupy a length of 0.3 in. Grid winding—1¼ turns of 22 s.w.g. tinned copper wire in insulated sleeving wound over earthy end of anode winding. Former, core and can as for aerial coil.

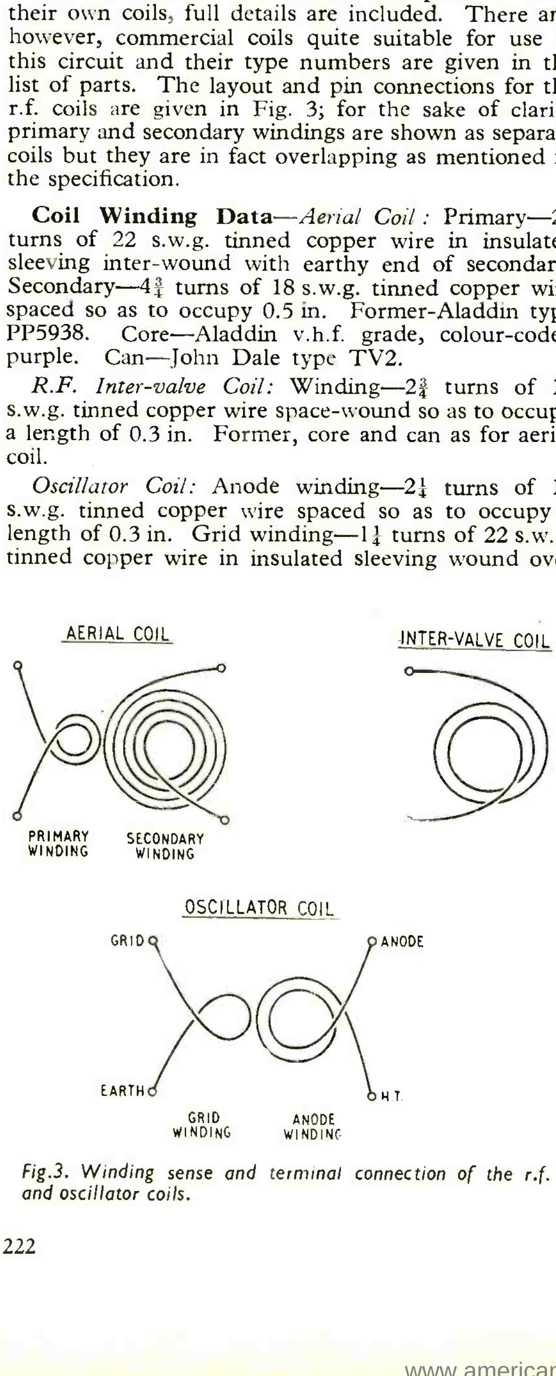


Fig.3. Winding sense and terminal connection of the r.f. and oscillator coils.

I.F. Transformer: Primary and secondary—23 turns of 28 s.w.g. single-silk and enamelled copper wire close-wound. Spacing between adjacent ends of windings—accurately $\frac{5}{16}$ in. Former—Aladdin type PP5937. Core—Aladdin, colour-coded grey. Can—John Dale type TV1.

Ratio-detector Transformer: Primary—35 turns of 36 s.w.g. single-silk and enamelled copper wire close-wound. Secondary—16 + 16 turns of 28 s.w.g. single-silk and enamelled copper wire, bifilar, close wound. Tertiary—9½ turns of 36 s.w.g. single-silk and enamelled copper wire close-wound over paper interlay 0.002 in. thick over end of primary remote from secondary. Spacing between primary and secondary—$\frac{3}{16}$ in. Former, core and can as for i.f. transformer.

CLUB NEWS

Barnsley.—At the meeting of the Barnsley and District Amateur Radio Club on May 13th, H. H. Eyre (G5KM) will give a demonstration of i.f. crystal filter operation. Meetings are held at 7.0 at the King George Hotel, Peel Street, Barnsley. Sec.: P. Carbutt (G2AFV), 33, Woodstock Road, Barnsley, Yorks.

Birmingham.—The subjects for the May meetings of the Slade Radio Society are (13th) "Amateur Radio Direction Finding," by N. B. Simmonds, and (27th) "Past and Present in Amateur Radio," by E. G. H. Brown (G5BJ). The first of the season's d.f. tests for the Harcourt Trophy will be held on May 8th. The club meets on alternate Fridays at 7.45 at The Church House, High Street, Erdington, Birmingham. Sec.: C. N. Smart, 110, Woolmore Road, Erdington, Birmingham, 23.

The Birmingham and District Short Wave Society, which meets on the second Monday of each month at 7.45 at the Y.M.C.A., 20, Soho Road, Hockley, Birmingham, 19, will be addressed by T. Burton on May 9th, when his subject will be aerials. Sec.: R. Yates, 28, Daimler Road, Yardley Wood, Birmingham, 14.

Canterbury.—The East Kent Radio Society continues to meet on alternate Tuesdays at 8.0 at The Two Brothers, Northgate Street, Canterbury. Details of the programme are available from the secretary, D. Williams, Llandogo, Bridge, Canterbury, Kent.

Cleckheaton.—A member of the Leeds Post Office staff will be talking on elementary direction finding to members of the Spen Valley and District Radio and Television Society at their meeting on May 4th. The club meets on alternate Wednesdays at 7.30 at the Temperance Hall, Cleckheaton. Sec.: N. Pride, 100, Raikes Lane, Birstall, nr. Leeds.

Coventry.—In addition to the regular meetings on May 9th and 23rd the Coventry Amateur Radio Society will be holding a two-metre field day on May 1st. At the meeting on the 9th K. Barber (G3HDP) will deal with receiver servicing and on the 23rd W. Grimbaldeston (G6WH) will speak on frequency modulation. Meetings are held at 7.30 at 9, Queens Road, Coventry. Sec.: J. H. Whitby (G3HDB), 24, Thornby Avenue, Kenilworth, Warwicks.

Two-Call Club.—The new president of the British Two-Call Club is Lt. Col. Sir Evan Y. Nepean, Bt. (G5YN, VS1YN, DL2YN), and Major K. E. S. Ellis (G5KW, DL2KE, HZ1KE) is the new vice-president. Membership of the club is open to British subjects who have held calls in two countries, or, alternatively, in two areas of the British Empire Radio Union. Sec.: G. V. Haylock (G2DHV), 63, Lewisham Hill, London, S.E.13.

Design for a 20-Watt High Quality Amplifier

By W. A. FERGUSON,* B.Sc.(Eng.), A.C.G.I., Grad.I.E.E.

Choice of Valves and Operating Conditions

IN recent years remarkable improvements have been made in the field of sound reproduction. Progress in the design of pickups, amplifiers and loudspeakers, coupled with the introduction of high-quality disc and tape recordings and v.h.f. sound broadcasting has set new standards for discriminating listeners. The amplifier and associated control circuits form the core of a sound-reproducing system and much interest has been focused on their design requirements and the manner in which high quality can be achieved.

The basic requirements of an amplifier designed for high-quality sound reproduction have previously been discussed in these pages[1, 2]. It is proposed here to discuss further some aspects of high-quality amplifier design, with emphasis on the output stage, and it is hoped to describe in a subsequent article a design for a high-quality 20-watt amplifier using 25-watt high-slope pentodes in the output stage.

The principal features of a good amplifier can be briefly recapitulated:

1. Very low harmonic and intermodulation distortion.
2. Linear frequency response in the audible range.
3. Good response to signals of a transient nature.
4. Low phase shift in the audible frequency range.
5. Low hum and noise level.
6. Adequate power output to allow peak passages to be reproduced without overload.
7. Low output resistance to provide electrical damping for the loudspeaker system.

Output Stage.—Although the power-handling capacity of an audio amplifier is not the most important factor from the listening point of view—a low distortion level being usually judged pre-eminent—it is nevertheless of prime importance from the point of view of the designer.

It is generally considered that for realistic reproduction of orchestral music in the home a peak output power of 10-15 watts is required, assuming the efficiency of the loudspeaker system to be about 5%. Apart from loudspeaker efficiency, the required power depends on the size and acoustic nature of the room and to a lesser extent on the taste of the listener. Thus, whilst 10 watts is found to be adequate in many, perhaps, the majority of, cases conditions in large rooms and small halls may merit a power reserve of at least 20 watts.

There exists a choice of two basic forms of output stage from which an effective output of 10-15 watts can be delivered to the voice coil of the loudspeaker. These two well-known forms of output stage are:

1. The Class AB push-pull pentode or tetrode stage.
2. The Class A or Class AB push-pull triode stage.

The choice between these is largely a balance between economy and performance.

Pentode Output Stage.—The use of pentodes or tetrodes of the 12-watt anode dissipation class, operated in a conventional Class AB push-pull stage, enables an effective output of 12-13 watts to be obtained easily, assuming an output transformer efficiency of about 80%. This latter value is typical of present practice. The appropriate supply voltage, limited by valve ratings, is about 300-320 volts. The overall power efficiency of such a stage is fairly high, being 50% for a typical stage employing Mullard EL84 output pentodes. Harmonic distortion is, however, of the order of 3%-4% at full output, and in consequence a high degree of negative feedback is necessary to reduce distortion to low levels, say below 0.5% at rated output.

The conditions for Class AB operation normally recommended and published by the valve manufacturer are based on measurements made with continuous sine-wave drive. The bias under zero-drive conditions and the anode-to-anode load resistance are so chosen that optimum performance is achieved when the working point of the valves is displaced under drive conditions. This displacement is due to the influence of increased anode and screen-grid currents in the cathode bias circuit. For a typical output stage on a 310-volt supply using EL84 pentodes the rise in cathode current, and thus, cathode bias voltage at full drive, is about 40% with a sinusoidal input voltage.

When such a stage is used in the reproduction of speech or music, however, operating conditions are rather different. The mean amplitude of the input

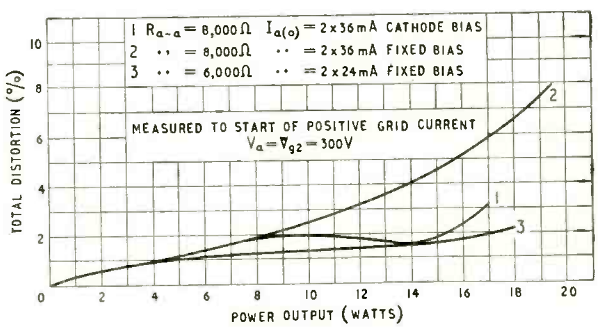


Fig. 1. Comparison of distortion curves under steady-state sinusoidal input conditions for a pair of EL84 valves in Class AB push-pull (1) with normal cathode bias, (2) with fixed bias under the same conditions, (3) load reduced for optimum fixed-bias operation.

* Mullard Valve Measurement and Application Laboratory.

signal is now very small compared with the peak values which occur from time to time and thus the mean variation of cathode current is also very small. Due to the relatively long time constant in the bias network the displacement of the working bias, even under peak signal conditions, is small enough for the stage to be considered as working with virtually fixed bias. If the normal Class AB stage (cathode biased) is measured under the corresponding fixed-bias conditions with a sine-wave input, it is found that at high output levels distortion is greater than when cathode bias is used. These two conditions are illustrated for the Mullard EL84 output pentode by curves 1 and 2 in Fig. 1. The quiescent bias is the same in both cases, curve 1 showing normal published operation with cathode bias, curve 2 operation with fixed bias. These results indicate that in practice, a cathode-biased Class AB stage designed on a sinusoidal drive basis will produce increased distortion when peak passages of speech or music are being reproduced.

One method of improving performance in practice is to adjust the quiescent operating conditions in the output stage so that they are nearly optimum for fixed bias working, although cathode bias is still used. This entails a smaller standing current and lower anode-to-anode load impedance. These changes result in larger variations in the instantaneous anode and screen-grid currents when the stage is driven, but the effect of these is at least partially compensated since the time constant in the cathode bias network has been increased at the same time. The excursion of the working bias is still kept very small under driven conditions.

It is found that good short-term regulation of the power supply is ensured by the use of large value (50μF) electrolytic capacitors for anode and screen-grid feeds. Peak currents corresponding to near overload conditions are effectively supplied by the capacitors with a reduction in line voltage of well under 0.5%, and the instantaneous power-handling capacity of the stage is not impaired.

Such a design, combined with a high degree of negative feedback (26 db), which includes the output stage and output transformer, is an alternative operating condition in the output stage of the 10-watt Mullard high-quality amplifier circuit[3, 4] and has proved very satisfactory in practice. A secondary feature of the use of these operating conditions is that the 12-watt output valves each run at a mean anode dissipation of only 7.5 watts. The corresponding fixed bias conditions in this case are illustrated in curve 3 of Fig. 1.

This form of operation is, however, suitable only for use in speech or music reproduction and cannot be used with a sine-wave input without excessive distortion. For this reason it is difficult to measure directly the distortion levels which obtain under practical conditions.

A second method of improving performance, described later, is to use distributed load conditions in the output stage. Depending on the precise loading used, the variation in anode and screen-grid currents can be reduced to such a level that almost identical performance is obtained under cathode and fixed bias conditions.

Triode Output Stage.—A low level of inherent distortion can be obtained in a push-pull triode stage operating under virtually Class A conditions. It is found that with 25-watt pentodes or tetrodes strapped as triodes a power output of 12-15 watts can be obtained at harmonic distortion levels below 1% using a supply voltage of 430-450 volts.

Maximum power output and the corresponding distortion vary appreciably with the value of load impedance and Fig. 2 illustrates typical performance of the Mullard EL34 high-slope output pentode, triode-connected in a push-pull stage operating slightly below its rated anode dissipation of 25 watts.

For anode-to-anode load impedances below 7,000Ω either a common, or separate cathode resistors (bypassed) can be used; above 7,000Ω improved operation is obtained with an unbypassed common cathode resistor. Operating conditions approach Class A as the anode-to-anode load impedance is raised and optimum performance for high-quality output stages is obtained with a load impedance of about 10,000Ω. An output of 14 watts is then delivered by the valves with total harmonic distortion well below 1%.

This type of output stage has found favour for a number of years in high-quality amplifiers giving about 12 watts effective output. Because of the low inherent distortion less negative feedback can be used to give acceptable linearity as compared with that required in pentode or tetrode output stages giving similar power output. Furthermore, in 3- or 4-stage amplifier designs, with most of the feedback applied over the whole amplifier, including the output transformer, it is then possible to achieve increased margins of stability for a given distortion level.

Distributed Load Conditions.—Increasing interest is being shown in various forms of distributed loading in the output stage[2]. These involve the application of negative feedback in the output stage itself. In the simplest form, the screen grids of the output valves are fed from suitably positioned taps on the primary of the output transformer and the stage can be considered as one in which negative feedback is

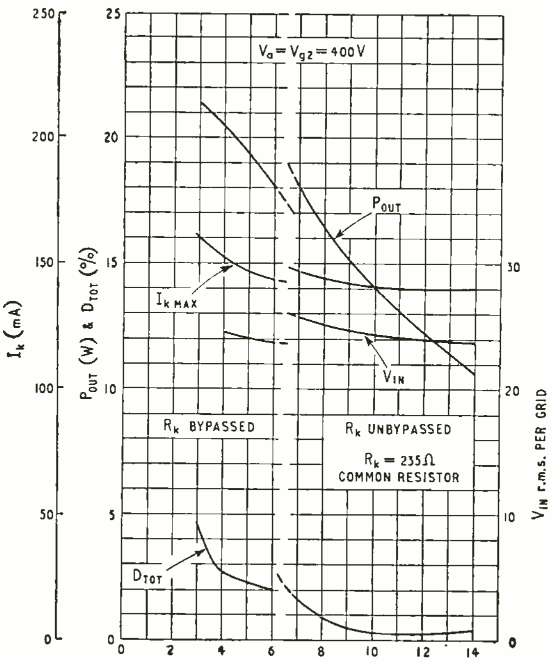


Fig. 2. Performance curves of two triode-connected EL34 valves in push-pull.

applied in a non-linear manner via the screen grids. The characteristics of the distributed load stage are intermediate between those for pentode and triode operation, approaching triode operation as the percentage of the primary winding common to anode and screen-grid circuits increases. It is found that under optimum conditions about two-thirds of the power-handling capacity of the corresponding pentode stage can be realized with much reduced distortion, whilst at power levels corresponding to triode operation, a similar order of distortion is obtained. At the same time the output impedance is reduced to a level approaching that obtained when a conventional push-pull triode stage is used.

Such a stage can thus be used with pentodes of the 25-watt class in high-quality amplifiers designed for power outputs well in excess of 15 watts, the overall power efficiency being appreciably greater than with triode operation. Conversely, the performance of 12-watt pentodes can be improved appreciably, although the power-handling capacity is somewhat reduced. However, effective power outputs of 10-12 watts can still be obtained.

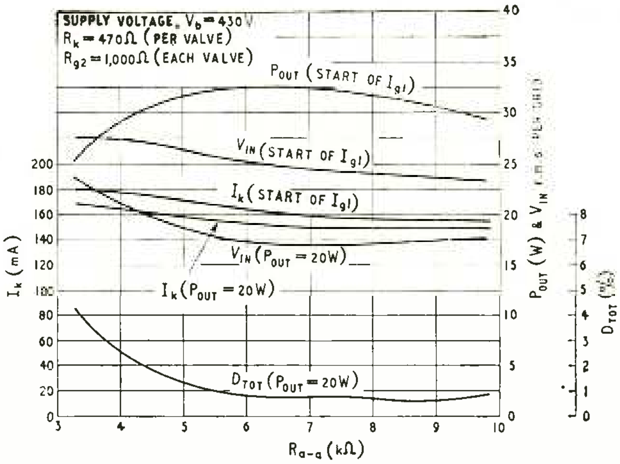


Fig. 3. Performance of EL34 push-pull pentodes under distributed-load conditions with screen tappings at 43% of primary turns.

A comparison is given in Table 1 of triode, pentode and distributed load operation for the Mullard EL34 and EL84 output pentodes. For valves of the EL34 type, comparison with triode operation is of most interest. It will be seen that distributed-load operation using a tapped primary output transformer enables the power-handling capacity to be more than double that possible with triode operation, whilst at the same time distortion in the stage can be held to a very low level.

Although with a common winding ratio of 0.2, i.e., with 20% of the primary winding common to anode and screen-grid circuits, the distortion level is comparable with triode conditions, it has been found that appreciable improvement is obtained at higher power outputs if the common winding ratio is further increased. Progressive improvement in overall performance has been obtained with the percentage of common primary winding increased up to 40-45%. Although with this increase power-handling capacity is still further reduced, at least 35 watts output can be obtained with distortion at the onset of grid current at about 2.5%.

Performance typical of the EL34 when used with an output transformer having a primary winding tapped at 43% of the turns is shown in Fig. 3. The output transformer used for these measurements was the Partridge type UL2 and the values of power out-

TABLE 1

Valve type	Mode of operation	Operating conditions					Total distortion (per cent)			
		V_a (V)	V_{g2} (V)	R_k (Ω)	R_{a-a} (kΩ)	R_{g2} (Ω)	at 10W	14W	20W	30W
Mullard EL34	Triode connection ..	400	*	470 (per valve)	10	*	0.5	0.7	—	—
	Distributed load: 43% common winding	400	400	470 (per valve)	6.6	1000 (per valve)	0.6	0.7	0.8	1.0
	Pentode connection ..	330	330	130 (common)	3.4	470 (common)	1.5	2.0	2.5	4.0
							at 5W	10W	15W	
Mullard EL84	Triode connection ..	300	*	150 (common)	10	*	1.0	—	—	
	Distributed load: 20% common winding	300	300	270 (per valve)	6.6	—	0.8	1.0	1.5†	
	43% common winding..	300	300	270 (per valve)	8.0	—	0.7	0.9	—	
	Pentode connection ..	300	300	270 (per valve)	8.0	—	1.5	2.0	2.0	

*Screen grid strapped to anode. †See text.

put quoted are those delivered to the load in the secondary circuit.

With valves of the 12-watt dissipation class, such as the EL84, comparison with normal pentode operation is more significant. Appreciable reduction in odd harmonic distortion is again obtained under distributed load conditions and approximately 15 watts is delivered by the valves with a common winding ratio of 0.2.

From the figures in Table 1, little advantage would appear to be gained by further approaching triode conditions. There are, however, at least two advantages in using a tap at about 40% of primary turns, particularly with the EL34 where a high power output is still available. In the first place almost identical performance is obtained under cathode- and fixed-bias conditions, since with the closer approach to Class A triode working, variations in anode and screen-grid currents are reduced when the stage is driven. Secondly, as with normal triode operation, power output and distortion are less dependent on the precise value of load impedance. With a primary tap at about 40% of turns little change in performance is produced by a change in anode-to-anode load impedance of 6,000 to 9,000Ω. In addition the output impedance of the stage is still further reduced by the use of the larger common winding ratio.

Circuit Arrangements.—The penultimate stage of the amplifier must be capable of providing a well-balanced push-pull drive of adequate amplitude and low distortion content. With 25-watt pentodes such as the EL34 the maximum drive voltage required is approximately 2 × 25 volts r.m.s., whilst for valves of the EL84 type the corresponding input is about 2 × 10 volts r.m.s. Input voltage requirements are similar for triode, pentode or distributed-load operation.

Bearing in mind the need to ensure stability when feedback is applied over the whole amplifier, the circuit should contain the minimum number of stages, in order to reduce phase shifts to the minimum. Thus if the functions of phase splitting and amplification can be combined in the penultimate stage, so much the better. This can be conveniently achieved by using the cathode-coupled form of phase splitter[5]. A high degree of balance is possible with this circuit, combined with a low distortion level at maximum drive to the output stage. By using a high-impedance double triode, an effective stage gain of about 25 times can be simultaneously obtained. This, combined with a preceding high-gain stage, enables a high overall sensitivity to be obtained, even when a high degree of negative feedback is used. A high sensitivity in the main amplifier enables the output voltage requirements of pre-amplifier and tone control circuits to be reduced; low distortion in these circuits is then more easily obtained.

It should be remembered in this connection that circuits preceding the main amplifier must be capable of handling, without appreciable distortion, voltages much greater than are necessary to load the amplifier fully.

With the use of such a valve as the Mullard EF86, which is particularly suitable for use in a high-sensitivity input stage, due to its low hum and noise levels, it is found that when feedback is applied input sensitivities of 50 to 100 mV for rated output can be achieved whilst at the same time hum and noise levels are low enough for high-quality requirements.

Negative Feedback.—In an amplifier employing single-loop feedback from output to input, instability will occur if the loop gain—the product of amplifier gain without feedback and the attenuation of the feedback network—exceeds unity at frequencies for which the total phase shift round the loop becomes either 0 or 360° and so renders the feedback signal in phase with the input. The conditions for negative feedback imply a phase change of 180°, so that instability is approached as the additional phase shift in the amplifier and feedback network approaches 180 degrees[6].

Since phase shifts are often difficult to measure, it is normal practice to utilize for design purposes the relationship between phase shift and attenuation characteristics. A simple CR low or high pass filter produces an ultimate phase shift of 90° and a rate of attenuation which approaches 6db/octave asymptotically. Thus an ultimate phase shift of 180° corresponds to a final rate of attenuation of 12db/octave. To preserve adequate margins of stability it is usual to design for attenuation rates not exceeding 10db/octave in the region where the loop gain varies from say 10db through unity gain (0db) to −10db.

It is thus necessary to control the amplifier characteristics over a frequency range much in excess of the designed working band. As the degree of feedback increases, this control becomes more difficult and is usually limited by the leakage inductance, self-capacitance and primary inductance of the output transformer.

It is a formidable task in practice to provide a constant and high level of feedback over the whole audible frequency range in a 3- or 4-stage amplifier where the main feedback loop includes the whole circuit and the output transformer. An adequate margin of stability in such circumstances is very difficult to obtain. Thus it is more usual to find that the effective feedback decreases towards the upper and lower audible frequencies.

Adequate feedback must, however, be available:

1. At frequencies in the region of the fundamental resonance of the loudspeaker system, to provide the low output impedance needed for efficient electrical damping.

2. Up to the highest audible frequency for which harmonics lie within the audible range, a frequency which can be taken as around 10 kc/s.

Output Transformer.—The performance of a high-quality amplifier is ultimately dependent on the quality of the output transformer. The use of distributed-load conditions does not modify the essential features of a first-class component—on the contrary the output transformer may be a more critical component, since precise balance of primary windings must be maintained.

The requirements in a very high-quality design are well known and have been previously described in some detail[1]; it is not, therefore, proposed to do more than refer briefly to them. It may be said that the better the compromise effected between the requirements of high primary inductance, low leakage inductance and self-capacity, generous core size and low winding resistances, judged solely from the view-point of performance, the more expensive is the output transformer. This is particularly so if it is designed to handle power outputs in excess of 15 watts.

Whilst the best performance necessitates a costly component, it is possible to achieve, in amplifiers of

10-12 watts power output, a suitable compromise which results in a very high standard of amplifier performance with a transformer of moderate cost. A low value of leakage inductance is, for example, obtained more easily if the shunt inductance requirements are lessened, and appreciable negative feedback can then be used to offset the increased distortion at low frequencies due to lower primary inductance, reduced core size and less expensive core material.

Summary.—When the power handling capacity of a high-quality amplifier is not designed to exceed 10-12 watts it is possible to achieve extremely high performance with 12-watt pentodes or tetrodes. Such advantages as are possessed by 25-watt valves strapped as triodes are offset by a negligible increase in power reserve and the need for a larger and more expensive power supply.

The introduction of distributed load operation, using valves of the 25-watt class permits the design of efficient high-quality amplifiers with power-handling capacities up to 30-35 watts. Whilst it is very doubtful if such a power reserve is necessary for domestic sound reproduction—it necessitates in any case a loudspeaker system capable of handling such peak powers—amplifiers of this description find application where larger audiences are present.

It should always be remembered that the performance required of a high-quality amplifier must be judged in relation to the quality of the equipment with which it is to be used. If the use of a high-quality amplifier meriting the term is to be really justified, the pickup, pre-amplifier circuits and the loudspeaker system must themselves have a very high standard of performance.

The use of high-grade equipment in association with the power amplifier is implied in the design for the 20-watt amplifier using Mullard EL34 output pentodes under distributed load conditions, which it is hoped to describe in a subsequent article.

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[4] "A High-quality Ten Watt Audio Amplifier," by D. H. W. Busby and W. A. Ferguson. *Mullard Technical Communications*. Vol. 1, No. 9. Nov., 1954.

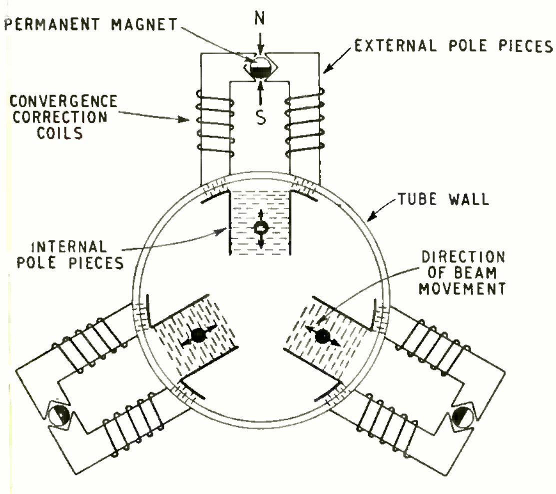
[5] "Push-pull Input Circuits, Part 5," by W. T. Cocking. *Wireless World*, May, 1948.

[6] "When Negative Feedback Isn't Negative," by "Cathode Ray." *Wireless World*, May, 1949.

21-in COLOUR TUBE

AN interesting feature of the new large-size tri-colour c.r. tube produced by R.C.A. is the use of a magnetic beam-convergence system with pole-pieces actually built inside the tube. The purpose of the beam-convergence system, which was electrostatic in the earlier 15-inch tube,* is to direct all three electron beams on to the particular group of three phosphor dots on the screen which is being scanned at any moment, so that one beam falls on the red phosphor dot, another on the green dot and the third on the blue dot. The convergence is helped in the first place by mechanical tilting of the electron guns. Each beam is then adjusted individually (see diagram) by the flux from an external permanent magnet, which is coupled through a pair of external ferrite pole-pieces to the pole-pieces inside the tube. The magnet is cylindrical in form and polarized as shown, so that by rotating it in the gap between the pole-pieces the component of its field which is coupled through to the internal system can be made to vary—and hence the convergence of the beam.

* "Colour Television Tube," *Wireless World*, May 1954.



Schematic of beam-convergence system, showing how the external magnets are linked to the internal pole-pieces through the glass wall of the tube.

Tri-colour cathode-ray tube, type 21AXP22.

Coils are wound on the external ferrite pole-pieces, and these produce an additional magnetic flux which varies with the scanning angle in such a way as to maintain the correct beam convergence at all points across the screen. This is necessary because of the particular geometry of the tube, as explained in the description of the 15-inch version. The varying current to energize the coils is actually derived from the output circuits of the line and frame scanning generators. An additional facility is a magnetic deflection system, again utilizing internal pole-pieces, which permits one of the electron beams to be adjusted laterally (at right angles to the arrows shown).

The phosphor-dot screen in this 21-inch tube is deposited on the inner surface of the glass faceplate, instead of on a separate plate inside the envelope as in the earlier model, and the picture size obtained is $19\frac{5}{16}$in by $15\frac{1}{4}$in. In most other respects the tube is similar to the 15-inch one, except, of course, that it has a higher final anode voltage—actually 25kV.

Commercial Literature

Electronic Picture Recording for television using television methods of studio production and standard 35-mm film. Description of the technique and apparatus in an illustrated brochure from High Definition Films, 24, Old Broad Street, London, E.C.2.

Components and Accessories; a new list (No. 194) from A. F. Bulgin & Company, Bye-Pass Road, Barking, Essex.

Electronic Computing Service for solution of research and design problems in commerce and industry. The Elliott type 402 digital computor and some typical problems described and illustrated in an outsize brochure from Elliott Brothers (London), Computing Machine Division, Elstree Way, Boreham Wood, Herts.

Magnetic Tape Erasers for ¼-in tape and spools of up to 7-in diameter. The tape is not unwound but demagnetized *en bloc* on the spool. Recent models are suitable for the Grundig "Stenorette" spools. Leaflet from Harvey Electronics, Farnborough Road, Farnborough, Hants.

High-Stability Resistors (Constanta) of carbon deposited on porcelain rods. Miniature resistors are now available with 5 per cent stability in 0.05-, 0.1-, 0.25-, 0.5- and 1-watt ratings while in the 0.5 per cent category 0.05-watt rating can be supplied. Folder from G. A. Stanley Palmer, Maxwell House, Arundel Street, London, W.C.2.

Voltage Stabilizer Tubes; a guide to their application, containing sections on fundamentals, interpretation of published characteristics, design formulæ for associated components and data on Mullard types. From Mullard, Century House, Shaftesbury Avenue, London, W.C.2.

Intercommunication Equipment, for two-way operation, comprising a master unit and an extension unit which can be either permanently alive or only when required by the operator. Leaflet from Hifi, Derry Works, Derry Hill, Brierley Hill, Staffs.

Network Calculations, using a time-saving "potentiometer" method for steady-state and transient conditions, described in a monograph (price 1s) from Stockman Electronics Research Co., 543, Lexington Street, Waltham 54, Mass., U.S.A.

Electronic Instruments, for measurements of various physical effects, designed so that they can be used together in integrated groups for particular applications. Chart showing types of measurements with the corresponding groups of instruments needed from the Brüel & Kjær range. Also a short catalogue giving details of the instruments. From Rocke International, 59 Union Street, London, S.E.1.

List of Products of the Plessey organization accompanied by photographs showing production facilities in the various factories of the company. From the Plessey Company, Ilford, Essex.

Peak Voltmeter for measurement of transient voltages between 5V and 35kV to an accuracy of 10%. Instrument based on the firing voltage of a thyratron described briefly in a folder from Varley (Oliver Pell Control), Cambridge Row, Woolwich, London, S.E.18.

Phase Meters used for testing of production electrical and electronic equipment. Description of methods in a laboratory report from the Technology Instrument Corporation, Acton, Mass., U.S.A.

Electronic Moisture Meter, based on the measurement of the dielectric or propagation constant of the material to v.h.f. Leaflet from Shaw Electronics, 31 Market Street, Bradford, Yorks.

Current Metering Socket (the "Amp-Check") for wiring permanently in circuit to permit an ammeter to be inserted without switching off the current. Leaflet from Phillips & Bonson, Imperial House, Dominion Street, Moorgate, London, E.C.2.

Silicone Insulating Materials, notable for high thermal stability. A range consisting of silicone resins and elastomers in various combinations with glass fibre, mica and asbestos described in an illustrated brochure from Midland Silicones 19 Upper Brook Street, London, W.1.

Marine Radio Telephone and direction finder for small craft with 8 crystal-controlled transmission channels between 1.4 and 8Mc/s. Consumption is 30 watts receiving, 80 watts transmitting, with a choice of supply voltages. Leaflet from Intercommunications Equipment Co., 286-8 Leigh Road, Leigh-on-Sea, Essex.

A.M./F.M. Tuners and other associated equipments and components imported from Germany. Descriptive booklet with circuit diagrams from Technical Suppliers, Hudson House, 63 Goldhawk Road, London, W.12.

Tape Recorder, the "Editor Super," with frequency response of 40c/s-10kc/s at 7½in per second speed and mixing and monitoring facilities for separate radio/gramophone and microphone inputs. Features described in a leaflet from Tape Recorders (Electronics), 3 Fitzroy Street, London, W.1.

Vented Loudspeaker Cabinet based on the B.B.C. design described in *Wireless World* (Nov., Dec., 1950). Height 44in, width 28in and depth 18in, with speaker hole as required. Leaflet from Lockwood & Co., Lowlands Road, Harrow, Middlesex.

Loud Hailer, for use on board ship, with amplified talk-back facilities between the main control panel and up to five sub-stations. Descriptive leaflet from Easco Electrical (Holdings), Brixton, London, S.W.9.

Wafer Switches assembled to specification with any desired contact arrangement or wafer spacing. Price list of 82 "standard" arrangements and switch design chart from Specialist Switches, 24 Cranbourn Street, London, W.C.2.

Communications Receivers by Hallicrafters. Three new models covering 540-1680kc/s and three short-wave bands from 1680kc/s to 34Mc/s. Leaflets from the McElroy-Adams Manufacturing Group, 328 Lillie Road, London, S.W.6.

Band III Television Aerials, single- or multi-element arrays (including folded dipoles) for either separate mounting or on existing Band-I masts. Illustrated catalogue from Belcher (Radio Services), 59 Windsor Road, Slough, Bucks.

Ease of operation is the design keynote of this new valve-test table recently put into service at the G.E.C. Research Laboratories. All meters can be read from one position with a minimum of head movement while most of the controls are operated by the left hand, leaving the right one free for recording measurements. Knobs and keys for any particular test are arranged adjacent to one another and the range on which any meter is working is indicated by an illuminated disc. To reduce visual fatigue all non-essential markings have been removed from the meter scales, while the colour and brightness balance between scale, case and surround has been arranged so that the pointers stand out clearly.

V.H.F. and U.H.F. Reception

Effects of Trees and Other Obstacles

By J. A. SAXTON, D.Sc., Ph.D., M.I.E.E., and J. A. LANE, M.Sc.

Some experiments to determine the attenuation caused by screens of trees and thick woods at frequencies of 100, 540 and 1,200 Mc/s are described, and these and other data are used to estimate the attenuation over the frequency range 30-3,000 Mc/s. This work was carried out as part of the programme of the Radio Research Board. The nature of the diffraction loss and variation of field strength behind opaque obstacles of various kinds for the same frequency band is examined on the basis of the Fresnel theory of diffraction.

Official communication from the D.S.I.R. Radio Research Station, Slough

ALTHOUGH there now exists a considerable body of literature on various characteristics of the propagation of metre and decimetre wavelengths—wavelengths of interest, for example, in television broadcasting—there is one aspect of the overall problem which has been quite inadequately treated, namely the effects of trees and other obstacles on reception at such wavelengths. It is perhaps not surprising that this should be so, for experience shows that these effects are not readily amenable to a generalized quantitative evaluation. As a consequence it is not easy to make an accurate estimation of the effects to be expected in one set of conditions on the basis of experimental observations carried out under different conditions. Nevertheless, in view of the increasing use of v.h.f. and u.h.f. for television, it is important to be able to make some assessment of the effects in so far as they may, for instance, influence the choice of a site for an aerial.

The logical conclusion of the arguments presented above is that each case of reception in circumstances where the field being sampled is influenced by local disturbances, due to trees and other obstacles, should be treated on its own merits. This, in general, is true; on the other hand, such a course may not always be really practicable, and it is clearly desirable that some attempt should be made at least to provide a guide as to the order of magnitude of the effects to be expected. It is the purpose to review the somewhat scanty experimental observations which are available, and so to try to provide such a guide.

If an opaque obstacle casts a shadow in the region of a given receiving point, the intensity of the shadow may be approximately calculated by an application of the principles of Fresnel diffraction, [1,2] and some typical cases falling within this category will be examined. A sufficiently dense and extensive wood may approach opacity for ultra high frequencies, but with less dense woods the signal transmitted through the wood may be greater than that diffracted either over or round it when the receiving point is near to the wood: a knowledge of the attenuation of metre and decimetre waves through typical woods is therefore of interest. Although the experimental information on this point is sparse, there is enough to show in a general manner the way in which the attenuation of the received signal varies with wavelength over the range concerned.

Attenuation Through Trees:—The most extensive measurements of the attenuation due to trees along a transmission path are those described by McPetrie and Ford,[1] but their published results relate only to the frequency of 3,260 Mc/s (9.2-cm wavelength). These workers did, however, supplement the centimetre-wave observations with measurements at 540 and 1,200 Mc/s, and the present authors are indebted to them for permission to quote the results for the lower frequencies. Some observations of the attenuation produced at frequencies of 250 and 500 Mc/s by a small wood extending 150 metres along the transmission path have been published by Trevor[3] and apart from this no other data appears to be recorded in the literature. Additional information relevant to the problem is that obtained some years ago by McPetrie and Saxton in measurements at a frequency of 100 Mc/s, and which has hitherto not been seen in any publication.

Attenuation at 540 and 1,200 Mc/s:—The method of procedure in the experiments carried out by McPetrie and Ford, at frequencies of 540 and 1,200 Mc/s, was to radiate a signal of known power from a suitably located transmitter and to measure the strength of the received signal at several positions behind the obstacle. In some cases it proved convenient to measure for comparison the field strength on an adjacent site for which there was an unobstructed path between the transmitter and receiver; in others it was necessary to calculate the field strength which would have existed had the trees been absent, having due regard to the ground profile between the terminal points. Observations were made using both horizontally and vertically polarized waves.

The field strengths measured at 540 Mc/s after transmission through about 85 metres of a thick, mainly deciduous, wood showed that there was hardly any significant difference between the rates of attenuation for the two types of polarization, the actual values obtained being 0.18 db/m and 0.20 db/m for horizontally and vertically polarized waves respectively. These results were obtained during the summer-time and thus refer to trees in full leaf; unfortunately no comparable observations were made for leafless trees at the same site. The rate of attenuation (db/m) naturally varies with the thickness of the wood under examination, also on the degree of undergrowth, and it cannot be expected that very close agreement will always be obtained between observations in different places. Trevor's measurements[3] at a frequency of 500 Mc/s in the U.S.A. also show that, for a fairly continuous wood of trees in full leaf, the attenuation is independent of wave polarization and about 0.12 db/m. For the same trees leafless, Trevor gives attenuation rates of 0.1 db/m and 0.08 db/m for vertically and horizontally polarized waves respectively.

In further experiments McPetrie and Ford investigated transmission through relatively thin screens of trees. In one case the screen consisted of a double row of beech trees about 17 m high in which the trunks were some 7.5 m apart, the spacing between the two rows being a similar distance. When the trees were leafless, individual objects in the background beyond the trees could be easily identified, but only small portions of the general background could be distinguished when the trees were in full leaf. In a second example there were four rows of lime trees about 27 m high with the trunks spaced about 6 m in both directions. Here, although some details of the background could be distinguished through the screen when the trees were leafless, this background was completely obscured at full leaf.

At a frequency of 540 Mc/s the attenuation in transmission through the beech-tree screen, even in full leaf, was too small for any definite rate per metre to be estimated; although variations of field strength over a range of 15 to 20 db were observed as the receiver was moved about in the clear ground behind the trees. The measurements through the rather more extensive lime-tree screen were also made when the trees were in full leaf, observations being made for both vertically and horizontally polarized waves at frequencies of 540 and 1,200 Mc/s. At 540 Mc/s the rate of attenuation of vertically polarized waves was found to be a little greater than for horizontally polarized waves, especially for receiving points immediately behind the trees: at 1,200 Mc/s, however, no definite difference between the rates of attenuation for the two states of polarization could be established. The average rates of attenuation through trees estimated from these measurements are as follows: at 540 Mc/s, 0.15 db/m and 0.25 db/m for horizontally and vertically polarized waves respectively: at 1,200 Mc/s, 0.35 db/m irrespective of the state of polarization. That the signals observed in the circumstances described above must have been mainly due to radiation transmitted through the trees, and could hardly have been influenced by diffraction over the top of the screen, may be shown by an application of the theory discussed later.

Attenuation at 100 Mc/s:—Just prior to the 1939-45 war a number of observations of the effects of trees on reception at a frequency of 100 Mc/s were made by McPetrie and Saxton. A variety of sites were examined, and the following examples are illustrative of the results obtained.

Measurements of field strength were made in the neighbourhood of a small clump of trees—roughly circular in shape, about 30 m in diameter, and not densely planted—first along a line passing through the centre of the clump and the transmitter, both at points in front of and behind the trees; and secondly along a line perpendicular to the first line and behind the trees. The results showed that such a short section of wooded path introduced no significant additional attenuation of the ground wave. The variations in field strength along the transverse line behind the trees, however, were considerable and covered a range of 20 db. These variations, which were more pronounced for vertically than for horizontally polarized waves, were presumably due to multipath transmission caused by diffraction.

In another series of observations at 100 Mc/s measurements were made of the field strength of signals after transmission through several hundred metres of a thick wood, mainly deciduous in character, and in full leaf, with some undergrowth. These measurements indicated attenuations of 0.06 and 0.03 db/m respectively for vertically and horizontally polarized waves. The attenuation due to trees is thus seen to be considerably less at 100 Mc/s than at 540 and 1,200 Mc/s, whilst the relative difference between the values for the two type of polarization is more pronounced at the lowest than at the two higher frequencies.

The spatial variations in the signal obtained as the receiving aerial was moved over a distance of a few wavelengths amongst trees were, in almost every case, less for horizontally than for vertically polarized waves. The maximum difference was observed in the case of transmission through a pine wood, with no undergrowth, where there was much more vertical than horizontal growth: the field variations here were predominantly of the order of ±2 db for horizontal polarization and ±10 db for vertical polarization. This represented an extreme case, however, and an analysis of the whole series of observations at 100 Mc/s shows that, for horizontally polarized fields, about 80 per cent of the receiving locations had a range of variation of less than 6 db; in the case of vertical polarization the same range of variation was found at 60 per cent of the locations. The majority of the observations were made with some trees of various kinds within a range of 5 to 100 m, and, whilst the above figures can only be regarded as approximate, it is interesting to note that they are similar to those quoted by Saxton and Harden[4] in an account of a recent field strength survey at 100 Mc/s, in which, however, trees were not always the only obstacles involved at a given receiving site.

Attenuation Through Trees as a Function of Frequency:—Although the conditions of experiment for all of the cases so far considered were by no means identical, it is obvious that the rate of attenuation through a given wood or screen of trees increases with frequency, and this general feature is illustrated in Fig. 1. Of the values of attenuation discussed above only those appropriate to trees in full leaf have been plotted, there being insufficient data to draw distinctive curves for the leafless state. It might, in any case,

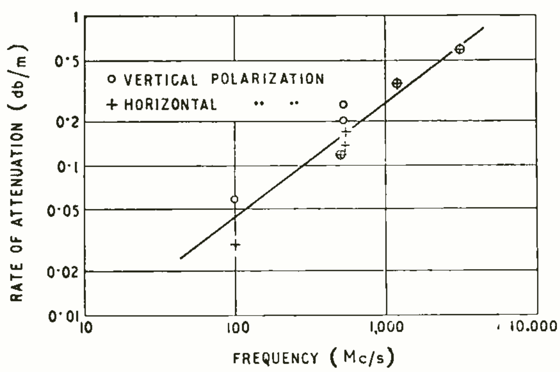


Fig. 1. Rate of attenuation in woods with trees in leaf as a function of frequency.

be argued that from the practical point of view, it is mainly important to know the worst conditions likely to arise, and these definitely correspond to trees in full leaf. (The point for 3,260 Mc/s plotted in Fig. 1 is obtained from the published work of McPetrie and Ford[1] referred to earlier.) It is also indicated in Fig. 1 how, as the frequency decreases through the u.h.f. and v.h.f. bands, there is a tendency for the attenuation to be less for horizontally than for vertically polarized waves. It must be stressed that Fig. 1 can only be used as a guide to the order of magnitude of the attenuation likely to be caused by woods, the actual value in any given case must depend on the density of the trees, and to some extent on their character, whether deciduous or otherwise.

Attenuation Produced by Other Obstacles:—In addition to trees the most important of the other obstacles affecting field strength characteristics at a given receiving location, apart from hills, are buildings. There are even fewer published measurements of the attenuation caused by buildings than there are for that due to trees; the only measurements known to the authors, in fact, being those of McPetrie and Ford[1] for 3,260 Mc/s. These experiments showed that the attenuation produced by a typical brick wall (of thickness 23 cm) is of the order of 10 db when dry, and may be considerably more when wet right through. This result indicates values for the permittivity and conductivity of such walls from which it may be deduced that attenuations of the order of 5 db are probable at 30 Mc/s in similar circumstances. To all intents and purposes, therefore, any substantial building—containing several walls—in a transmission path may be regarded as opaque to v.h.f. and u.h.f. radiation. Such a building will thus throw a shadow, inside which the field strength is mainly determined by diffraction round the sides and over the top.

Evidence has been provided by Megaw[2] as well as by McPetrie and Ford[1] that a useful estimate may be made of the field strength behind opaque obstacles by an application of the principles of Fresnel's diffraction theory. This method of approach should be satisfactory in the v.h.f. and u.h.f. bands, not only for the shadows produced by well-defined hills or ridges, but also for the rather more local shadows cast by buildings or by dense woods. Indeed, McPetrie and Ford have shown that the field strength distribution behind a single tree at 3,260 Mc/s is quite well accounted for by the Fresnel theory; whilst according to Megaw, to some extent the same is true for the case of diffraction by a steel mast at 600 Mc/s.

It is hardly feasible here to consider the diffraction fields behind obstacles of a wide variety of shapes, but in the following chapters calculations are made for what are probably the two most important forms of obstacle occurring in practice.

Diffraction by Opaque Obstacles:—The two classes of diffraction phenomena to be examined are (1) diffraction over an opaque obstacle of considerable extent transverse to the path of propagation (e.g., a thick screen of trees or a continuous row of buildings), and (2) diffraction round a tall opaque obstacle (e.g., a single tall building). These two classes correspond to the optical cases of diffraction by straight edges and opaque strips respectively, as treated by Fresnel. The optical theory refers to ideally sharp edges and very thin strips, and the obstacles with which this paper is concerned do not really conform to these conditions: there is, however, little doubt, in view of the fact that the distance of the source is generally very great compared with the thickness of the obstacles, that the predictions of the simple theory are reasonably accurate.

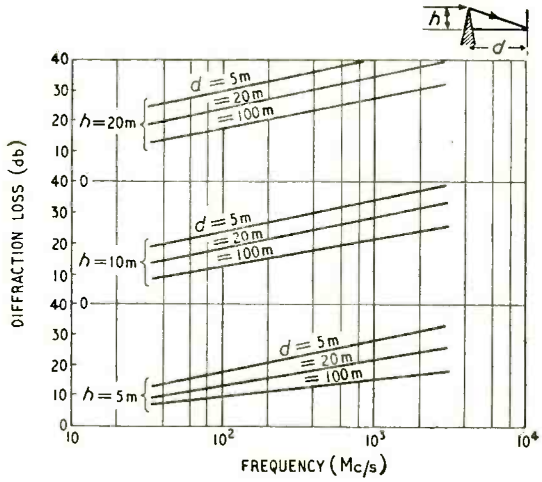


Fig. 2. Diffraction loss at a straight edge. (Fresnel theory)

Diffraction at a Straight Edge:—Typical examples of the diffraction loss at a straight edge are given in Fig. 2 for frequencies in the range 30 to 3,000 Mc/s. The distance of the transmitter from the obstacle is assumed to be large compared with d, the distance from the obstacle to the receiving point. The loss has been calculated for locations of the receiving aerial 5, 10 and 20 m below the line from the transmitter passing through the top of the obstacle, and is relative to the field which would have existed at the diffracting edge had the obstacle not been there. In the curves of Fig. 2 only the contribution of the direct wave from the edge of the obstacle has been considered; and in a more rigorous treatment it would be necessary to include the effect of the wave arriving at the receiver after reflection at the ground between the diffracting edge and the receiving aerial, but the neglect of this component is probably not serious for many of the cases of greatest practical interest. For example, in a typical broadcast receiving installation in the v.h.f. and u.h.f. bands the height of the aerial above ground may be expected to be about 10 m, and under these conditions, for the deep-shadow region relatively close to the diffracting obstacle, it may be shown that the angle at which the ground-reflected component is diffracted is such that the amplitude of this component is much smaller than that of the direct wave.

A further point to be borne in mind is that the loss given in Fig. 2 is relative to the undisturbed field at the height of the diffracting edge, and since, for the practical case of a distant transmitter, this field will generally be greater than that which would have existed at the receiving point had the obstacle not been present (approximately in the ratio of the heights of the obstacle and the receiving aerial) the "true" diffraction loss will be somewhat less than indicated in Fig. 2. This correction to the curves may readily be estimated from a knowledge of the heights of the obstacle and receiver. For most practical cases, however, the curves of Fig. 2 will give a direct indication of the changes in field strength to be expected for various displacements of the aerial within the shadow region; and they also give a reasonably accurate picture of the variation of diffraction effects with frequency.

The relative gain produced by increasing the height

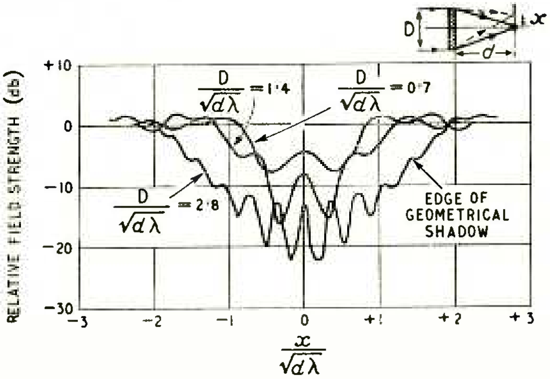


Fig. 3. Diffraction pattern behind opaque obstacles.

of an aerial situated within the shadow as compared with increasing the distance of the aerial from the diffracting edge is evident from Fig. 2. For example, at 500 Mc/s, the improvement in received signal on moving back from d=20 m to d=100 m behind an obstacle of effective height (h) of 10 m is about 6 db, whereas the same improvement could be obtained by raising the aerial by 5 m at the distance of 20 m. Provided the diffraction loss is appreciable—at least 12 db, say—the following equation may be used to calculate the loss for conditions not covered by Fig. 2:

$$E_o/E_d = 0.36\, h\, (f/d)^{\frac{1}{2}} \quad (1)$$

where E_o is the undisturbed field at the diffracting edge, E_d is the diffracted field at a point d metres behind and h metres below the edge, and f is the frequency in Mc/s.

Diffraction by an Opaque Strip:—Typical diffraction patterns behind an opaque strip are illustrated in Fig. 3, where the variation of field strength along a line perpendicular to that from the transmitter through the centre of the obstacle is shown for various distances d metres behind the obstacle of width D metres.

The individual curves all exhibit a local maximum at a receiving point located in the symmetrical position behind the obstacle (i.e., at x=O, x being the displacement from the symmetrical position), a result well known in optical theory and practice. The actual signal loss, however, relative to the field which would have existed in the absence of the obstacle, and the form of the diffraction pattern both show considerable variation with wavelength for a given d. In the case of a vertical opaque strip no correction is needed to allow for the presence of the earth since, to a very close approximation, the diffraction losses associated with the direct and ground reflected waves behind the obstacle are the same. Thus, at a distance of 10 m behind an obstacle of width 10 m the diffraction pattern at 240 Mc/s is that given in Fig. 3 by the curve for which $D/\sqrt{d\lambda}=2.8$, whilst that appropriate to the frequency 60Mc/s is the curve for $D/\sqrt{d\lambda}=1.4$. The magnitude of the diffraction loss, expressed in decibels, at the two minima on either side of the axis is approximately twice that at the symmetrical position on the axis. In general, provided the diffraction loss is appreciable (as in the case of edge diffraction) its value on the axis may be calculated from the relation:

$$E_o/E_d = 0.092\, D\, (f/d)^{\frac{1}{2}} \quad (2)$$

E_o being the undisturbed field at the receiving point in the absence of the obstacle (the distance of the transmitter from the obstacle being assumed to be much greater than d), E_d the field at the receiving point and f the frequency in Mc/s.

In the reception of v.h.f. and u.h.f. radiation in built-up areas, for obstacles much wider than, say, 20 m, the diffracted field over the top is likely in general to be greater than that diffracted round the sides of the obstacle. It should also be pointed out that, when the diffraction loss in a given case is very large, as indicated by equations (1) and (2), it is probable that the effect of the shadow will be alleviated as a result of energy scattered to the receiving point from other obstacles in the locality, but it is difficult to make a quantitative assessment of the importance of this factor.

Conclusions:—Whilst the attenuation caused by a few trees in a transmission path at v.h.f. and u.h.f. may not be serious, significant attenuation can be caused by thick and extensive woods. For a continuous wood the attenuation is of the order of 0.02 db/m at 30 Mc/s, whilst the corresponding figure at 3,000 Mc/s is about 0.5 db/m; and there is evidence that for frequencies less than 1,000 Mc/s the attenuation rate is slightly greater for vertically polarized than for horizontally polarized waves. On the other hand a small number of trees, or even a single tree, can cause considerable spatial variations of field strength at points within the shadow region, and when siting a receiving aerial for v.h.f. or u.h.f. transmissions this fact should be borne in mind. The same is true if the receiving aerial has of necessity to be placed behind a building, since for all practical purposes most buildings of any size may be regarded as opaque in these bands.

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I.E.E. SCHOLARSHIPS

A NUMBER of scholarships, founded in memory of eminent electrical engineers to provide for the education and training of students, are awarded each year by the Institution of Electrical Engineers. This year a new scholarship (the Arthur Fleming) is available for a student wishing to follow "a works-based sandwich diploma course in electrical engineering." It is valued at £120 p.a. and is tenable for four years. Details of this and the other scholarships available this year are given in "Scholarship Regulations" obtainable from the I.E.E., Savoy Place, London, W.C.2.

The existing scholarships include the Duddell (value £200 p.a. for three years), the Salomons and David Hughes (each valued £60 for one year). There is also the Paul scholarship (value £75 p.a. for four years) which is for instrument making.

Nominations must be submitted by May 2nd on the form available from the I.E.E.

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"Needles for Talking Machines"

Present Trends Reviewed Against the Background of Early Invention

By S. KELLY*

DURING the fifty or sixty years which we have been blessed (?) with the gramophone, the ubiquitous needle has probably resulted in more inventive effort and original thinking than that applied to all the rest of the bits and pieces which comprise the reproducing system. During this period the needle, or stylus as we now prefer to name it, has gone the full circle. Sapphire or diamond in 1900, steel needles from about 1910 to 1935 when sapphire again made a tentative appearance; but it was not until after the war, and particularly with the advent of microgroove records that the sapphire and more recently the diamond have achieved the overwhelming popularity which they enjoyed at the turn of the century.

The original commercial stylus was that used on the Edison phonograph and was the theoretically correct shape, namely spherical. Fig. 1(a) shows a photograph of one of these early styli. Compared with present-day dimensions of 0.001in radius, they were enormous, actually 0.025in dia. Fig. 1(b) shows for comparison a "miniature" (0.030in diameter) shank with 0.001in radius sapphire. Fig. 1(c) is a mounted spherical sapphire for an early type of disc machine. The original Edison sapphires were used on "hill and dale" records and apparently, within the then prevailing limitations of the art, gave satisfactory results. According to the inventor, sapphire was necessary because it was the only material which would take the high polish required to mitigate damage to the soft wax cylinder.

At this stage it is interesting to note that the styli were made by the late Principal Alderman Fred Lee of Coventry, and during the period 1900-1910 he supplied approximately 4,000 styli per week to the U.S.A. He can rightly be named the father of the stylus industry. About 1910 the disc finally ousted the cylinder for domestic reproducers and it was from this date that the steel needle became firmly established for the next thirty odd years.

Nowadays we automatically assume that the ancients of the pre-electrical recording era were virtually savages compared with the now civilized exponents of the art of sound reproduction. An examination of the early literature reveals that if precise technical knowledge of the finer points of electromechanical analogues were missing, it was more than made up for

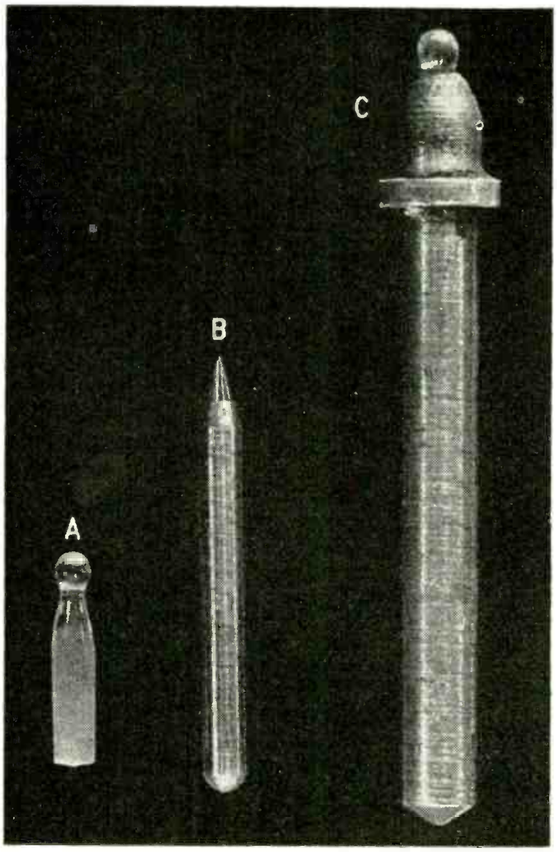

Fig. 1. (A) Edison sapphire stylus with spherical head compared with a modern microgroove stylus (B). An early spherical-tipped stylus for a disc machine is shown at (C).

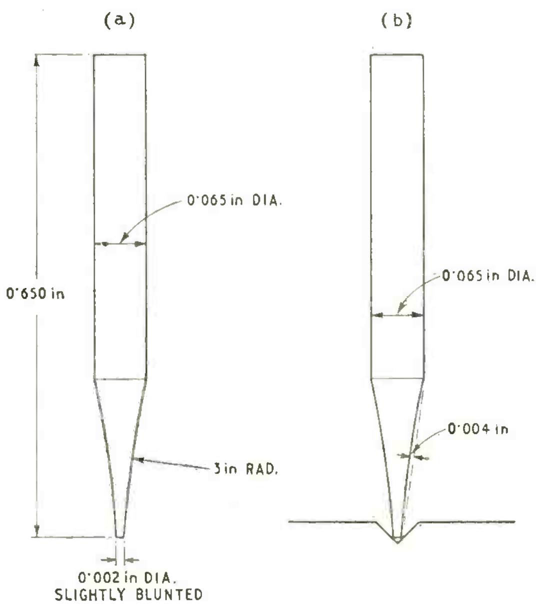

Fig. 2. Two steel needles (circa 1907) designed (a) to trace the bottom of the groove and (b) to make contact only with the walls.

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by careful experiment and acute perspicacity. Record and needle wear were already serious problems, and in 1907 it was found "that owing to the extreme nicety with which the delicately defined groove of the record must be followed by the needle of the reproducing mechanism, in order that the finest recorded vibrations may be accurately reproduced, great difficulty has been heretofore experienced. This is due to the minute but practically serious wear of the needle and groove which results from their frictional contact throughout the long and devious course of the record groove, and to the modification of the original sounds which ordinarily result from a scratchy action of the needle in following the sinuous patch to which it is confined. The material preferably employed is high grade steel wire" (as shown in Fig. 2(a)).

"The improved effect of this novel shape of record-needle tip is very marked, both in the securing of more accurate reproductions of the exact original sounds free from the unpleasing tones commonly introduced in the reproduction; and in the avoidance of wearing action upon the record whereby its usefulness is ordinarily soon destroyed or impaired. The point so rests in the *bottom of the groove* as to greatly reduce friction and "scratch" while at the same time accurately following the delicate deflections of the groove; and the relative diameters and lengths of the so-called "concaved" tip and round body, as indicated by the dimensions of the drawing give sufficient rigidity to the needle to prevent alteration of the tones because of undue yielding in the needle structure."

This solution of the problem was by no means the only one and another inventor about the same time had other ideas for the optimum dimensions of a needle for talking machines. He claimed:—

"My experiments indicate that the body of the needle should be 0.065in in diameter; the diameter of the point-face 0.002in; the maximum concavity of the curve forming the tapered point should be 0.004in; the length of the point 0.235in; the length of the cylindrical body 0.451in, and the total length 0.685in. (See Fig. 2(b).)

"It is believed the reason for the increased efficiency of the improved needle is largely due to the form of the point and the position it occupies in the groove. Its concavity insures *contact on the sides of the groove at two points only,* and the flat face at the termination of the point lies always above and out of contact with the bottom of the groove, thus the area of contact is extremely limited resulting in greatly lessening the objectionable 'scratch' ordinarily very noticeable. The form of the point permits it to penetrate to sufficient depth in the groove to insure perfect engagement therewith, and the attenuation of the point permits the latter to follow accurately slight sinuosities in the lateral bends or convolutions of the groove, by which the sound vibrations are reproduced, thus avoiding 'slurring'.

"Whether the above theoretical reasoning be correct or not, the fact remains that a needle formed as shown and described produces results far in advance of those produced by any other needle known to me. The improvement is especially marked in the reproduction of instrumental music and the tones of the singing or speaking voice. The clearness of detail, accentuation and the tone qualities of the human voice are distinguishable to the faintest inflection and intonation. In band music the broad tones of the bass horns are reproduced with softness and true tonal value, preserving all the effect of their great sound volumes. On the middle register and high notes there is a clearness of tone and distinctness of sound identical with actual playing.

"The improved needle by reason of its form and peculiar engagement with the groove, wears but little and apparently reproduces the last notes of the record as clearly and distinctly as the first, and also acts less destructively on the record, thus prolonging its term of usefulness."

How long during the playing of a record this ideal was maintained is a matter for conjecture. Both gentlemen used approximately the same material and almost the same dimensions, but it would appear that the latter experimenter's explanation is more nearly in accord with our present-day ideas on the correct functioning of the stylus and the record groove.

Needle Replacement

The trouble of having to change needles after every record soon became apparent.

"The mechanism (shown in Fig. 3) relates to machines of the character known as 'talking machines,' more particularly those employing disc recordings, and the object is to provide a multiple needle holder which may be mounted upon a suitable supporting arm whereby attachment may be made to the recording or reproducing element of the talking machine.

"The multiple structure is rotatable and operates in such a way as to permit the needles carried thereby to be used consecutively and afterward removed at one time and others set in their places, and it may be made of any suitable material, preferably metal."

One imagines that the mass of moving parts was not of paramount importance!

Until the advent of electrical recording, with almost limitless amplification of energy, numerous attempts were made at improving the transmission of energy from the record to the sound box, and 1909 saw the production of collar type loud-tone needles. Although it functioned somewhat differently from later types, it "consisted of a round rod carrying at a short distance from its lower extremity, which is cut to a point, a metallic collar of which the upper surface is destined to lean against the head of the needle carrier which is bound to the diaphragm of the sound-box of the machine. This arrangement considerably augments the surface of contact of the needle with the carrier and in consequence the amplitude of the sound waves

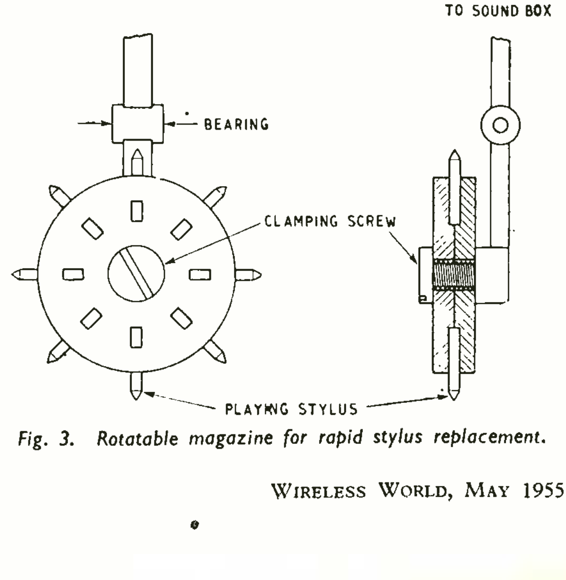
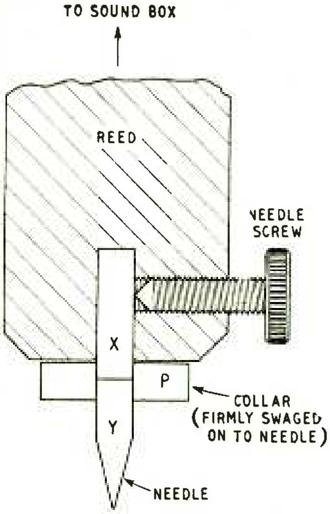
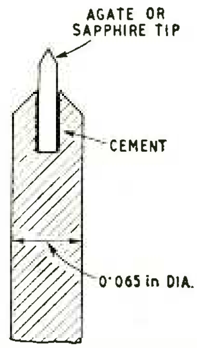


Fig. 3. Rotatable magazine for rapid stylus replacement.



Left: Fig. 4. Use of a collar to give rigidity to the needle.

Below: Fig. 5. Hard tip with shank of different material, chosen for good acoustic properties (1915).



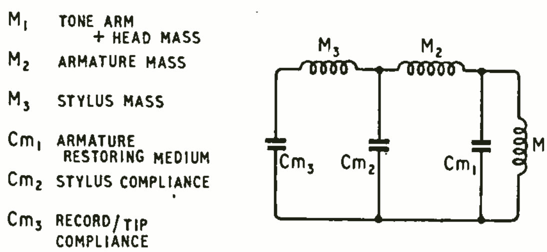


Fig. 6. Electrical analogue of the mechanical parameters of a pickup.

engendered by the movement of the disc or cylinder. The diagram (Fig. 4) shows the general arrangement and provision is made for a sapphire or like point to be constructed on the same principle. A shank X is inserted in the round metallic piece P and on the opposite side is inserted a sapphire (or other suitable precious stone) Y of which the point is slightly blunted or rounded.

"Numerous experiences have proved that in order to arrive at an improvement and an augmentation of the force of the sounds emitted by the machine, the thickness of the round metallic piece P must have a certain relation with the diameter of the shank A, that is to say the said thickness must be equal or very nearly equal to the diameter of the shank. The lower surface must further be fixed to the shank at the beginning of the reduced part."

Needle scratch was an ever-present problem, and by 1915 the whole of the animal, vegetable and mineral kingdoms had been explored in order to produce a needle or stylus for talking machines in which "the sound produced would be improved and purified, and also be capable of operating upon sound records formed of relatively hard materials without wearing away or otherwise deteriorating such records.

"With these ends in view a stylus was produced for talking machines having a body of relatively hard, slightly elastic, insulating material, a cylindrical recess in one end of the body, and an agate point cemented in the socket, said agate having a smooth conical or rounded end projecting from the body. (See Fig. 5.)

"One of the many advantages is that no shrill tones are produced, the always present scratch is minimized, and a very mellow rendering of the sound is obtained as the improved stylus softens the sound and gives a full and natural tone. A needle may be used about four hundred times without requiring substitution. Furthermore, it reduces the wear on the record and also tends to eliminate imperfections in the record."

It can be said that generally design of steel needles more or less stagnated after this period. Improved materials in the special chrome steels, and later tungsten wire in a copper sheath were produced but all metallic needles suffered from the defect of a rapid and untimely end, usually about four grooves from the inside of the record when a final crescendo had roused one's emotions almost to a frenzy only to be shattered by the raucous sounds which were suddenly emitted; then a lively dash to the talking machine to disengage the offending sound box and needle before one's precious records were irretrievably ruined!

It is often said that nothing is new, and skipping many years we come to 1948 when a new stylus was announced for sound reproduction, "more particularly a sapphire styli (*sic*) for reproducing sound on all records. The object was to produce a form of stylus which gives high quality reproduction with minimum wear, and consequently long life to the record."

The sapphire stylus consisted of "a tapered conical portion flat ground on the point of a diameter of from 0.001 to 0.005 inches so that the point enters a standard record sound groove and only makes substantially point contact with the inclined side walls of the sound groove."

One of the important advantages of the disc-type record over the cylinder was the much higher modulation which could be engraved upon it. With few pre-war (1939-1945) exceptions, all reproducing heads, whether acoustic or electric, suffered from a very high inherent stiffness with the result that the playing weight had to be relatively enormous, 4oz being common. Under these circumstances the force exerted at the point of contact between the stylus and the record was such as to tend to shatter any sapphire stylus, or at the best to reduce the life of the stylus to only a relatively short time, and out of all proportion to its cost, with the attendant risk that if the stylus did chip records could be ruined.

During the 1930's the needle armature, with its attendant reduction in mass and hence extended high-frequency response, made its appearance. At a somewhat later date miniature steel needles with a still lower mass, and miniature thorn needles made their debut.

Record Wear

Up to this time the only stylus available with these medium and heavyweight pickups which offered some degree of protection to the record was the thorn type, and this protection was more apparent than real unless the records were kept meticulously clean and no pieces of abrasive material became embedded in the thorn during the sharpening process. By virtue of the very compliant nature of the material (about twenty times that of steel) the forces existing between the record and the stylus are considerably reduced, and it is to this fact that we owe the continued existence of many precious old records which would have been irretrievably ruined had they been reproduced by the blunt steel instrument now mercifully relegated to the museum.

With the concept of high-compliance, low-mass pickups a sapphire stylus of small radius became feasible. A comparison of the heavyweight pickup using a steel needle stylus and a modern lightweight unit may not be inappropriate. Fig. 6 shows the basic analogue for the two pickups. Their constants are tabulated below, together with the approximate forces involved for standard 78 r.p.m. records.

Stylus	M_1	M_2	M_3	Cm_1	Cm_2	Cm_3	Playing Weight (grams)
Loud tone..	112	0.600	0.235	10^{-7}	1.35×10^{-9}	10^{-9}	112
Soft tone ..	112	0.600	0.060	10^{-7}	8.5×10^{-7}	5×10^{-9}	85
Cantilever..	30	0.020	0.013	2×10^{-6}	2×10^{-7}	1.5×10^{-8}	8

M_1, M_2, M_3 in grams; Cm_1, Cm_2, Cm_3 in cm/dyne. All values refer to needle tip.

From the table it will be seen why the soft tone needle did in fact give a "softer tone" than the loud-tone "blunderbuss," namely that the shunt effect of Cm_2 was very much greater.

During the 1930s serious investigations were undertaken, notably by Pierce and Hunt, into the various forms of distortion which were inherent in disc recording and reproducing systems, these various distortions being due solely to the physical dimensions of the stylus and record, and assuming the rest of the system to be linear. It was shown that one of the most serious forms of distortion was due to pinch-effect at high frequencies resulting in harmonic and intermodulation distortion, and they suggested that a method to overcome this would be the use of a stylus which would not only transmit lateral vibrations to the transducer but also decouple effectively the vertical vibrations. This was the genesis of the cantilever stylus.

The cantilever stylus can be made with an effective mass at 10 kc/s as low as 3 milligrams, although the more usual type (see Fig. 7) used in commercial units had a mass of approximately 13 milligrams, made up as follows:—

Sapphire	1.00
Bush	0.75
Arm (effective)	6.00
Head	5.50
	13.25

An effective stylus mass of approximately 13 mgm appears to be somewhat excessive in view of present-day recordings using high velocities at the upper end of the frequency band, and some effort should be expended in reducing this mass.

It will be seen from the dimensions of Fig 7 that the stylus uses a rondel of 0.020in in diameter. If the rondel is reduced to 0.015in in diameter the stylus weight is halved, and if the bush is eliminated a total 1.25 mg is saved. This saving of 1.25 mg would be thrown away if the stylus arm of Fig. 8 were used, because the 0.035in diameter blank removed from the end weighs approximately 1.55 mgm. Fig. 8 shows a method of exploiting this reduction in mass. An undersized punch is used to pierce the hole for the stylus and the "rag" thus thrown up is used in place of the bush as the rondel support. No material is blanked out from the hole, all of it being used to form the approximately cylindrical projection used for supporting the stylus. The "rag" on the underside is tightly swaged round the stylus and sometimes a cement such as shellac or one of the artificial resins is used as an additional safeguard. The arm shown in Fig. 8 is completely satisfactory and gives an effective mass as shown above:—

Sapphire	0.50
Arm (effective)	6.00
Head	3.00
Total	9.50 milligrams

showing a saving of 4 mgm over Fig. 7. A simplification in tooling would be to increase the width of the arm to 0.035in and reduce the thickness to 0.009in. The effective mass of the stylus arm will be the same, the lateral compliance will be reduced by 50% and the vertical compliance will be approximately

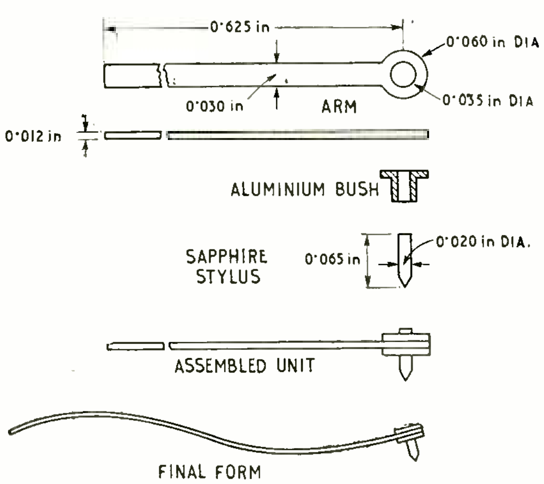
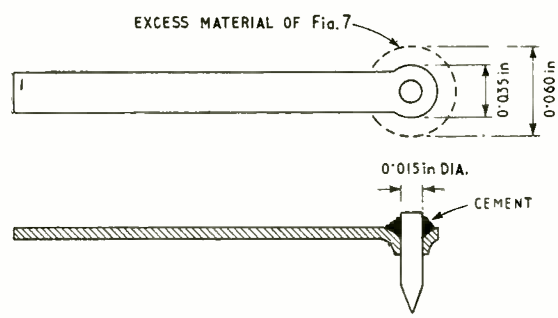


Fig. 7. Construction of a typical cantilever stylus.

Fig. 8. Alternative construction without aluminium bush.



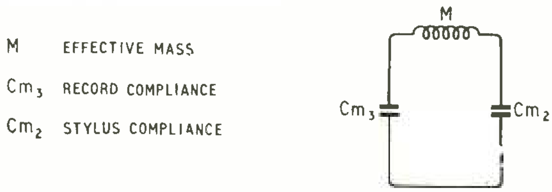


Fig. 9. Electrical analogue of cantilever stylus. Typical values of Cm_3 are 2.5×10^{-8} for plastic microgroove records and 1.1×10^{-8} for standard shellac.

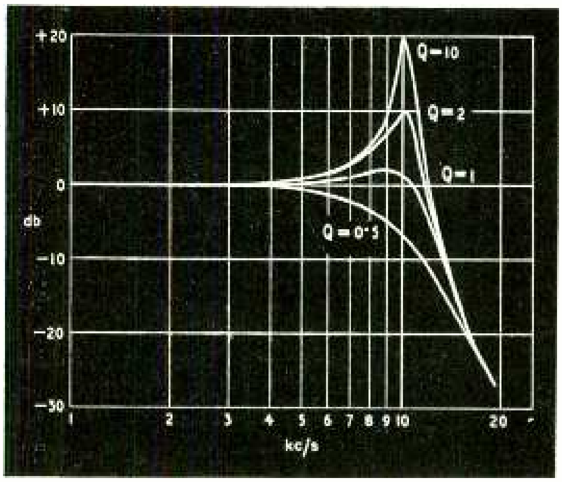


Fig. 10. Effect of load resistance on the response of the low-pass analogue of Fig. 9.

doubled; this can result in an improved high-frequency transmission characteristic, because of the 20% increase in resonant frequency.

The ultimate will probably be a rondel of 0.007in to 0.010in in diameter, 0.020in long in a pure beryllium arm.

The analogue of Fig. 9 shows the cantilever behaving virtually as a low-pass filter, while the effective mass M is given by $\frac{dLWT}{3}$ and the compliance Cm_2 by $\frac{4L^3}{EWT^3}$, where: L=length, W=width, T=thickness, d=density, E=Young's modulus.

From these equations it is seen that for maximum high-frequency transmission the Young's modulus should be at a maximum and the density a minimum. The table below shows Young's modulus (E), density (d), and a goodness factor $G=\frac{E}{d}K$, where K is any convenient constant, in this case 10^{-11}.

Substance	Young's Modulus	Density	G
Beryllium copper ..	12.5×10^{11}	8.2	1.53
Phosphor bronze ..	12.0×10^{11}	8.8	1.36
Steel C.08	19.0×10^{11}	7.7	2.46
Steel C.38	20.0×10^{11}	7.7	2.60
Monel	18.0×10^{11}	8.8	2.05
Aluminium	7.3×10^{11}	2.7	2.70
Beryllium	12.7×10^{11}	1.8	7.05

From the above figures it will be seen that pure

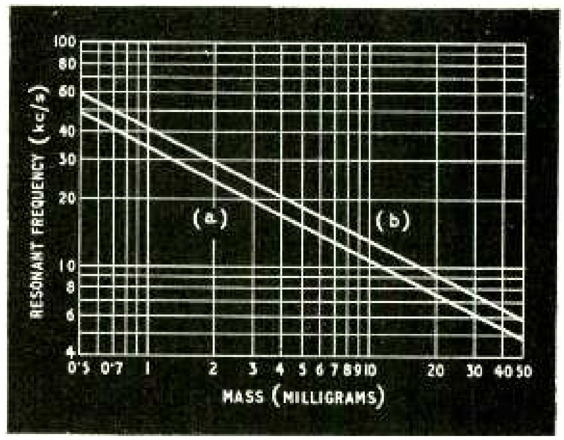


Fig. 11. Relationship between stylus resonance and effective stylus mass under the conditions specified in the text. (a) microgroove, (b) standard shellac records.

beryllium is by far the best, but unfortunately it is not commercially available. Using currently available materials, and provided that the dimensions of the stylus are modified accordingly, there is not a great deal to choose between the other metals, although steel will probably be the general commercial choice.

Fig. 10 shows the effect of varying load resistance of the low-pass analogue shown in Fig. 9. Under normal working conditions the resistive component of the terminating impedance is extremely small, so the system behaves as a resonant circuit comprising the effective mass of the stylus assembly and the record compliance in series with the stylus compliance (the reactance of the rest of the pickup moving system which is in parallel with this latter compliance is usually sufficiently great to be neglected). Fig. 11 shows the relation between "stylus resonance" and effective stylus mass (a) when applied on a standard vinyl microgroove record, at a playing weight of 8-10 gm, and stylus radius of 0.001in; and (b) when applied on a 78 r.p.m. shellac record and 0.0025in radius stylus at a playing weight of 8-10 gm. It will be found that reducing the playing weight will often reduce this resonant frequency on vinyl records due to the smaller area of contact between the stylus and the groove walls and hence an increased value of compliance.

The resonance can result in an increase in output of 10-15 db in a lightly damped system (this also means the needle tip impedance has increased by ×3 to ×6 at this frequency). The obvious method of reducing this resonance is to apply additional damping. Unfortunately all semi-solid materials have a high reactance to resistance ratio, with the result that if sufficient damping is applied to make the system aperiodic at this frequency, the overall compliance of the pickup is reduced considerably. In one case the low frequency compliance of the system was 4.5×10^{-6} cm/dyne and application of a piece of plasticized cellulose 0.020in in diameter by 0.060in long, cemented between the stylus head and the case of the pickup, reduced the resonance from +12 db to +2 db, the resonant frequency remaining at about 15 kc/s, but the low-frequency compliance was reduced to 1.1×10^{-6} cm/dyne. In other words, the low-frequency impedance, and hence the playing weight was considerably increased. Fig. 12 shows the reason-

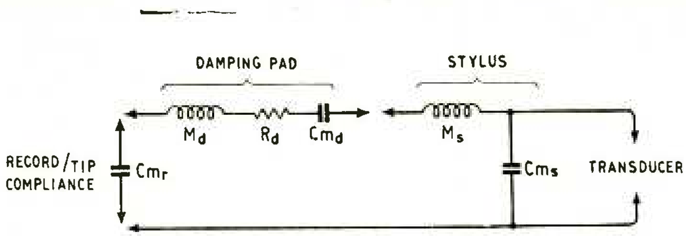


Fig. 12. Electrical analogue of the stylus with the addition of a damping pad.

ing behind this statement, where Cm_d is about 1.5×10^{-6} cm/dyne.

If the damping material is cemented only to the stylus tip and the other end left free, the high frequency resonance can be damped by virtue of the inertia of the damping material effectively clamping the remote end and as the frequency is progressively increased. The effective mass referred to the stylus tip will be increased by approximately 1.25 mgm, the low-frequency complicance will not be affected and the resonant peak can be reduced to +2 db or less. The actual frequency or resonance will be reduced, but the overall response will be improved because of the "flattening" of the resonance curve.

Cantilever Cross-sections

The majority of cantilever arms at present used are of rectangular cross-section with the idea of obtaining a maximum lateral stiffness to prevent undue high-frequency loss; and at the same time allowing for adjustment of the vertical thickness to give the correct ratio of overall transducer lateral compliance to vertical compliance (which latter should be confined entirely to the cantilever arm). In practice this ratio is between 5 and 10. If the ratio is reduced to much less than 5 considerable attenuation will take place, especially at high frequencies, and if the vertical stiffness is too great a subsidiary difficulty may be experienced in that the vertical resonance of the complete pickup and tone arm may be moved up into the lower audio band, say 100-300 c/s, with disastrous results to reproduction if the transducer is sensitive to vertical impulses. By suitably proportioning the dynamic constants of the rest of the pickup the cantilever arm may be made of circular cross-section, which can materially reduce the production costs of the complete stylus assembly. It also leads the way to a reduction in effective mass of the cantilever arm for a given stiffness. The compliance (reciprocal of stiffness) for a cantilever or rectangular cross-section is given by the formula $\frac{4L^3}{EWT^3}$ and for a cantilever or circular cross-section by $\frac{4L^3}{3ER^4}$. The effective mass referred to the stylus tip of each of these cantilevers is $\frac{dLA,}{3}$ where A = cross-sectional area. As before stated, we wish to reduce the effective mass by the greatest possible amount for a given value of compliance. In the case of the rectangular cantilever there is not a lot we can do, except possibly make it of channel section. In the case of the circular material, however, it can be made in the form of a tube, and if the value of the outside and inside diameters are in the ratio of 1.125 and 0.875 to the diameter of the solid rod the effective mass will be reduced by half for the same stiffness. The logical development from that is to form the tube into an elliptical cross-section in order that the correct ratio of vertical and lateral compliance be obtained. This novel form of producing a headache for the stylus manufacturers is offered to pickup designers "for free."

The quantities of styli produced at all times during this era have mounted to prodigious propertions. An article in the *Talking Machine World*, dated 15th August 1911, describes one manufacturer as producing "needles for talking-machines" at a rate of 6,500,000 per day. This, of course, was in America. However, to-day there is at least one company in the United Kingdom producing sapphire styli at a rate of 140,000 per week and the capacity of other individual production units is probably not far short of 100,000. Possibly some statistician will produce figures giving the number of miles (in light years?) travelled by all the "needles for talking-machines" in their devious convolutions produced to date.

As is well-known, the average velocity on a 78 r.p.m. record is of the order of 3 cm/sec and in the case of the best acoustic reproducers (playing weight 100 grams) the sound pressure was of the order of 10 dynes/cm² at a distance of one metre. The available power at the stylus point at 1 kc/s under the above conditions is about 1.5×10^{-3} watt and the acoustic output power is about 10^{-4} watts, giving an efficiency of 6 per cent. In the case of an electrical reproducer the available mechanical power is the same, and the acoustic level is approximately the same. However, the total power consumed from the supply mains is usually of the order of 60/100 watts, giving an overall efficiency of an electrical reproducer of 0.0001 per cent or, in other words, the efficiency is 60,000 times worse than the acoustic reproducer. It is a sad commentary on our so-called technological advances that in our pursuit of "high fidelity," we use not a sledge hammer to crack the walnut but almost the whole resources of the Battersea Power Station; and it is suggested that possibly the correct approach to this art of sound reproduction is to learn again our first principles of acoustics and develop the art to its logical conclusion without any playing about with electrons and such new-fangled notions.

Grateful acknowledgement is made to Fred Lee & Co. (Coventry), Ltd., Technifon, Ltd., and Sapphire Bearings, Ltd., for information and samples.

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J. A. Pierce and F. V. Hunt, *J.S.M.P.E.*, Vol. 31, August, 1938.

"Two-valve Superhet"; Modifications

AN improvement in performance of the above receiver (described in our March, 1955, issue) can be effected by connecting the 1-MΩ triode section grid leak of the ECL80 valve to the cathode of this valve instead of to the chassis and by reducing the value of the 3.3-kΩ smoothing resistor to 1.5kΩ. Incidentally, C_5 should be between 1 and 2 pF.

MORE DISTORTION

What Causes Musical Unpleasantness?

By "CATHODE RAY"

LAST month we dismissed frequency distortion as no longer a problem,* and concentrated on non-linearity distortion. The object was to decide, if possible, what the distortion figures given nowadays by makers of sound-reproducing equipment mean. They are usually "percentage harmonic distortion," but there is often a strong undercurrent of suggestion that they ought to be intermodulation. If they were, would we be any the wiser?

Well, after reviewing the elementary facts of harmonic production by non-linear equipment, I referred to an experiment I described in 1938 to demonstrate that the unpleasantness of non-linearity distortion is due not so much to the harmonics as to intermodulation products. These only occur when there are at least two frequencies present in the original signal, and the experiment was to apply two different frequencies and note that at an amplitude great enough for considerable harmonic distortion they sound quite clear when heard separately, but perfectly horrible when together, even if the total amplitude is then no greater. On the other hand they sound clear together if the amplitude is substantially reduced so that the distortion is slight. I mentioned that some doubt had been expressed whether it was safe to conclude from this one experiment that most of the unpleasantness of distortion is due to intermodulation. Even though at this much later date that is generally accepted, it seemed to me there would be no harm in looking into the matter more closely. And so (limiting our enquiry to musical programmes) we considered what it is that makes some combinations of sound frequencies blend smoothly and harmoniously and others harshly. Generally speaking, the smaller the numbers in which the frequency ratio can be expressed, the less conspicuous is the addition of the second frequency (assumed to be the higher one). The simplest of all (not counting 1 : 1) is of course the 2 : 1, or octave, and the higher frequency is then so concordant with the lower as to form a new starting point for the musical scale; for example, if the two frequencies are 100 c/s and 600 c/s (fundamental and sixth harmonic) the 600 can be reckoned in relation to the nearest octave above 100, namely 400, and the ratio of frequencies can be regarded as 600 : 400, or 3 : 2, a basic musical harmony. For this reason the even harmonics have to be higher than the odd before they are noticeably discordant; the lowest odd harmonic that sounds definitely discordant is the 7th, but the lowest discordant even harmonic is the 14th. After considering the relationship between the shapes of equipment transfer (input/output) characteristic curves and the resulting harmonics, we concluded that with properly designed and operated equipment, in which only second and/or third harmonics are appreciable, the harmonics alone wouldn't cause any harshness of tone, though they might perhaps shift the balance of tone upwards in frequency and also make it sound richer or thicker (according to personal reactions). In arriving at this conclusion we considered only the harmonics in relation to their own fundamentals. But how about the harmonic frequencies of different notes played at the same time? For instance, two of the notes in the common chord are in the frequency ratio 5 : 8 and the third harmonic of one and the second harmonic of the other are therefore in the ratio 15 : 16, roughly a semitone apart, and that is not a pleasant musical sound. But unless both second and third harmonics are comparable in strength with the fundamentals (which, if due to distortion, would *not* be typical of properly designed and operated equipment!) this discordant tone would be relatively very weak. I am told that musical composers are aware of the inadvisability of prescribing chords for strongly harmonic-producing instruments if they want to obtain a smooth-sounding result.

Experiment Repeated

And now we are ready to compare the results of purely harmonic distortion with what the same knowledge of musical harmony would lead us to expect the effects of intermodulation to be. Anybody who may have been so painstaking as to compare the account of my experiment given last month with the original in 1938 has no doubt been itching to accuse me of cheating. The original frequencies were given as 50 and 400; last month's, as 100 and 533. Well, perhaps I did cheat. Having recently repeated the experiment, I believe that if my original frequencies had been *exactly* as stated, in 8 : 1 ratio, they wouldn't have made such an unpleasant noise as they did. Using an exact frequency ratio, the two reproduced together by a distorting triode or pentode do not lose all trace of their individual character, as in the pre-war experiment, though they do sound much more distorted than simply their separately distorted selves added together. But if the ratio is not exact—say 50 c/s and 410 c/s—the result fully deserves my earlier description. As the upper frequency is varied, the unpleasantness goes through marked fluctuations, being sometimes very bad indeed and sometimes by comparison almost tolerable (though of course not by "hi fi" standards!)

This fits in perfectly with our musical ideas. With exactly 50 and 400 c/s, the second-order intermodulation products (as they are called), $f_1 \pm f_2$, are 350 and 450. These, of course, are the 7th and 9th harmonics of 50 c/s, and 400 c/s is the 8th, so the only difference as compared with harmonic distortion of 50 c/s alone is that these three harmonics are abnormally strong. In fact, this seems to be quite a good way of finding out what exaggerated upper-harmonic distortion sounds like. If the intermodulation were mainly

* Don't take that too literally, of course!

third-order, $f_1 \pm 2f_2$, the frequencies created would be 300 and 500, the 6th and 10th harmonics, which ought to sound smoother than the musically discordant 7th and 9th. Fig. 1 shows the frequency pattern.

A critic complained that frequencies such as 50 c/s and 400 c/s are an unlikely basis for musical programmes. Had they been, say, 200 and 600 or even 150 and 400 the intermodulation products would have been the same frequencies as non-discordant harmonics. If, in order to demonstrate the objectionableness of intermodulation I deliberately chose frequencies such as 50 and 410, or 200 and 410, I would be wide open to the criticism that such ratios do not occur in music at all, except perhaps the kind of music in which the worst discords could pass unnoticed. So this time I chose 100 c/s and the rather odd figure of 533, because although these actual frequencies do not come on musical instruments with standard tuning, they are in the ratio (which is what mainly counts) of notes G and C, which very frequently do occur together in music, being the so-called dominant and tonic of the scale of C major. Unless both second and third harmonic distortions are grossly excessive, any jarring tone is almost or quite negligible. But the corresponding intermodulation product frequencies are 433 and 633, and 333 and 733, respectively (Fig. 2). These are out of tune with any notes on the musical scale, harmonious or discordant, so the unmusicalness of the sound is hardly surprising.

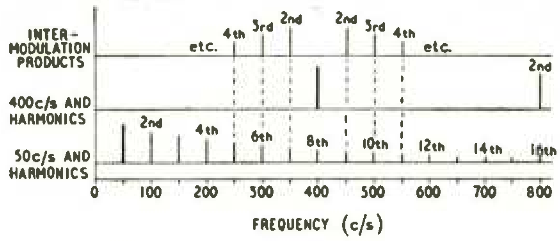


Fig. 1. This diagram shows, above a frequency scale, the harmonic frequencies of a 50-c/s signal, the same for a 400-c/s signal (only fundamental and second are within range), and the frequencies of the products of intermodulation between the two.

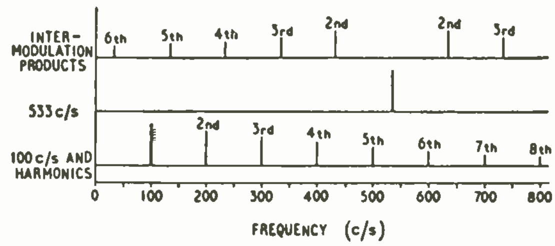


Fig. 2. Similar to Fig. 1, but with fundamental frequencies of 100 c/s and 533 c/s.

Here, then, we have two frequencies which are harmonious with one another and with one another's lower harmonics, but whose intermodulation frequencies are altogether unmusical by any standard. The listening test confirms these expectations. On the other hand frequencies could be chosen for the two input tones that would yield concordant intermodulation products, and this too is confirmed by one's ears. I don't know whether it would be practicable to compose music using only notes that could not, when sounded together, be distorted into discordant intermodulation tones, but I fancy composers would find it rather a serious restriction. And not only are the intermodulation tones introduced by distortion into typical musical programmes likely to be more discordant than the harmonics, but they are far more numerous. One has only to try to reckon the number superimposed on orchestral music to guess how the confused "muddy" sound of non-linear reproduction is caused. The doctrine that most of the audible unpleasantness of non-linearity distortion is due to intermodulation tones rather than harmonics is, I conclude, in general justified, at least for the lower-order distortion that is normal in reasonable apparatus.

Distorted Discords

One criticism that has been voiced is that modern composers like nothing better than a good hearty discord, and so discordant distortion products are not so serious as I made out. But (1) the amount of listening to music by that kind of composer is a small fraction of the whole, (2) even that kind of composer does not (except for a few obscure experimenters) write music for notes outside all recognized musical scales, and (3) in spite of what such music may sound like to some, the occurrence and nature of the discords is intended to be as composed and not as it may happen to result from chance distortion. A similar reply can be made to the criticism that intermodulation tones are generated in our ears because they are non-linear, and therefore distortion doesn't matter. But this ear distortion becomes prominent only when the sound is loud, so the distortion coming from reproducers, which doesn't disappear when we walk away and hear it more distantly, sounds unnatural.

Very well then, let us take the relative unpleasantness of intermodulation as established, and pass on to measurement of the distortion. And here there seems to be a tendency to argue that because intermodulation is the cause of the unpleasantness it is the thing that should be measured, rather than harmonics. It may quite possibly be true that it is better to measure intermodulation than harmonics, but this is not the argument to prove it. Remember, we can't measure unpleasantness as such; we can only look for something to which unpleasantness seems to be more or less proportional. If we find that unpleasantness is proportional to the percentage of intermodulation products, then it may seem natural to measure that. But it could be equally appropriate to measure percentage harmonics, even if they themselves contributed nothing to the unpleasantness, *provided that they were directly proportional to the intermodulation.* It is rather like voltage measurement. A difference of potential causes mutual electrostatic attraction, whereas it does not directly cause a magnetic field, but nevertheless voltmeters actuated by magnetic fields are far commoner than electrostatic voltmeters. The magnetic voltmeters are worked by current, which (according to Ohm's law) happens to be directly proportional to a voltage.

The relationship between harmonics and intermodulation is even closer than that between voltage and magnetic field, because harmonics are actually a particular kind of the same thing as intermodulation. This is a suitable moment for clearing up the numbering of these things. At one time it was quite usual to call the double-frequency harmonic the first harmonic. I believe musicians still do (they also often use the word "partial" for "harmonic.")

It was quite reasonable. But it was also rather awkward that the *n*th harmonic should be $n+1$ times the frequency, so to make the *n*th harmonic *n* times the fundamental frequency the fundamental is now reckoned as the first harmonic. Similarly the simple sum and difference intermodulation products, of frequency $f_1 \pm f_2$, were (and are) sometimes called the first-order intermodulation products; and this too was awkward because the kind of distortion causing them also caused what we now call *second* harmonic. So the rule is that the order number of the general intermodulation product $pf_1 \pm qf_2$ is $p+q$. With $f_1 \pm f_2$, p and q are both 1, so the order is 2. In this way the order of intermodulation is always the same as that of the harmonic produced by the same kind of distortion. If you didn't at first see my point about the vast number of intermodulation products compared with harmonics, it should be clearer now. Seventh-order distortion of two frequencies comprises only two seventh harmonics—$7f_1$ and $7f_2$—but all these intermodulation products: $6f_1+f_2$, $5f_1+2f_2$, $4f_1+3f_2$, $3f_1+4f_2$, $2f_1+5f_2$, f_1+6f_2, $6f_1-f_2$, $5f_1-2f_2$, $4f_1-3f_2$, $3f_1-4f_2$, $2f_1-5f_2$ and f_1-6f_2. Both mathematical calculation and practical test show that this distortion also produces fifth, third and first harmonics and intermodulation products. So imagine the result with a full orchestra playing!

Next, see what happens to the distortion products just listed when f_2 becomes equal to f_1. The only harmonic frequency, of course, is $7f_1$ (because $7f_2$ is the same). All the sum intermodulation products also boil down to $7f_1$. The difference products are $5f_1$, $3f_1$ and f_1, which also were there before. So harmonic distortion is not an entirely separate subject from intermodulation, but can be regarded as a special case of it. No wonder then if there is a close numerical relationship between figures for harmonic distortion and those for intermodulation.

It would take too long to go through all the calculations here and now to show what the relationship is, because it depends on the kind of distortion. But the data have been clearly tabulated in the article by Callendar and Matthews I mentioned last month. There are also some very interesting comparisons between calculations and experimental results in a paper by W. J. Warren and W. R. Hewlett*. All I can do in the space left is to outline some of the main principles.

We have already seen that the relative strength of each harmonic produced by distortion depends on the shape of the transfer characteristic of whatever is causing the distortion. The same goes for intermodulation products. And I have mentioned that the shape that generates, say, second harmonics, is also the shape that generates second-order intermodulation. Conveniently enough for the memory, it is the second-power (or square-law) shape. What does that mean? Well, suppose we take first of all a linear device, say a resistor. The equation stating the relationship between the voltage applied and the current flowing through it is commonly known as Ohm's law: I=E/R. In algebra, however, it is a custom to use small letters for variables and capitals for constants. The whole meaning of Ohm's law is that however the current and voltage may vary, the ratio of the two—the resistance—is constant. So we can write the same thing

$$i = \frac{1}{R} e$$

and because 1/R is the conductance, for which the usual symbol is G, we can make a neater job:

$$i = Ge$$

If we plot a graph of i against e, by choosing some fixed value of G and then choosing various values for e to give corresponding values for i, giving points to join up into a line, we find that the line is always a straight one. That is what we mean when we say that the resistor is *linear*. We can alter the slope of the line by choosing a different value for G; that would mean a different, but still linear, resistor. We could also shift the line bodily (which would be useful for approximately imitating the nearly-linear part of a valve characteristic) by adding another constant, say I_o, to stand for the current flowing when there is no voltage:

$$i = I_o + Ge$$

Our e stands for any value of input voltage varying in any way at all, but supposing we use a definite kind of input voltage, with a sine waveform, we can substitute for e the equation of that waveform, usually written $e = E \sin\omega t$, where E is the peak voltage and ω is 2π times the frequency. The result of the substitution is

$$i = I_o + GE\sin\omega t$$

from which we see that the current also has the same sine wave form and frequency. What we have done is to prove that a linear device—resistor, valve, amplifier or what not—is distortionless (as if we didn't know!).

To study non-linear devices we try to find an equation which, when graphed, closely imitates the characteristic curve of the device. One of the commonest shapes, especially where valves are used, is the one that bends increasingly in one direction, as in Fig. 3. This can be imitated by adding a square or second-power term to the equation, with its own constant to decide the amount of curvature:

$$i = I_o + G_1 e + G_2 e^2$$

When the signal waveform is substituted for e the new term becomes $G_2 (E \sin\omega t)^2$, and this is equal to $\frac{1}{2}G_2 (1 - \cos 2\omega t)$, which shows that a signal of twice the frequency (i.e., the second harmonic) is produced. To imitate the device's curve more accurately it is usually necessary to add some higher even-number terms, and each brings in its own harmonic and also harmonics of all the lower even numbers.

If the curve bends over equally at both ends it

* An Analysis of the Intermodulation Method of Distortion Measurement," *Proc. I.R.E.*, April 1948, p. 457.

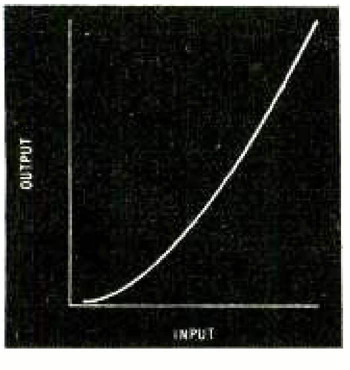


Fig. 3. Type of transfer characteristic giving rise to even-number distortion.

can be shown in a similar way that odd-number terms are needed in the equation, and odd harmonics are produced.

The same procedure is adopted in studying intermodulation, except that e must be (at least) two sine (or cosine) waves of different frequencies. The algebra and trigonometry needed to reckon up all the frequencies in the output, and the amplitudes of each, becomes really formidable, and that is why it was very kind of Messrs. Callendar and Matthews to go through it all and present the results in convenient tables. They show that the relationship between the powers of e in the characteristic equation and the harmonic frequencies produced by the corresponding distortion holds good for intermodulation products—that an even power causes intermodulation products of that order and all lower even orders, and similarly for odd powers.

Distortion Measurement

The fact I have been leading up to in all this is that if the equation of a distorting device's transfer characteristic is known, the amplitude of every harmonic and intermodulation product follows (provided, of course, that we have the skill and patience to deal with all the necessary calculation!). So there is, corresponding to any combination of harmonics resulting from a given combination of input signals, one particular combination of intermodulation products. And vice versa. Theoretically at least, if either harmonics *or* intermodulation are known, both are known. So theoretically at least it doesn't matter which is measured. There is a fixed rate of equivalence between the two.

But that doesn't mean that for every 1% harmonic distortion the intermodulation distortion is some fixed number of %. It isn't nearly as simple as that. In general, there is a different ratio between harmonics and intermodulation for every order (second, third, etc.), and that number is not fixed but depends on the respective amplitudes of the two or more input frequencies, and on the amount of distortion of other orders. The reason for this last is that the amount of second-order distortion (say) depends not only on the second-power term in the equation but also all higher even-power terms. This complication drops out if the distortion is exclusively second or third, as approximately it often is. Another complication can be avoided by always using the same ratio of signal amplitudes for intermodulation testing; a commonly-used ratio is 4 : 1. If the single signal used for harmonic testing has the same peak value as these two combined (i.e., 5 times the amplitude of the weaker) then with second-order distortion alone each of the two intermodulation products, reckoned as a percentage of the weaker signal forming its "carrier wave," is 1.6 times the percentage harmonic distortion. With third-order distortion alone, the corresponding ratio is 1.92. And if both "sidebands" are counted, these two figures are doubled. Fortunately these ratios are not very much affected by reasonable amounts of higher-order distortion, and practical tests with the 5 : 4 : 1 signal ratio show that the intermodulation product percentage of any order is usually 1.5-2 times the same-numbered harmonic percentage. Because the carrier wave is only one-fifth of the amplitude used for harmonic testing, however, the intermodulation product itself is smaller than the corresponding harmonic, so it is not really correct to say (as American writers do) that intermodulation measurement is more sensitive.

All this is on the assumption that there is no frequency distortion. Of course if the various frequencies are amplified by different amounts in the "device," that upsets the calculations accordingly.

For the sake of simplicity, everybody wants to sum up the distortion in a single number. But looking at Figs. 1 and 2 again we may well ask how this can be done. Even single-signal harmonic measurement is liable to produce a considerable number of harmonics of assorted amplitudes, and intermodulation measurement yields vastly more. Is there any way of combining those groups of percentages into one, in such a way that it gives a fair indication of the unpleasantness of the distortion?

It would be very nice if there were, and several ways have been proposed, but I am afraid that the answer is, if not an outright negative, at least doubtful. One of the most popular schemes of measurement is to apply a single tone at the input, measure the total output (fundamental plus harmonics due to distortion), and then insert a bridge filter between output and meter to stop the fundamental completely, so that what is measured is the total harmonics. The ratio of 100 times the second reading to the first is "percentage total harmonics." This scheme is popular because it can be worked with comparatively simple apparatus and gives a single figure. But unfortunately that figure is not a *fair* measure of unpleasantness. Although the subject is full of controversy, one thing universally agreed is that a given amount of third harmonic distortion is worse than the same amount of second, and that the high harmonics are worse still. To make the "total" figure take this into account it was proposed in 1936 that harmonics should be measured separately and each multiplied by $n/2$ before being combined. For the second harmonic n is 2, so its reading is unaffected; the third is multiplied by 3/2; the fourth 2; and so on. By the way, whether the individual harmonics are "weighted" like this or not, they must not be just added together to give the total; as I explained in "Total Power" (March, 1952) when adding up a number of simultaneous voltages or currents it is necessary to square each, add them all together, and take the square root of the result.

According to D.E.L. Shorter of the B.B.C.*, this system still doesn't give enough weight to the unpleasantness of the high-order distortion, and he reckons that multiplying each harmonic reading by $n^2/4$ lines up better with listening tests. You can see, of course, how difficult it is to discover exactly how much worse one kind of distortion sounds than another; for one thing it probably depends a good deal on the kind of programme being heard. So any weighting system is rather arbitrary. I doubt whether anyone would be prepared to swear that fourth harmonic is either 4/3 or 16/9 times as bad as third, or even that it is equally bad. And besides the extra calculation, measuring all the harmonics separately necessitates much more expensive apparatus, especially for the Shorter weighting, in which the very high harmonics are multiplied so much that one has to be able to measure accurately very small percentages of them.

How about intermodulation measurements? They

* "The Influence of High-Order Products in Non-Linear Distortion," *Electronic Engineering*, April 1950, p. 152.

are even more controversial. The most popular method (again, because it requires simple apparatus and gives a single reading) applies a strong low-frequency signal and a quarter-strength high frequency signal, and measures the total of the "sidebands" around the latter; e.g., those shown on the top line in Fig. 1. The procedure has been described in *Wireless World* by Thomas Roddam (April 1950) and E. W. Berth-Jones (June 1951). It comes under the same criticism as the total harmonic distortion method, over which it seems to have no very obvious advantages.

Another system, called the C.C.I.F. method, varies the frequencies of both input signals in such a way that one signal is always a certain number of c/s (say 1,000) more than the other. The frequency of the second-order intermodulation product f_1-f_2 is therefore constant and hence relatively easily measured. This method is very highly spoken of in some circles, but since it indicates only second-order distortion, it presumably pronounces a push-pull amplifier having strong third-order distortion as absolutely perfect. To my mind this is a fatal objection.

The simpler methods have their uses (e.g., production tests of units having possibly varying amounts of similar distortion), so long as one doesn't regard them as unpleasantness meters. For thorough investigation it seems to be necessary to have a wave analyser for separately measuring every distortion product, and preferably to supplement it by visual examination of the transfer characteristic and of the output when the fundamental has been removed. For most purposes I should say that harmonics are enough, but there is an exception if one wants to know what the distortion is like near the upper frequency limit, because then the harmonics are all "off the map," but two signals inside the limit can still intermodulate to give a distortion product right inside the audible range.

Nobody would be more pleased than I to be able to hand out a simple cut-and-dried solution to this problem of distortion measurement. Perhaps some painstaking and well-provided organization will give a team of research workers a year or two to find out what reasonable conditions and method of test take into fair account every cause of unpleasantness of distortion.

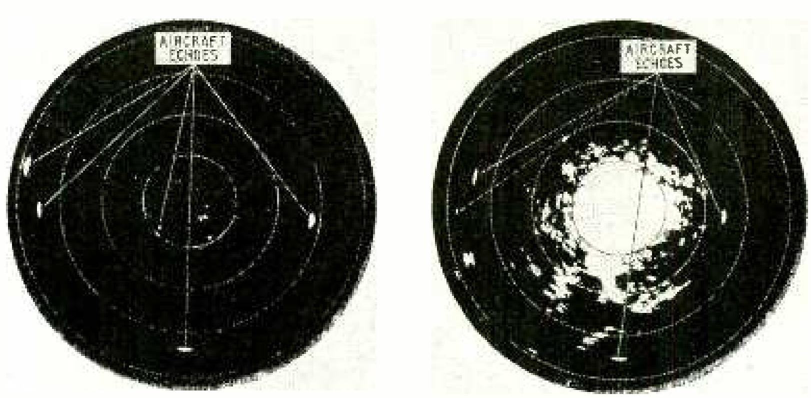
AIRFIELD RADAR DEVELOPMENTS

Crystal-controlled and with Permanent-Echo Suppression

THE clutter of permanent echoes (p.e.'s) familiar to all operators of radar equipment, and which is particularly troublesome on airfield radar screens, can now be successfully eliminated by an ingenious cancellation system embodied in the latest Type S232 airfield radar introduced by Marconi Wireless Telegraph Company. Known as "Moving Target Indicator" (MTI) it provides permanent-echo suppression better than 46 db. Another unusual feature is that it is crystal-controlled throughout, which to a large extent accounts for the good p.e.-suppression.

Briefly, the operation of the equipment is as follows:—the output from a crystal-controlled reference oscillator on 5.625 Mc/s is mixed with an harmonic of another crystal-controlled oscillator and the beat frequency amplified and multiplied to give the final output frequency, which in this case is in the frequency range 500 to 610 Mc/s (50 cms). The output power is between 50 and 60 kW at a pulse length of 2 to 4 μsec as required and at a pulse repetition frequency of 500 to 800 c/s.

The received (echo) signals after conversion to an intermediate frequency of 45 Mc/s together with the eighth harmonic of the 5.625-Mc/s reference oscillator (also 45 Mc/s), are fed to a homodyne detector. The output from this detector is therefore proportional to the difference in phase of the two input signals. As the phase of the reference oscillator is fixed, echoes from stationary objects will have the same phase difference on all successive echoes, but those from a moving target will have a continuously changing phase. It is only necessary to compare the homodyne output produced by successive echoes in order to determine whether an echo is moving or not. A special liquid delay line is used for this purpose and in this device identical signals resulting from permanent echoes cancel out and only those whose phases have changed between successive echoes appear in the output circuit. Here they are rectified and fed through a video amplifier to separate cathode followers and thence by coaxial cables to p.p.i. display consoles. Up to eight p.p.i. display units can be used with one aerial head so that the equipment can be used for long-range, short-range or segmental viewing simultaneously in several different places. As demonstrated by an experimental equipment installed at London Airport, this radar is capable of detecting aircraft at ranges of from ¼ to 100 miles.



P.p.i. displays showing permanent-echo suppression (MTI system) with the Marconi Type S232 airfield radar. On the left MTI switched on, on the right, switched off. Range markers at intervals of 5 nautical miles.

Manufacturers' Products

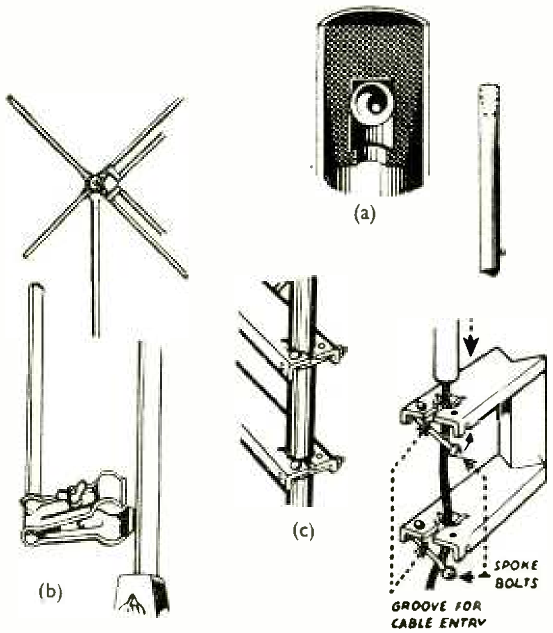
NEW EQUIPMENT AND ACCESSORIES FOR RADIO AND ELECTRONICS

Television Aerials

IMPROVEMENTS to existing models and the introduction of Band III add-on elements comprise some of the latest changes made in the television aerials produced by Antiference.

One of the most interesting is a vibration damper to alleviate the audible howl sometimes produced by wind causing vibration of the elements. When transmitted down a chimney shaft it can be most annoying.

The damper consists of a hollow plastic plug containing a small weight having a slight lateral movement and inserted in the end of each aerial rod. The movements of this weight oppose the vibrations of the rod and silence the aerial. It is also claimed that a further advantage of the new device is that it tends to alleviate signal "flutter" caused by vibration of the aerial. It is shown at (a) in the drawing above.



Antiference aerial damper (a), new harness bolts (c) and "Addex" Band III units (b).

Another improvement concerns the mast clamps on the chimney harness. Captive "spoke-bolts" are fitted in place of loose bolts and greatly simplify the erection of the mast when complete with aerial and feeder; (c) in the drawing.

The Antiference "Snapacitor" fitting, which relies on a capacitance in place of the usual electrical connection between feeder and the aerial elements, has been improved by employing a more effective type of anodizing of the contiguous surfaces. The capacitance of the coupling is by this means raised to 1,000 pF or more.

The same type of coupling is used for the new add-on elements which have been brought out to convert a Band-I aerial for Band-III reception. These are known as "Addex" units and are available for plain dipoles, "H" or "X" aerials. Where the high- and low-band stations are not co-sited reception from opposite directions can be effected by fitting a suitable Addex kit to an Antex (X) aerial. It is not applicable to other types. Prices range from 7s 6d to 15s for a set.

The address of the maker is Bicester Road, Aylesbury, Bucks.

Four-Band Coil Pack

THE majority of coil packs cover the three recognized broadcasting wavebands only; i.e., short, medium and long, but in the latest addition to the Denco range of packs a fourth band is included with a coverage of 50 to 160 metres. The other three bands have coverages of 16 to 50 metres, 194 to 550 metres and 800 to 2,000 metres respectively when tuned by a 500-pF gang capacitor using an i.f. of 465 kc/s. The additional waverange takes in the 80- and 160-metre amateur bands and the wavelengths employed by trawlers and coastwise shipping.

Known as the model CP3F it comprises a small chassis of $2\frac{1}{2} \times 4\frac{1}{4}$in with an overall depth of 1in, excluding the switch spindle, carrying 4 oscillator and 4 signal circuit coils with adjustable dust iron cores, 8 trimming capacitors, oscillator tracking capacitors and a 2-pole 4-way switch.

The makers are Denco (Clacton) Ltd., 357-359 Old Road, Clacton-on-Sea, Essex, and the price is 49s plus 16s 4d U.K. purchase tax.

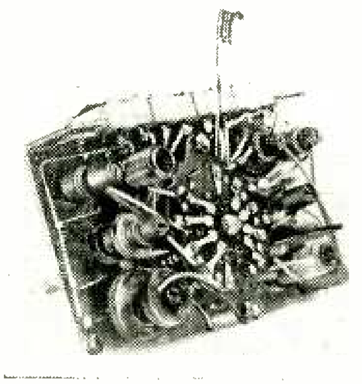
Light-Action Push Switch

A RECENT addition to the range of Bulgin switches is a spring-loaded push-to-make, single-pole switch for use in test equipment and apparatus where temporary excitation only of the circuit is required. It is a single-hole fixing type with a large screwed bush, forming also the main body of the switch, measuring $\frac{3}{4}$in in diameter. It measures 1in deep behind the bezel rim and will take panels up to $\frac{13}{32}$in thick. The case is completely insulated from the contacts.

The switch is rated at 110 V, 1 A or 30 V, 2 A in a.c. circuits with some derating for d.c. over 12 V. The push-button is of generous size, measuring $\frac{1}{2}$in in diameter and operates without undue pressure. Self-aligning and self-cleaning internal contacts undoubtedly contribute to the very light action. The finish is chromium and black.

Known as the Type MP12 the new switch costs 3s 9d and the makers are A. F. Bulgin & Co., Ltd., Bye Pass Road, Barking, Essex.

Above: Bulgin new push-switch type MP12.



Left: Denco Model CP3F four-range coil pack.

The Ratio Detector

By M. R. MURRAY*

Principle of Operation in F.M. Receivers

RATIO detectors are so called because they produce two voltages whose ratio varies with the frequency swings of the incoming f.m. signal. The difference between these two voltages provides the audio output. A ratio detector circuit can easily be distinguished from other double-diode discriminators because its diodes are connected back-to-back (see Fig. 1), that is, the tuned secondary circuit L_2C_S of the transformer is connected from the cathode of one diode to the anode of the other. The main advantage of the circuit, which will be decisive in set design, is that it reduces the number of i.f. stages required. Other detectors do not remove unwanted amplitude modulation superimposed on the f.m. signal by impulsive noise or gain variations in the receiver, and a separate i.f. stage has to be provided solely for this purpose.

How is the amplitude modulation removed? The two voltages mentioned above are added together in the circuit, but although their ratio varies the sum of the two is held constant. At low audio frequencies this sum is prevented from varying by the " flywheel " action of a 5- or 8-μF stabilizing capacitor, C_3 in Fig. 1. When amplitude modulation on the f.m. input to the ratio detector makes the signal rise momentarily, both diodes are driven harder and the extra current flows into C_3; current is drawn out from C_3 when the signal falls on the downward half-cycle of the amplitude modulation, so that successive half-cycles of the a.m. cancel each other out. At higher unwanted audio frequencies the damping effect of the diodes on the L_2C_S tuned secondary circuit varies during the a.m. cycle and compensates for the a.m. variations.

The circuit can be arranged in a symmetrical or balanced form in which the voltages are produced across two equal capacitors connected in series across the diode load (Fig. 2), but preference may be given to the unbalanced circuit (Fig. 1) in which only the lower of the two capacitors is retained. Removing one capacitor makes for economy and leaves the circuit sufficiently capable of suppressing unwanted amplitude modulation. However, a difference voltage can no longer be taken from the common connection of two capacitors, and by the time the circuit has been rearranged it is not at all obvious how the audio output arises. This article therefore is concerned chiefly with the unbalanced circuit, since the explanations can readily be adapted to include the Fig. 2 circuit where both capacitors are present.

The internal impedances of the ratio detector diodes must be small and at least approximately equal, and one diode must have its own cathode pin connection. Suitable diodes are a''_d and a'''_d of the Mullard EABC80. Subscript has been used to indicate voltages applied to k''_d and a'''_d, and in this way to make it quite clear that the a'_d diode is not used in the ratio detector. Actually, the a'_d diode is the a.m. detector and rectifier for a.g.c. voltages.

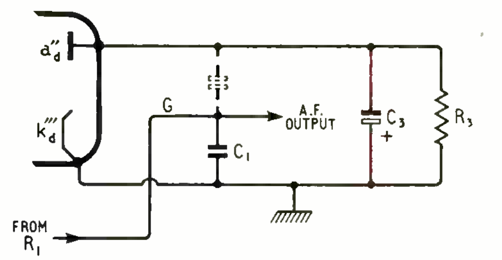


Fig. 2. Part of a balanced ratio detector circuit, showing how it is related to the unbalanced version. C_1 here corresponds to C_1 in Fig. 1.

The transformer, or ratio filter, is similar to that required for other discriminators, and only a brief description of the effect of frequency swing upon phase need be given here.[1]

The L_1C_P and L_2C_S circuits a retuned to a central intermediate frequency of, say, 10.7 Mc/s. Current and voltage in the tuned circuits will only be in phase at the central intermediate frequency. Primary L_1 has a current which lags (or leads) the f.m. input voltage as the signal frequency is swung higher (or lower) than the intermediate frequency. Secondary L_2 picks up the flux generated by the primary current and produces voltages in its two halves whose phase θ varies at the same audio frequency as the phase of the primary current. Tertiary winding L_3 is not tuned, and injects an i.f. reference voltage from the primary into the secondary. This voltage

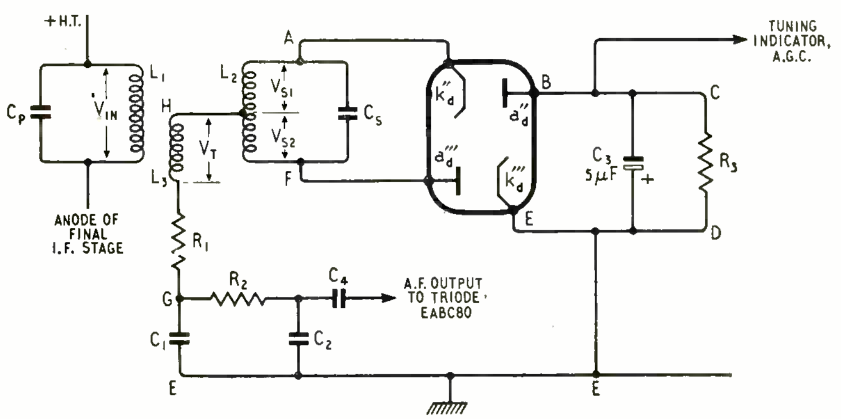


Fig. 1. Typical ratio detector circuit of the unbalanced type.

* Mullard Technical Service Department. This article is based on one which originally appeared in *Mullard Outlook*.

combines vectorially with the "phase swinging" i.f. voltage across each half of the secondary and makes the ratio of the voltages taken off to the diodes vary at audio frequency.

To interpret the vector diagram (Fig. 3) it is sufficient to know that the lengths of the arrows have not been drawn to scale as they usually are to represent the number of volts, etc.; while the angles between the arrows can be read off as phase differences in degrees. Start, then, by picking out the input voltage V_{IN}; the phases of all the other quantities are measured with reference to it. In the secondary the induced current I_S lags (or leads) V_{IN} when the signal frequency is higher (or lower) than the intermediate frequency. The voltages across the two halves of the secondary are V_{S1}, V_{S2}. They respectively lag and lead I_S, whatever the position of I_S, by 90°. Because the secondary is centre-tapped V_{S1} and V_{S2} are equal and 180° out of phase with each other, so on the diagram they are drawn with equal and opposite arrows. The phase angle between I_S and V_{IN} ($= \theta$) varies with the frequency swing, so that I_S is waggling to left and right of V_{IN}, while V_{S1} and V_{S2} are see-sawing up and down, at the audio (modulating) frequency.

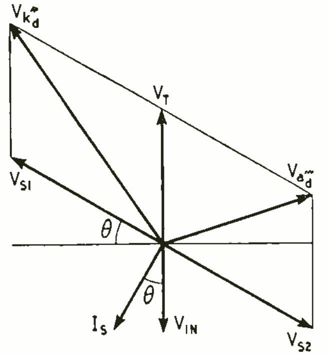


Fig. 3. Vector diagram illustrating the mechanism of the ratio detector.

Next pick out V_T on the diagram; it is the tertiary voltage injected into the secondary from the primary, and is in series with the voltage across each half of the secondary. Now the tertiary consists of a few turns wound closely over the anode end of the primary. So V_T does not waggle; it is fixed and can be drawn 180° out of phase with V_{IN}.

The voltage $V_{k''d}$ applied to cathode k''_d is the vector sum of voltages V_{S1} and V_T in series. This vector sum is formed on the vector diagram by the "parallelogram law," that is, the sum $V_{k''d}$ is the diagonal of a parallelogram whose sides are V_{S1} and V_T. Similarly, the voltage $V_{a'''d}$ applied to a'''_d is found by drawing a parallelogram using V_{S2} and V_T as the two sides.

If V_T had not been injected into the secondary, the voltages taken off from the secondary would be V_{S1} and V_{S2} whose lengths on the diagram remain constant as I_S is waggled to and fro. By combining V_{S1} and V_{S2} with V_T, however, two voltages $V_{k''d}$ and $V_{a'''d}$ are obtained which are equal only at the intermediate frequency when I_S is in phase with V_{IN} ($\theta = 0$). But when I_S lags V_{IN}, then $V_{k''d}$ is greater than $V_{a'''d}$ (as in the diagram), and diode a''_d passes more current than diode a'''_d; or when I_S leads V_{IN} the position is reversed and $V_{a'''d}$ is greater than $V_{k''d}$. With a suitably designed circuit the ratio $V_{k''d}/V_{a'''d}$ follows faithfully the original audio modulation as I_S is made to waggle to left and right of V_{IN} by the frequency swings contained in the signal.

The current through each diode has two paths in the secondary system; those for a''_d are (i) BCDEFA and (ii) BCDEGHA, while for a'''_d they are (i) FABCDE and (ii) FHGE. The paths numbered (ii) have a common section $L_3R_1C_1$, and because of the way the diodes are connected their currents through $L_3R_1C_1$ oppose each other. At the intermediate frequency, when $V_{k''d} = V_{a'''d}$, there is no audio output voltage at G: above the intermediate frequency current flows in the direction HGE (when $V_{k''d}$ is greater than $V_{a'''d}$) or in the direction EGH below the intermediate frequency ($V_{a'''d}$ greater than $V_{k''d}$). Thus the a.f. voltage taken off at G depends on the frequency swing of the incoming signal; it follows the ratio $V_{k''d}/V_{a'''d}$, and therefore reproduces the waveform of the original studio sounds.

There is also an "i.f." variation in the vectors shown in Fig. 3. They can be imagined as contracting to zero length then, expanding out again but in the opposite direction, contracting back to zero again, and finally returning to their original length in their original direction; and they complete this cycle the same number of times per second as the frequency of the signal after it has passed through the frequency changer. In actual fact, the vectors do not return exactly to their original direction, for in the meantime their i.f. frequency will be changing and θ will have changed too—but the to-and-fro waggle of I_S, of course, is at audio frequency. These i.f. variations in $V_{k''d}$ and $V_{a'''d}$ are rectified by the two diodes, the secondary system being by-passed to earth at the i.f. by C_1. Further filtering out of the i.f. is performed by the C_2R_2 de-emphasis network usually placed at this point; but the main function of the de-emphasis network is to compensate for treble boost applied at the transmitter. In f.m./a.m. receivers the "pure" a.f. output is passed via a d.c. blocking capacitor C_4 and a volume control to the triode grid of the EABC80. In a line-up designed solely for f.m. reception a double diode such as the EB91 could be used in the ratio detector.

REFERENCES

[1] "Cathode Ray." "Frequency Modulation, Part 3," *Wireless World*, July, 1951; with corrections, August, 1951.

[2] Seeley, S. W., and Avins, J. "The Ratio Detector," *RCA Review*, June, 1947.

1955 A.R.R.L. HANDBOOK

A CONSIDERABLE quantity of new material is included in this, the 32nd, edition of the Radio Amateur's Handbook, which is compiled by the American Radio Relay League, the U.S. equivalent of our R.S.G.B. Almost all its 27 chapters are affected, but by omitting outmoded designs of equipment and techniques the very latest in amateur practice is included without any increase in the size of the volume. It remains the same at 608 pages, of which 67 are given over to valve and transistor data, two more than last year.

The mobile radio chapter has been almost entirely revised and contains descriptions of the most up-to-date equipment extant in amateur circles. These are applicable to this country, and for that matter everywhere where amateur radio flourishes.

It is often the little things that give the final polish to amateur work; for instance, the handbook explains the correct way to lash a bunch of wires in a receiver, how to operate a break-in system to the best advantage, how to get the most out of DX working and such-like. Information of this kind is not easily found elsewhere.

Copies of the handbook are obtainable from the Modern Book Co., 19-23, Praed Street, London, W.2, or ordered from the Radio Society of Great Britain, New Ruskin House, Little Russell Street, London, W.C.1, for delivery from the U.S.A. The price is 30s (31s 6d by post).

NORTHERN RADIO SHOW

AS already announced, the second post-war Northern Radio Show, organized by the Radio Industry Council, will be held in the City Hall, Manchester, from May 4th to 14th. The show will open daily from 11.0 to 10.0, except on the 10th when it will close at 11.0. Admission to the exhibition, which will be officially opened at 3.30 on the 4th by Her Royal Highness the Princess Royal, will be 2s (children 1s). There will be special rates for parties of 25 and over, and trade season tickets will be available, price 5s.

As will be seen from the following list of 53 exhibitors the majority are domestic receiver manufacturers, although some accessory and component manufacturers are also participating. As at the London Show the exhibition will include a studio from which the B.B.C. will broadcast sound and television programmes. The B.B.C. is providing a demonstration comparing broadcast reception on medium waves with frequency-modulated v.h.f.

	Stand No.
Aerialite	46
Antiference	6
Ambassador Radio & Television	15
Arrell Electrical Accessories	25
B.B.C.	56
Balcombe, A. J.	11, 13
Belling & Lee	54
British Radio and Television	39
British Railways	10
Bush Radio	36, 103
Cole, E. K.	53
Co-operative Wholesale Society	51
Cossor, A. C.	4, 17
Decca Record Co.	9, 23
E.M.I. Sales & Service	49
Edison Swan Electric Co.	47
English Electric Co.	22
Ferguson Radio Corpn.	16
Ferranti	29
Garrard Engineering Co.	3
General Electric Co.	37, 43
Grampian Reproducers	26
Gramophone Co.	35
Granada Theatres	41
Invicta Radio	19
Kemsley Newspapers	104
Kolster-Brandes	14

	Stand No.
McMichael Radio	28
Marconiphone Co.	38
Mercantile Credit Co.	40
Mullard	8, 20
Multicore Solders	50
Murphy Radio	55
National Provincial Bank	1
Pam Radio & Television	31
Permanoid	25
Philips Electrical	34, 48
Pilot Radio	21
Practical Wireless	5
Pye	18
Radio Gramophone Dev. Co.	27
Regentone Radio & Television	52
Slingsby, H. C.	100
Sobell Industries	30
Stella Radio & Television	24
Taylor Electrical Instruments	12
Telerection	44
Ultra Electric	32
Vidor	33, 102
Waveforms	45
Whiteley Electrical Radio Co.	7
Wildbore, J. E.	42
Wireless & Electrical Trader	2

MAY MEETINGS

Institution of Electrical Engineers

London.—May 2nd. "A Simple Introduction to Telegraph Codes" by H. V. Higgitt.

May 5th. "The Electrical Activity of the Brain" by Dr. W. Grey Walter.

May 11th. Group of papers on "Transistors and other Semi-conductor Devices" including "Junction Transistor Noise in the Frequency Range 7-50 kc/s" by W. L. Stephenson and "Noise in Silicon Microwave Diodes" by G. R. Nicoll.

The meetings will be held at 5.30 at Savoy Place, W.C.2.

Physical Society

Acoustics Group.—May 12th. "Measurement of Equal Loudness Contours" by R. S. Dadson and D. W. Robinson at 5.30 at Imperial College, London, S.W.7.

Institute of Physics

Non-Destructive Testing Group.—May 6th. "Xeroradiography" by R. L. Durant (Ministry of Supply) at 6.30 at 47, Belgrave Square, London, S.W.1.

British Institution of Radio Engineers

London Section.—May 18th. "The Development of the Underwater Television Camera" by D. R. Coleman, D. A. Allanson and B. A. Horlock, at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, W.C.1.

British Sound Recording Association

London.—May 20th. Annual convention at 7.0 at the Waldorf Hotel, Aldwych, W.C.2.

Electroencephalographic Society

There will be a meeting of the above society on May 21st at the Maudsley Hospital, London, S.E.5.

Incorporated Practical Radio Engineers

South Coast Section.—May 12th. "Band III Aerial Equipment" (Antiference) at 7.30 at the Kings Arms Hotel, Castle Street, Christchurch.

Midlands Section.—May 4th. "Philco Television Receivers" at 7.30 at the Crown Hotel, Broad Street, Birmingham.

RANDOM RADIATIONS

By "DIALLIST"

The Achilles Heel

ACHILLES, if you remember, was dipped as a baby into a certain sacred spring, whose waters had the power of rendering invulnerable any part of the human frame wetted by them. By an oversight Aphrodite, his mamma, omitted to push under the one heel by which she was holding him. When he grew up and became in due course a fully fledged hero spears and arrows and things just bounced off him without doing the slightest harm. But one day a javelin got him in his one vulnerable spot —that unwetted heel—and that was the end of him. And ever since then the expression "the heel of Achilles" has been used to signify the weak spot in otherwise robust beings or things. Now, I wonder what you'd pick out as the Achilles heel in the television receiver of to-day. My own experience is necessarily limited; but I've discussed the matter with a good few dealers and servicemen and most of them, after hearing the Achilles story are of the opinion that whoever mothered the television set must have held on to both heels during the ducking process. There are in fact two far-too-frequent sources of trouble. The first is the e.h.t. winding of the line output transformer and the second, the e.h.t. rectifier.

Kicks in the Neck

USING the flyback to induce from 4 to 25 kV by shock-excitation is pretty well universally accepted practice nowadays. But the winding in which that shock-excitation takes place gets 10,125 kicks in the neck during every second that the TV set is in use and it should always be so designed and made that it has an ample factor of safety. Too often this is not the case, as many viewers know from sad experience. The e.h.t. rectifier, again, is not always of a type fully up to the work in hand and can cause a lot of trouble if it isn't. I wonder sometimes that valve manufacturers are not more conservative in the limits that they lay down, or don't stick their toes in harder when set makers propose to use a particular e.h.t. rectifier of theirs in what might be called borderline conditions. It doesn't do their reputation much good when such a valve needs frequent renewal—and matters are made still worse when replacements are in such short supply that the unfortunate viewer has to wait for weeks before his dealer can put his TV receiver into action again.

Band III Service Areas

ONE'S FIRST impression on examining the I.T.A.'s expected-service-area map of the London district was that it perhaps erred a *leetle* on the optimistic side. I hope I'm wrong; and I've no doubt that as time goes on and as experience is gained an even larger area will be well served from Croydon. But as to the immediate future two recent statements make one think a bit. The first, by Belling & Lee, is that owing to the small size of its elements the Band III aerial will have to be more elaborate than that for Band I if it is going to be an equally efficient collector at a given range. Various factors limit the number of elements that can be usefully employed in a Yagi array. The second statement (from Ekco this time) is that the amplitude of the Band III signal fed to sets of theirs fitted with convertors will need to be twice as great as that of the Band I signal to give the same results on the screen. Both B. & L. and Ekco know what they're talking about. Adding up, one is forced to the conclusion (if one hadn't arrived at it already!) that if it is going to cover adequately the area served by a Band I transmitter, a Band III transmitter will need to have a power output many times greater. That, I think I'm right in saying, has been found in America, where Band III stations are authorized to use considerably larger outputs than their opposite numbers on Band I. There must, I suppose, be some particular reason why we decided to use vertical polarization for our Band III system; but it was surely something of a leap in the dark. Had we chosen horizontal polarization, a mass of data, culled from some years of American experience, would have been at our disposal. As it is, we are launching out into an entirely unexplored TV field. Perhaps it's another instance of our legendary national predilection for being different.

Sorting Things Out

WHAT a business it is to pull up one's roots and move from a house in which one has lived for many years! I speak from vivid experience, for that's what I did less than a week before I sat down to write these notes. Like, I suspect, most folk who are fond of making up and trying out new things for sound and television as they come along, I had amassed a vast and varied collection of bits and pieces; I could never bear to throw anything away for fear that I should need it. The result was that shelves, cupboards, drawers and boxes, crammed higgledy-piggledly with gear ranging from toroidal tuning coils to tweeters, from odd lengths of wire to obsolete valves, occupied every available part of my own particular stamping ground. Weeks before the move I kept telling myself that it was high time to make a start on sorting out what I really wanted from what could be dispensed with. Being by nature, however, a confirmed putter-off I didn't get down to it till only a few days were left and I've a haunting fear that I'll find myself saying sadly: "If only I'd kept *that,* it would have been just the thing for this job."

Radiating at Random

Going through stacks of files and making a bonfire of old and useless letters and papers was one of the worst parts of the job. But it was not without its rewards. One letter was, to me, particularly interesting. Written over 20 years ago, it was from the Editor of *Wireless World,* confirming his acceptance for a trial run of a new feature to be called "Random Radiations" and signed "Diallist." *Wireless World* was then a weekly and remained such up to the outbreak of the last war. As "R.R." has appeared in every issue since January 18th, 1935, this present set of notes must be somewhere about the four hundred-and-thirtieth of the series! "Free Grid" can, I believe, beat that hollow, if he can be induced to work out his figures. "R.R." has brought me over the years a vast amount of correspondence from people in almost every part of the world. And it has led to the formation of not a few close and valued friendships. One letter I shall never forget. It came early in those lean and rather ghastly years which immediately followed the war from a generous-hearted New Zealand reader who "hoped I wouldn't mind if he sent along some food parcels." I'm not an emotional person but I was nearly moved to tears. We've never met, and probably we never shall; but his family and mine have written to one another ever since and it's a very real friendship.

UNBIASED

By FREE GRID


From my scrapbook

Base Uses

"DO right and fear no man; don't write and fear no woman" is an old and true maxim. Through ignoring this advice many a man has been mulcted of a tidy sum in a breach of promise action. Modern invention has, however, rendered it completely out of date as a South American court has awarded exemplary damages against a man despite the fact that he did right and didn't write.

"Cuddles can be costly if accompanied by the whispering of sweet nothings in the shell-like ear of a girl who is a Bachelor of Science," as the learned judge remarked, in giving judgment. It appeared that the lady had a tiny microphone concealed in her hair and a pocket tape recorder hidden "elsewhere about her person." I don't know what this latter expression means, but presumably a female B.Sc. would conceal it in the top of her blue stocking.

Another application of a tape recorder has been brought to my notice by the makers of a well-known instrument on this side of the herring-pond. Tape recordings were recently used by an anæsthetist to provide what is called "distraction-anæsthesia" for a patient in the dentist's chair.

I have no wish to detract from the merits of this idea, but I am compelled to point out that there is nothing new in it. Thousands of years ago Chinese teeth extractors used thumbscrews to distract the patients' attention from the comparatively minor pain of manhandling a molar. Even the idea of using music as a "distractor" is not entirely new, for the original purpose of a military band was to drown the cries of the dying on the battlefield and thereby distract the attention of the hale and hearty from sounds which might undermine their morale.

Music has always been held to be of great psychological value, as we know from the old saying "Music hath charms to soothe the savage breast. . . ." But it must be the right kind of music, as every snake charmer knows, and the tape recorder is the only instrument suitable for providing it. If you switch on a wireless set you don't know what you are going to get and gramophone records—even L.P. ones—are too short for a major operation. There must be no break while a record changer does its stuff.


Cuddles can be costly

Planned Listening

IN these days of ubiquitous planning, system is being applied to almost every human activity. I see that in the U.S.A. there is even a society making plans for rebuilding the world in the event of its destruction in an atomic war. But amidst all this activity people still seem to listen and view haphazardly instead of planning their radio enjoyment for a week ahead after studying the programmes as I do.

Now to a large extent I blame this on the set makers for, so far as I know, there are still only two sets on the market with a built-in programme time-switch. Even in these two sets, the programme clocks are only capable of being set for twelve hours ahead. So far as I know there is not even a 24-hour programme clock on the market. What is really wanted, of course, is an instrument whereby programmes could be preset for the whole week.

Presumably there is no great demand for programme clock sets, and there are, I believe, two reasons for this. In the first place the public has the good sense to agree with me that it is a seven-day clock that is wanted, and in the second place no great effort has been made to put over the idea of planned listening.

My demand for planned listening and looking may seem a trumpery idea; so was the idea of railways before 1825. Indeed, the old Duke of Wellington called the idea "damned dangerous."

Eros or Cupid

A READER who wrote to approve of my condemning the B.B.C. announcers for their incorrect pronunciation of "polio" suggested that I should castigate them for their manhandling of Eros, the little god on the fountain in Piccadilly Circus. There is not much that slips past my observant eye or ear, and I actually dealt with the pronunciation of Eros over 23 years ago, and I reproduce here the sketch I used then. The lapse of time is vividly illustrated by the fact that I likened the B.B.C.'s pronunciation to a Piccadilly cabby's references to his steed ("This 'ere 'oss"). Horse cabs certainly don't ply in Piccadilly now, and I believe there were only two in 1932.

I notice that I also referred to the seven-metre broadcasting experiments which the B.B.C. was then conducting with a view to supplementing the m.w. service with metre-wave transmissions.

To conclude, the correct pronunciation of Eros should, of course, be Cupid. I defy even the B.B.C. to make a hash of that.

W.W. Diary 1980

AS I sat the other evening entering up the events of the day in my *W.W.* Diary I fell to wondering how much longer it will continue to be published in its present form. The only grouse I have against the present diary is that, although it undoubtedly suits the needs of many of its buyers, it is not a great deal of use to Mrs. Dale or me as the daily events of our lives are far too numerous to be recorded in the small space provided unless resort is made to the truncated *staccato* method of self-expression used by Mr. Jingle.

By 1980 all our wireless receivers will be for sight as well as sound and all will be provided with tape decks for recording voice or vision. The *W.W.* Diary will then consist of a self-contained magazine slipped into a special tape-deck chamber of its own enabling us to record our daily thoughts which can be played back through the loudspeaker at will.

I also make bold to say that all the technical information will be available on a separate tape and will be reproduced, not as the spoken word but as the printed word on the TV screen.